Interaction between Different Sources of Situational Probability Information to Anticipate the Bowler's Intention in Cricket

David-John Lilford (214046427)

A dissertation submitted in fulfilment of the requirements for the degree

Master of Human Movement Science (Research)

In the Department of Human Movement Science, Faculty of Health Sciences

At Nelson Mandela University

Supervisor: Mr R Raffan

April 2020

Declaration

NAME: David-John Lilford

STUDENT NUMBER: 214046427

QUALIFICATION: Master of Human Movement Science (Research)

TITLE OF PROJECT: Interaction between Different Sources of Situational Probability Information to Anticipate the Bowler's Intention in Cricket

DECLARATION:

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

SIGNATURE: ………………………

DATE: 14 April 2020

Acknowledgements

I would like to acknowledge and thank the following individuals and organisations for their support during this study:

- To the Lord, without whom I would not be able to achieve anything.
- To my family and friends for all their support.
- To my supervisor, Mr Ryan Raffan for his guidance, advice and feedback given throughout the study.
- To the Madibaz Cricket club of Nelson Mandela University who provided the facilities in which testing could take place. More specifically, Mr, Sipho Sibande and Mr Abraham du Randt for their willingness to provide participants and facilities.
- To Eastern Province cricket, more specifically, Mr Andre du Plessis for his assistance in providing participants
- To Mr Joshua du Preez and Mr Matthew Bonnesse for their guidance, advice, and support.
- To the participants, for their time, patience and interest without whom, this study would not have been possible.
- To the DST-NRF Innovation Master's Scholarship for their financial support.
- To the Nelson Mandela University for post-graduate financial support.
- To the Nelson Mandela University Unit of Statistical Support for assistance and guidance.

Table of Contents

List of Tables

List of Figures

Abstract

In elite fastball sports, such as cricket, performance occurs at the limit of human capability as the time constraints of perceiving and acting are severe. Cricket batsmen are therefore required to use the two sources of advanced information (kinematic cues and situational probability) to anticipate an upcoming delivery to negate the effects of the time constraints. The source of information that will be focused on in this study will be situational probability, with the aim being to determine the interaction between bowling sequence and field placement as sources of situational probability used by skilled cricket batsmen to predict a bowler's intention. Four different conditions were created according to the situational probability information presented to the batsmen, namely no sources, sequence alone, field placement alone, and both sources. Fifteen skilled cricket batsmen were required to face deliveries projected by a bowling machine and make predictions as to where the next delivery outcome was going to pitch based on perceived situational probability information and attempt to make successful bat-ball contact. In order to compare the use and importance of the four conditions of situational probability information, prediction accuracy, response accuracy and the initial movement time of the batsmen were recorded and analysed. Results of the study revealed no significant difference between conditions of situational probability presented to batsmen for prediction accuracy, response accuracy, and initial movement time. However, significant differences were found between categories of congruency for prediction accuracy results. The prediction accuracy results reveal that batsmen equally value each source of situational probability information and that when sources were presented in conjunction with each other, no enhancement in anticipatory performance or interception of the cricket ball occurred. The results of the current study 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. The prediction accuracy of batsmen is dependent on the nature of the information presented rather than the amount of information presented. Performers draw upon more pertinent information variables according to the relevance to the task at hand. The response accuracy results reveal that the batsmen have the required action capabilities to make successful bat-ball contact regardless of whether or not they correctly anticipate the upcoming delivery’s landing position.

Keywords: Anticipation, Situational Probability, Cricket

Chapter 1: Problem Identification

1.1. Introduction

In the modern age of professional and commercialized sport, cricket has transformed from a recreational hobby to a paying profession for many. As modern cricket affects the livelihood of those associated with it, athletes and coaches are looking for every advantage possible. These advantages come in many different forms and might only be slight, but in high-performance sport, a slight advantage might be what differentiates winning from losing. Anticipation is one of the specific aspects that provides players with an advantage in cricket. Therefore, the use of anticipation in cricket, more specifically, the use and interaction of different sources of situational probability information to successfully anticipate a bowler’s intention will be the focus of the current study.

Skilled performance in a large variety of sport occurs at the limits of human capability (Müller, Abernethy & Farrow, 2006; Cotterill, 2014) and is due to the range of constraints imposed upon performers, which is particularly true in the case of interceptive timing tasks (Brenton, Muller & Mansingh, 2016). Many sports are comprised of interceptive timing tasks that require both spatial and temporal anticipation. The analysis of the time constraints associated with cricket batting suggests that it is crucial for batsmen to judge when and where the ball will arrive in order to make successful contact (Müller & Abernethy, 2008). The batsmen’s judgements are made through the use of anticipation using advance information (Müller & Abernethy, 2008; Williams, 2009; Rosalie & Müller, 2013; Triolet, Benguigui, Le Runigo & Williams, 2013).

The importance of anticipatory skill in striking sports has been well documented (Abernethy & Zawi, 2007). Anticipation has been firmly proven as a vital part of skilled performance in dynamic fastball sports such as cricket, with the use of advance information being viewed as essential to batting as it allows the performer to overcome constraints such as the temporal constraints imposed on successful interception in cricket batting by balls bowled at high velocities (Müller, Abernethy, Reece, Eid, McBean, Hart & Abreu, 2009).

Research conducted on cricket batting has found there to be a relationship between skill level and anticipation, which is consistent with results seen in other fastball sports. According to Pinder, Renshaw and Davids (2009), only skilled batsmen are able to use advance information to anticipate; whereas less-skilled batsmen react primarily on the projectile motion characteristics. Anticipation is facilitated through the use of advance information emanating from cues available prior to the presentation of projectile motion in the form of kinematic and situational probability information (Müller & Abernethy, 2006). Kinematic information refers to advance information gathered from the movement pattern of the opponent (Müller & Abernethy, 2006). Whereas, according to Roca and Williams (2016), situational probability is defined as the advanced ability to better predict what opposing players are likely to do in any situation. Situational probability encompasses situation recognition, and mobilisation of knowledge to efficiently orientate an athlete's attention to relevant information (Milazzo, Farrow, Ruffault & Fournier, 2016).

Skilled performance in dynamic, temporally constrained sports, require performers to make rapid and accurate predictions based on minimal information (Murphy, Jackson & Williams, 2018). In these situations, skilled performers extract and use kinematic information derived from postural cues to anticipate the opponent's intentions more effectively (Murphy et al., 2018). For example, in a study conducted by Müller and Abernethy (2006) in cricket, four experiments examined the ability of cricket batsmen of different skill levels to pick up advance information to anticipate the length and type of balls bowled by bowlers. Results showed that skilled batsmen were able to pick up advance information from some specific early cues such as the bowler's bowling hand and arm. Additionally, research also revealed that skilled cricketers accurately anticipate opponent's movement prior to vital kinematic cues emanating from the opposing player, therefore emphasizing the importance of perceiving situational probability information in anticipation (Murphy et al., 2018).

Research conducted by Alain and Proteau (1980) was the first research that focused on situational probabilities. Rallies of badminton, squash, and tennis players in match situations were filmed and then replayed to the players that were filmed. Players were required to assign subjective probabilities to the occurrence of different types of serves executed by their opponents. Results revealed that serves that were assigned higher probabilities were associated with a greater frequency of anticipatory movements on court. This implies that a strong relationship exists between the participants' subjective assessment and the subsequent anticipatory movements.

Following the research conducted by Alain and Proteau (1980), Abernethy, Gill, Parks and Packer (2001) identified that situational probabilities could be utilised to successfully predict action outcomes in the absence of an opponent's movement information. In the study, skilled (n=6) and less-skilled (n=6) squash players were required to complete a squash stroke when their vision was occluded using remotely triggered liquid-crystal spectacles. The prediction of the performers was assessed, and results revealed that the skilled performers were superior to their less-skilled counterparts when vision was occluded prior to the initiation of pre-contact preparatory movements of the opponent. This additional source of skilled performer superiority is attributed to the attunement to situational probability information related to the opponent's pattern of play.

According to the author's knowledge limited studies have investigated the role of situational probability information in anticipation. The studies focused on different sources of situational probability that include patterns related to game score (Farrow & Reid, 2012), exposure to an opponent's action preferences (Mann, Schaefers & Cañal-Bruland, 2014); exposure to previous sequences of action outcomes (Loffing, Stern & Hagemann, 2015), to highlight a few. Although these studies have been conducted on the different sources of situational probability, limited research has been done on the interaction of the different sources, and more specifically whether specific sources are deemed more important to successfully anticipate an opponent's actions. The current study examines the interaction between two different sources of situational probability information, namely bowling sequence and field placement information, and how these sources are used by cricket batsmen to anticipate a bowler's intention. This research has been recommended in a recent opinion paper by Cañal-Bruland and Mann (2015) to broaden the understanding of the role situational probability information plays in anticipation in sport, as well as by Runswick, Roca, Williams, Bezodis, McRobert and North (2017) who stated that future researchers should manipulate access to each source of information presented in order to quantify the degree to which each influences anticipation in a specific task. The findings of the study will be beneficial as it will help researchers identify the most relevant source/s of information used by performers to successfully predict an opponent's intention.

1.2. Research Aim and Objectives

1.2.1. Research Aim

The aim of this study is to determine the interaction between different sources of situational probability information (field placement and bowling sequence/pattern) 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 primary 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 presented
  - Categories of congruency
  - Combinations of congruency and condition
- To describe the level of certainty associated with the prediction accuracy of cricket batsmen when anticipating the event 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 presented
  - Categories of congruency
  - Combinations of congruency and condition
- 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 presented

- Categories of congruency
- Combinations of congruency and condition

1.3. Statistical Hypotheses

1.3.1. Prediction Accuracy

The following statistical hypotheses were formulated:

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 only bowling sequence information;

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

$PA\mu_4$ = Prediction accuracy for trials containing both field placement and bowling sequence information.

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 hypotheses were 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 only bowling sequence information; $RA\mu_3$ = Response accuracy for trials containing only field placement information;
$RA\mu_4$ = Response accuracy for trials containing both field placement and bowling sequence information.

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 hypotheses were formulated for initial movement time:

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 only bowling sequence information; $IMT\mu_3$ = Initial movement time for trials containing only field placement information; $IMT\mu_4$ = Initial movement time for trials containing both field placement and bowling sequence information.

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 Clarification

The following concepts are clarified to facilitate an understanding of the study:

- **Contextual information:** Synonym for situational probability information.
- **Delivery:** The act of bowling the ball in cricket ("Glossary of Cricket Terms and Cricket Terminology", 2020).
- **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).
- **Initial Movement time:** The length of time between the presentation of a stimulus and the first recorded movement (Milazzo et al., 2016).
- **In - situ test:** In terms of the sport research setting, in-situ is defined as an experimental test conducted in the actual sport skill setting where the performer competes against the opponent, where the object to be intercepted is delivered by the opponent at a speed similar to those experienced in the sport setting, and where visual-perceptual information is available to the participant (Müller, Brenton & Rosalie, 2015).
- **Kinematic information:** Information emanating from an opponent's biological motion (Croft, Button & Dicks, 2010).
- **Leg-Side:** The side of a cricket field that the batsman's back is facing when in their batting stance ("What Is The Off Side And Leg Side In Cricket? | Cricketers Hub", 2020).
- **Off-Side:** The side of a cricket field that the batsman is facing when in their batting stance ("What Is The Off Side And Leg Side In Cricket? | Cricketers Hub", 2020).
- **Over the wicket:** Refers to the side of the wickets from which the bowler delivers the ball. If the bowler is right-handed, over the wicket refers to the left of the wickets and if the bowler is left-handed, it refers to the right of the wickets

("What's The Difference Between Over & Around The Wicket? | Cricketers Hub", 2020).

- **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).
- **Situational probability:** Situational probability encompasses situation recognition, and mobilisation of knowledge to efficiently orientate an athlete's attention to relevant information (Milazzo et al*.*, 2016).

1.5. Scope of the Study

The study is classified as a quasi-experimental research design as it involves the manipulation of an independent variable without the random assignment of participant (De Vos, 2005). A within-subject design with multiple conditions was employed as each individual was exposed to the same conditions. A variety of conditions were presented to participants including a control condition (De Vos, 2005). A non-probability, purposive and convenient sampling technique was used.

The participants were cricket batsmen who at the time of data collection were members of the top five senior cricket clubs from Port Elizabeth and batted in the top six of their respective batting line-ups. The participants who met the inclusion criteria were selected to participate in the study and their data was used for analysis purposes.

1.6. Significance of the Study

The current study attempts to answer the call made by Cañal-Bruland and Mann (2015), and Roca and Williams (2016) to broaden the understanding of the role situational probability information plays in anticipation in sport. Findings might benefit in the quest to identify the most relevant source/s of information used by performers to successfully predict an opponent's intention. Furthermore, the information gathered from the study can potentially be used to inform and educate batsmen, bowlers, and coaches about which sources of situational probability information batsmen use to anticipate the bowler's intention. A slight advantage might be the difference between winning and losing in high performance sports. Anticipation might provide players with the required advantage in cricket batting. Therefore, identifying how each source of situational probability information is utilised to anticipate a bowler's intention may potentially enhance a batsman's or bowler's performance.

1.7. Advanced Organizer

The current research study will consist of five chapters. The chapters will be as follows:

- Chapter 1: Problem identification – This chapter contextualizes anticipation in sport, particularly the lack of research relating to the use of situational probability to anticipation. The chapter also addresses the aims and objectives.
- 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.

The chapter to follow contains all the relevant literature pertaining to the topic of the current study.

Chapter 2: Literature Review

2.1. Introduction

The focus of the present study is on the interaction between different types of situational probability information to anticipate the bowler's intention in cricket. More specifically, focus will be placed on the interaction between using field placement information and information regarding a specific bowling sequence to anticipate the bowler's intention. The purpose of this chapter is to provide literature that will serve to bring about an understanding of the topic under investigation through the review of previously conducted empirical research. Four subsections are provided in this chapter. The first subsection describes the demands imposed on performers in time-constrained interceptive tasks, particularly cricket batsmen. Secondly, how performers are able to negate the demands of the event will be discussed in the information processing and decision-making subsection with emphasis also being placed on anticipation. The third major subsection reviews the literature pertaining to the sources of information that performers utilize with a particular focus on the empirical evidence surrounding situational probability information. Finally, a summary of the chapter will be provided.

2.2. Demands of the Event

Skilled performance in sport occurs at the limits of human capability (Müller & Abernethy, 2006; Cotterill, 2014) and is due to the concurrent constraints imposed upon performers. For example, in interceptive timing tasks, constraints are imposed by the time pressure for responding, as well as the need for interception to be so spatially accurate as to send the projectile in the desired direction with the necessary velocity (Müller & Abernethy, 2012).

Interceptive timing tasks are very intricate and demanding. They allow only minimal error tolerance and occur in situations where time constraints are severe. Therefore, successful execution requires very high spatial as well as temporal accuracies in order for effective timing to be achieved in situations where uncertainty persists as to precisely where and when the projectile will arrive (Müller & Abernethy, 2008). One of the sports that accurately portrays the demands of interceptive timing tasks and is the sport of focus in the current study is cricket, more specifically, the demands of cricket batting.

As a batsman, participation in a cricket match is constrained by the rules of the game. For example, in unlimited overs cricket, batsmen have two opportunities (innings) to participate; whereas, in limited-overs, batsmen only have one opportunity. Therefore, a single error in judgement may end a batsman's participation in the match. In order for a batsman to avoid being dismissed and continue his involvement in the match, he/she must negotiate a number of naturally occurring constraints, as well as a number of different constraints imposed on him by the bowler (Müller & Abernethy, 2008).

Naturally occurring constraints include aspects that affect the performance of the batsman such as the surface of the pitch and the nature of the cricket ball. The surface of the pitch complicates the task of batting as pitch characteristics may vary throughout the duration of the match. The varying pitch characteristics hinder batsmen in timing bat-ball contact (Müller & Abernethy, 2008). The nature of the cricket ball further complicates the spatial and temporal complexity of batting in cricket as the ball can deviate in the air (swing) and off the pitch (seam). The naturally occurring constraints provide a challenge to batsmen as judgement of the impending trajectory and final location of the ball is essential to select and execute an effective motor response (McRobert, Ward, Eccles & Williams, 2011).

The game of cricket has evolved throughout the years to produce a situation in which there is a fair contest between the batsman and the bowler. There is a balance between the visual-motor skills of the batsman and the speed and skill of the bowler with the ability of cricket batsmen to achieve effective interception dependent on constraints imposed upon them by the bowler (Land & McLeod, 2000). Bowlers take advantage of the naturally occurring constraints to further complicate the task of cricket batting. For example, bowlers can use weather conditions, the surface of the pitch, as well as the nature of the ball to produce swing, spin, and seam movement to influence the trajectory of the ball and ultimately the performance of batsmen (Land & McLeod, 2000).

Through the number of concurrent constraints brought upon batsmen in skilled performance, a latency in processing sensory information into the suitable motor response occurs. The latency is known as the simple reaction time delay and refers to the time taken by a performer to recognise and process visual information prior to the initiation of an action (Müller & Abernethy, 2008). The delay which is typically 200 milliseconds (ms) causes the batsman to respond to the bowler's action only once reliable information (information with a high degree of certainty) about the projectile's motion becomes available (Loffing & Cañal-Bruland, 2017). Furthermore, Land and McLeod (2000) indicated that a batsman requires approximately 200ms to adjust his stroke and due to this movement time, the batsman is required to make a correct prediction as to the arrival point and speed of the delivery at least 200ms prior to the ball reaching him (Land & McLeod, 2000; Renshaw & Fairweather, 2000). However; the time constraints associated with cricket batting are such that batsman cannot simply wait to see the projectile motion in order to make spatio-temporal decisions (Müller & Abernethy, 2008). Once reliable ball flight information is presented, there is insufficient time for the batsman to get to the right position to successfully make contact with the ball (Loffing & Cañal-Bruland, 2017). The abovementioned statement is confirmed through chronometric analysis results (Figure 2.1) that show that the travel time of the ball from the point of release from the bowler's hand to the point of interception by the batsman may be equal to or even less than the combined reaction and movement time of the batsman (Müller & Abernethy, 2006). Therefore, skilled batting performance is dependent on successful information processing and decision-making. More specifically, skilled performance is dependent on the capability of the batsman to use advance information, namely kinematic and contextual information, to make predictive judgements as to the landing position and time of arrival of the ball (Müller & Abernethy, 2006; Müller & Abernethy, 2008).

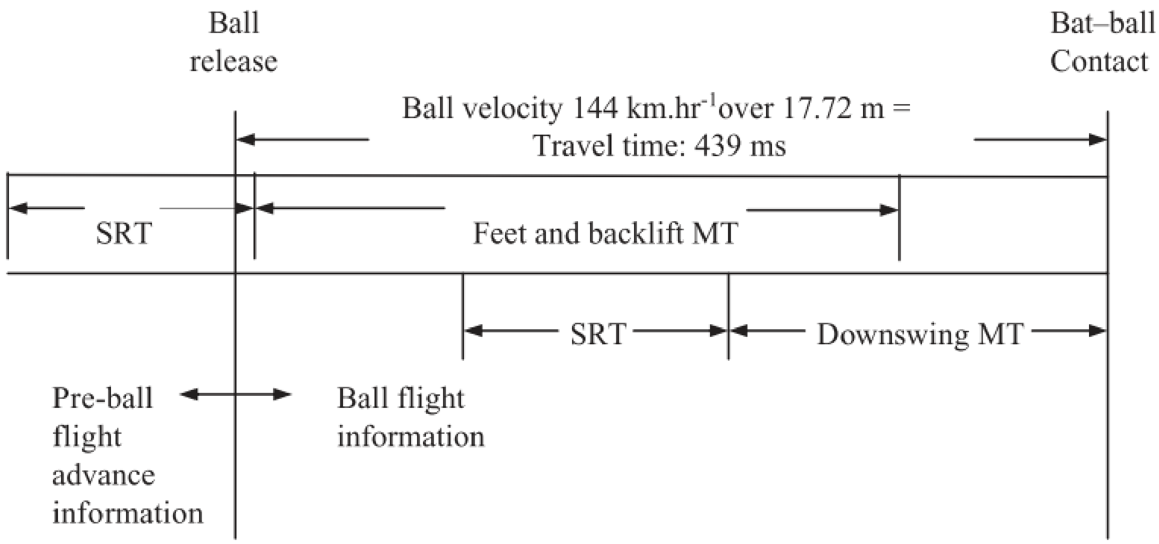


Figure 2.1- A chronometric analysis of the components and relative durations of a cricket batsman during a typical cricket stroke (Müller & Abernethy, 2008). The movement times (MT) of the feet and bat required for successful bat-ball impact are shown separately, with each preceded by a latency equivalent to simple reaction time (SRT).

2.3. Information Processing and Decision-Making

The demands imposed upon athletes in interceptive timing tasks influences information processing and decision-making. Performers are required to identify the most information-rich areas in the sporting environment, focus their attention accordingly, and extract meaning from these areas effectively to guide appropriate motor responses (Hagemann, Strauss & Cañal-Bruland, 2006; Loffing & Cañal-Bruland, 2017). It has been well documented that skilled performers when compared to less-skilled performers, are able to more effectively process information and produce appropriate motor responses to counter the potential adverse constraints and demands imposed upon them (Müller & Abernethy, 2006; Loffing & Hagemann, 2014).

In a meta-analysis conducted by Mann et al*.* (2007), an intricate body of expertise research (n=42 studies) was synthesized and quantified in order to examine the expert/novice difference in information processing and decision-making. Effects were examined for a few dependent measures (response accuracy, response time, number of visual fixations, visual fixation duration, and quiet eye period) through the use of point-biserial correlation. Response accuracy results revealed that skilled performers were approximately 31% more accurate across research studies when compared to less-skilled performers. Furthermore, response time results revealed that skilled performers responded approximately 35% faster than less-skilled performers across research studies. The study concluded that skilled performers were more accurate and quicker in their information processing and decision-making when compared to their less-skilled counterparts.

Information processing and decision-making capabilities play a crucial role in success in sport as skilled performers are often required to make the correct decisions under extreme constraints (Levi & Jackson, 2018). Cricket is a sport in which the above statement applies. For example, for each delivery that is bowled, the batsman is required to make a decision about the shot to be played, the bowler is required to make a decision regarding the type of ball to be bowled, and the captain has to make decisions regarding the positioning of the fielders. Therefore, successful information processing and decision-making is an essential component of cricket, and one of the key factors that distinguishes skilled from less-skilled cricketers (Cotterill, 2014).

A number of models regarding information processing and decision-making have been developed including the ecological approach (see Gibson, 1979); the Naturalistic decision-making (NDM) approach (see Levi & Jackson, 2018); the Take the First Heuristic (TTF) (see Hepler & Feltz, 2012); and the Recognition-Primed Decision model (RPD) (see Klein, 1993). However, the model most applicable to information processing and decision-making for the current study was proposed by Cotterill (2014). The model was developed to outline the factors that affect information processing and decision-making in cricket batting throughout performance. The model is composed of three factors: The first factor consists of the influencing factors that impact the individual and the situation in which information processing takes place. The second factor is concerned with the decision-making process which includes information perception, information processing, and action generation. The last factor focuses on intervention points that can be focused on to improve decision-making skills and ultimately performance in cricket (Cotterill, 2014).

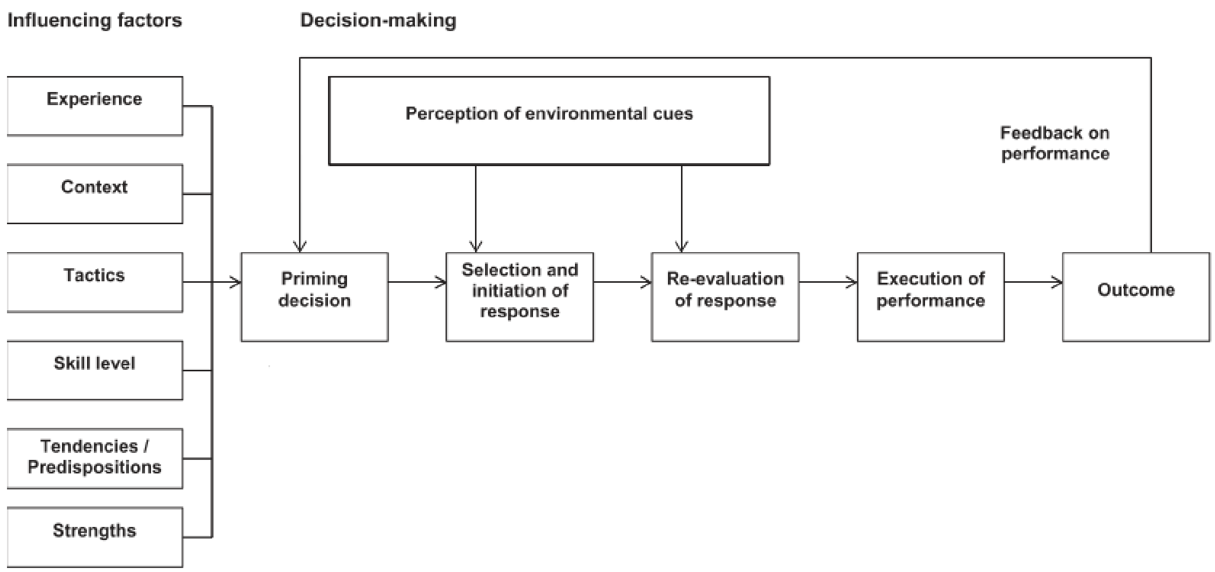


Figure 2.2 - An information processing and decision-making framework (adapted from reference) outlining the factors that affect information processing and decision-making throughout performance (Cotterill, 2014).

According to the framework illustrated in Figure 2.2, information processing and decision-making can be indirectly impacted on by a number of different influencing factors. Influencing factors may include but are not limited to the context of the game, action preferences of the opponent, sequence of events, and patterns of play. Once the relevant information has been gathered, the process of information processing and decision-making can commence.

Information processing refers to the integration of sensory data from a number of different sources into a summarized, meaningful whole (Chan, 1992). The decision-making stage includes the selection of one course of action over another and it is clear that the nature of the specific task greatly influences the processes underpinning decision-making (Chan, 1992). In the framework proposed by Cotterill (2014) for decision-making, the decision-making component is where the performer interacts with the information gathered and as a result, a specific course of action is chosen. The decision-making process consists of four specific stages. These include the priming decision, perception of the environmental cues, re-evaluation of the response, and the outcome and feedback of the decision (Cotterill, 2014).

The first stage of the decision-making progress is the priming decision. The priming decision is the predetermined action that is slected based on the information gathered such as team tactics, the context of the game, and/or the actions of opponents during a specific sporting situation (Cotterill, 2014).

Selectively attending to relevant information following the priming decision is the next step in the decision-making process. The need to selectively attend to relevant information is critical in decision-making (Cotterill, 2014). The perception of environmental cues refers to the selection and initiation of a course of action, with the specific course of action being selected based upon the perception of specific environmental cues such as the kinematic cues of the opponent (Cotterill, 2014). Skilled performers, unlike less-skilled performers, are able to focus on only the critical sources, while disregarding non-relevant sources (North, Ward, Ericsson & Williams, 2011). For example, A study by Ward, Williams and Bennett (2002) was conducted with the aim being to examine visual search during the anticipation of a groundstroke in tennis to uncover expertise differences in terms of what information is used to anticipate. Results from the study revealed that experienced tennis players spent significantly more time fixating on the head-shoulder and trunk-hip regions in comparison to arm-hand, leg-foot, and ball areas of the display. In contrast, inexperienced tennis players spent more time fixating on the racket than any other area. The study concluded that the experienced tennis players were able to focus on only the critical sources while disregarding non-relevant sources, whereas the inexperienced tennis players were not aware of the critical sources.

Once the information has been derived from the perceptual mechanism, it is passed through to the decision mechanism, where the appropriate action is decided upon. The decision mechanism selects the response as well as forms a strategy to execute the motor response (Elmurr, 2011).

Re-evaluation of the response occurs after attending to relevant information in the decision-making process. In order for successful performance to occur, in some circumstances, rapid adjustments of the selected course of action are required. This, in turn, requires the performer to rapidly re-select an appropriate course of action in response to late occurring perceptual information. For example, a cricket batsman might be required to rapidly alter his/her course of action following the bounce of the ball due to factors such as swing or spin causing the ball to deviate from its original trajectory (Cotterill, 2014). The ability to make these rapid modifications is dependent on the action capabilities of the batsman (Dicks, Davids & Button, 2010).

The final stage in the decision-making process consists of the outcome and feedback of the decision. Performers develop a framework in memory through feedback with regards to which decisions were more successful than others (Cotterill, 2014). The framework is extensive and intricate and takes into consideration many different aspects such as the opponent faced, the specific context, etc (Cotterill, 2014). The framework is used in future situations to inform successful decisions (Cotterill, 2014).

2.3.1. Anticipation

Research conducted by Mann et al*.* (2007) revealed that skilled performers are more proficient in their information processing and decision-making; however, the study also revealed that the use of advance information can be used to facilitate performance by aiding in the anticipation of an opponent's action outcome. Performance in sport may improve as a result of anticipation strategies, especially in time-constrained situations. This is the case as uncertainty permeates decision-making in sport due to the time constraints imposed upon athletes and decisions are often required to be made in the absence of complete information. Therefore, a strong relationship exists between the accuracy of decision-making and anticipation in sport (Afonso, Garganta & Mesquita, 2012).

According to Borysiuk and Sadowski (2007), anticipation is the process of mentally foreseeing an upcoming event based on the perception of environmental information. Through anticipation, it is possible to program motor responses that are applicable to the situation, alter them and correct them before the occurrence of disturbances (Borysiuk & Sadowski, 2007). Anticipation can be explained using the concept of by-passes (a model of information processing). According to this concept, successful anticipation which includes accurate spatial and temporal anticipation makes it possible to limit or avoid the response selection stage (see Figure 2.3) resulting in a significant decrease in motor response time and thus potentially negating the time constraints imposed upon the performer (Borysiuk & Sadowski, 2007). Studies have shown that advance information can lead to reductions in response time by 100 to 150ms. For example, research conducted by Borysiuk and Sadowski (2007), revealed that the presentation of advance information led to a 42ms decrease in initial movement time on a time anticipation test.

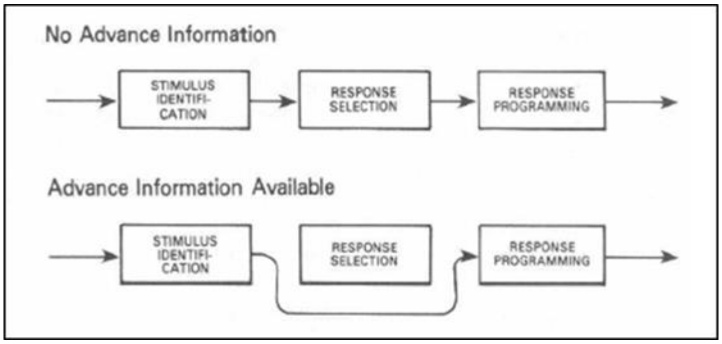


Figure 2.3 - The process of anticipation using advance information (Borysiuk & Sadowski, 2007).

Anticipation has been firmly proven as a vital part of skilled performance in dynamic fastball sports such as cricket, with the use of advance information being viewed as essential to batting (Pinder et al., 2009). Research aimed at studying cricket batting has found there to be a relationship between skill level and anticipation, consistent with results seen in other fastball sports. According to Pinder et al. (2009), only skilled batsmen are able to use advance information to anticipate; whereas less-skilled batsmen primarily rely on the projectile motion characteristics. A study conducted by Müller and Abernethy (2006) in cricket aimed to examine the ability of cricket batsmen of different skill levels to perceive information from the pre-release kinematics of the bowler, from pre-bounce ball flight, and from post-bounce ball flight to facilitate anticipation. Skilled (n=6) and less-skilled batsmen (n=6) batted against three different leg-spin bowlers. Measurement was made on each trial of the accuracy of the foot movements made by the batsmen and their success in making bat-ball contact. The results of the study revealed a superior capability of the skilled batsmen to make use of earlier ball flight information to make successful bat-ball impact, thus replicating the superior use of anticipation by skilled performers when compared to less-skilled performers.

Many sports, such as cricket, are comprised of interceptive timing tasks that require both spatial and temporal anticipation (Müller & Abernethy, 2008; Williams, 2009; Rosalie & Müller, 2013; Triolet et al., 2013). Spatial anticipation refers to where and what will happen; whereas, temporal anticipation enables the perception of when the event is going to occur (Borysiuk & Sadowski, 2007). There are certain situations in which the two types of anticipation interfere. In these circumstances, the temporal aspect dominates and causes a significant influence on the effectiveness of anticipatory decisions (Borysiuk & Sadowski, 2007). There are several reasons why spatial and temporal anticipation are essential for cricket batting. Firstly, anticipation can be used to degrade the effects of the simple reaction time delay (Müller & Abernethy, 2008). An earlier start in processing visual information can provide more time to execute the required motor response (Müller & Abernethy, 2008). Secondly, anticipation can allow for quicker initiation and completion of gross body movements allowing for a balanced base of support to be established which will aid in producing more effective bat-ball contact. An earlier completion of gross movements can also aid the batsman in achieving the correct body positioning to reduce the potential lateral movement of the ball. The successful use of advance cues from the bowler can help explain the batsman's capability to seem to possess "all the time in the world" when playing a cricket stroke (Müller & Abernethy, 2008).

Although anticipation has proven to be a vital part of skilled performance, the use of anticipation strategies in certain situations is minimal or less prevalent than other situations (Cañal-Bruland & Mann, 2015). Anticipation is based on uncertain information and therefore can in some instances lead to incorrect decisions (Cañal-Bruland & Mann, 2015). Researchers have argued that the use of anticipation in different sports and situations vary because the cost of making an inaccurate prediction might outweigh the benefits of anticipation (Triolet et al., 2013; Cañal-Bruland & Mann, 2015). For example, the costs involved with anticipating inaccurately in a tennis match are high compared to the benefits associated with a "conservative" strategy (strategy where the performer waits longer before initiating a response) (Triolet et al., 2013). Additionally, deceptive actions presented by opponents may lead to a negative effect of anticipation (Müller & Abernethy, 2012). Although anticipation of an upcoming event may be essential for the performer, deception (presentation of false cues) and disguise (delayed onset of informative cues) are strategies used by opponents to minimize the benefits of anticipation (Müller & Abernethy, 2012). Consequently, being able to distinguish between relevant and irrelevant information through selective attention is vital for successful anticipation (Müller & Abernethy, 2012).

2.4. Sources of Information

Anticipation and decision-making are crucial for successful performance, however, it is of vital importance that the performer detects and selects the most informative cues from a large amount of intricate visual information to make successful anticipations and decisions (Hagemann et al., 2006; Loffing & Cañal-Bruland, 2017).

There are three broad categories of information that performers rely on to facilitate anticipation: projectile motion information, kinematic information, and situational probability information (Rosalie & Müller, 2013; Loffing & Hagemann, 2014; Loffing et al., 2015). The different sources of information are weighted differently in terms of their facilitation of anticipation depending on the stage of the unfolding event (Loffing & Hagemann, 2014; Loffing, Solter, Hagemann & Strauss, 2016). Performers' predictions of an opponent's action-outcome should rely predominantly on situational probability information at the initial stages and become more refined as more kinematic information, presented through the postural orientation of the opponent's movements, and projectile motion information becomes available (Loffing & Hagemann, 2014; Loffing et al., 2016).

Skilled performers are able to utilize perceptual information prior to (situational probability information) and during the opponent's precontact movement pattern (kinematic information) (Müller & Abernethy, 2012). This early information is used to guide the gross positioning of the body. Information presented from projectile motion is then used to guide and refine interception. The integration of advanced and projectile motion information facilitates a reduction in the uncertainty of the opponent's movement and guides successful interception (Müller & Abernethy, 2012).

The three broad categories of information that facilitate anticipation will be discussed in the sections to follow.

2.4.1. Projectile Motion Information

The motion of the projectile to be intercepted provides the most salient information to guide successful interception (Müller & Abernethy, 2012) and an expert advantage has been revealed in the use of projectile motion information to enhance performance. Research conducted by Müller et al*.* (2009) aimed to differentiate the capability of skilled and less-skilled cricket batsman to use information prior to and during ball flight to make successful ball contact. Skilled (n=6) and less-skilled (n=6) batsmen wore occlusion spectacles and were required to strike deliveries bowled by three different fast bowlers while their vision was selectively occluded. Three visual occlusion conditions existed: occlusion prior to ball release (providing only advance information), occlusion prior to the bounce of the ball (providing advance information and projectile motion information), and no occlusion (where advance information, projectile motion and ball bounce information were available). Regression analysis revealed that early projectile motion information was crucial in judging the landing position of the delivery with ball bounce and late projectile motion information providing information related to the interception point. Results of the study conducted by Müller et al*.* (2009) further revealed that the ability to pick-up early and late projectile information was well developed in skilled batsmen but was less developed in less-skilled batsmen. The study concluded that the skilled batsmen were more proficient at using projectile motion information when compared to less-skilled batsmen, therefore leading to more successful interception.

Information used to guide successful performance in fast-ball sports is presented throughout the entire trajectory of the ball (Müller & Abernethy, 2012). In relation to cricket batting, information perceived from early and late projectile motion, as well as from ball bounce has been found to guide successful bat-ball contact (Müller et al*.*, 2009). Suggestions have been made stating that early projectile motion information may be useful to guide initial bat positioning; whereas, ball bounce and late projectile motion information may be valuable to refine interception when experiencing lateral deviation at or after ball bounce (Müller et al., 2009; Müller & Abernethy, 2012)

A method in which projectile motion information can be assessed in isolation to other sources of information is through the use of a ball projection (bowling) machine. Although the use of bowling machines has been criticised as they do not mimic the natural batting task (Pinder et al., 2009; Cork, Justham & West, 2010), they present an environment in which projectile motion information can be examined. One of the criticisms of using bowling machines is that the biological motion (kinematic cues) of the bowler and situational probability information is not present (Pinder et al., 2009; Cork et al, 2010). This, however, provides a perfect environment to study projectile motion information as it is presented in isolation. As no kinematic cues are provided by the bowling machine, batsmen are provided with no pre-release information regarding the type of ball to be delivered and no pre-release information as to when the ball is to be delivered. The only pre-release information presented is the raising of the hand of the bowling machine operator to show the batsmen that the ball is about to be fed into the machine (Cork et al., 2010). Not only are there differences in the information presented through the use of bowling machine, research has also shown that there are technique differences when batsmen face bowling machines compared to when they face bowlers (see Renshaw, Oldham, Davids & Gold *(*2007)).

Although the object in motion provides performers with the most salient information regarding interception, under severe time constraints, the use of object motion information is limited or impossible (Müller & Abernethy, 2012). Through the examination of gaze behaviour, it has been established that anticipation is facilitated through the use of additional sources of information (Müller & Abernethy, 2006). In a study conducted by Müller and Abernethy (2006) in cricket, four experiments were conducted to examine the ability of cricket batsmen of differing skill levels to pick up advance information to anticipate the length and type of balls bowled by bowlers. The study consisted of a skilled group (n=31), an intermediate group (n=10), and a less-skilled group (n=16). The information available to batsmen with which to make anticipatory judgments was manipulated through the combination of temporal and spatial occlusion of the video simulations. Temporal occlusion is a method in which the amount of visual information is systematically varied and is used specifically to specify the temporal course of cue extraction; whereas spatial occlusion is the occlusion of presented visual information and is used to reveal the sources of information used by experts during anticipation in sport (Müller & Abernethy, 2006). Results showed that besides a capability to pick up advance information from the projectile motion used by the intermediate and less-skilled batsmen, the skilled batsmen demonstrated the ability to pick up advance information from some specific kinematic cues (especially cues emanating from the bowler's bowling hand and arm). When facing fast bowlers, all batsmen showed a reliance on projectile motion information to make anticipatory judgements regarding ball type; however, only skilled batsmen were able to extract advance information from the period ranging between front-foot impact of the bowler and ball release. The information was derived through kinematic information presented by the bowler’s arm and hand (Müller & Abernethy, 2006). Only skilled batsmen were able to pick-up advance kinematic information in order to determine ball type when spin bowlers were bowling. The pick-up of the kinematic information occurred early in the bowling action between the bowler’s back-foot impact and front-foot impact. The information was derived primarily from the bowling hand (Müller & Abernethy, 2006). In conclusion, batsmen supplement information from the bowler’s biological motion with available projectile motion information to enhance performance (Croft et al., 2010). These findings imply that kinematic cues are utilized in the anticipatory process.

2.4.2. Kinematic Information

The motion of the projectile to be intercepted provides the most prominent source of information to guide successful interception; however, this information is often presented too late to serve as the sole source of information for successful interception (Müller & Abernethy, 2012). Therefore, information perceived from projectile motion often only provides either confirmatory information or information to update and fine-tune a general movement response selected from the earlier information perceived (Müller & Abernethy, 2012).

At the level of skilled performance in temporally constrained sports, performers are required to make rapid and accurate predictions based on minimal and uncertain information. In these situations, skilled performers perceive and utilize kinematic information, which is derived from the postural cues of opponents to anticipate their intentions more effectively (Murphy et al., 2018). Performers predict an opponent's intentions through the relative motion between specific body features, rather than through the use of information from more superficial features or isolated areas of the body (Williams, Hodges, North & Barton, 2006).

The severe time constraints associated with certain sports are such that the pick-up of information from the movement pattern of the opponent is essential to successful performance (Abernethy et al., 2001; Hagemann et al., 2006). Relevant kinematic information derived from the opponent's movement pattern provides the performer with additional time to initiate and execute the most appropriate response (Müller et al., 2009; Mann, Abernethy & Farrow, 2010). Kinematic patterns possess the vital information underlying biological motion perception (Huys, Smeeton, Hodges, Beek & Williams, 2008; Cañal-Bruland, van Ginneken, van der Meer & Williams, 2011). The biomechanics of an opponent's action are such that intent must be clearly stated, at some point prior to the action by the kinematic properties of his or her movement pattern (Abernethy et al., 2001).

Findings from past research on perceptual expertise show that there is a close link between expertise and the ability to perceive information about the kinematics of an action ((Müller & Abernethy, 2006; Weissensteiner, Abernethy, Farrow & Müller, 2008; Cañal-Bruland et al., 2011; Rosalie & Müller, 2013; Mann et al., 2014; Loffing et al., 2015). Successful anticipation is based on the skilled performer's more effective search strategy and better use of kinematic information to understand an opponent's intentions (Müller & Abernethy, 2006; Weissensteiner et al., 2008; Cañal-Bruland et al., 2011;

Rosalie & Müller, 2013; Mann et al., 2014; Loffing et al., 2015). In a study conducted by Abernethy and Zawi (2007), experiments were conducted to examine the role of kinematic information in anticipation. In the first experiment, skill-level differences in the use of kinematic cues were examined. Skilled (n=12) and less-skilled (n=12) badminton players were required to complete two tasks (temporal occlusion and point-light task displayed on a monitor). Point-light display involves the portraying of the activity of a human by the relative motions of a small number of markers (or lights) positioned on the head and joints of the body. The tasks displayed the hitting patterns of a badminton player from the view of the player's opponent. The participants were required to predict whether the upcoming shot would be played cross-court or down-the-line. Predictions were made by circling their response on a response sheet. Each task consisted of 32 different tasks that were presented in five different temporal occlusion conditions ranging from 167ms before racquet-shuttle contact to when the shuttle was no longer visible to the camera. Results of the first experiment revealed that except for the condition that was occluded 167ms prior to racquet-shuttle contact, skilled performers produced significantly greater prediction accuracy than the less-skilled group. The results indicated that skilled athletes possess a superior attunement to kinematic information when compared to less-skilled performers. In the second experiment, similar procedures were used, but the researchers isolated kinematic cues through the presentation of incomplete point-light displays in order to identify which cues skilled and less-skilled performers made us of. The results of the second experiment revealed that skilled performers made us of information emanating from the racquet and lower body kinematics, whereas, the less-skilled athletes were unable to make use of any kinematic cues when each cue was presented in isolation.

Similar research regarding skill-related differences in the use of kinematic information has been conducted in various other sports. Research conducted by Williams, Huys, Canal-Bruland and Hagemann (2009) in tennis used point-light display to manipulate specific body regions (e.g., shoulder, hips, arm-racket area) of opponents hitting tennis shots and presented the actions as point-light animations terminating at the point of racket-ball contact; whereas research conducted by Müller and Abernethy (2006) in cricket used an in-situ setting and liquid crystal spectacles to present batsmen of differing skill levels with temporally occluded deliveries bowled by leg-spin bowlers. Both studies aimed to examine skill-related differences and the findings of both studies revealed that skilled performers were superior at anticipating the opponent's action when compared to their less-skilled counterparts. Additional studies that conclude that skilled performers are superior to less-skilled performers with regards to the use of kinematic information include Loffing and Hagemann (2014) in handball, Takeuchi and Inomata (2009) in baseball, Huys et al. (2008) in tennis, Savelsbergh, Van der Kamp, Williams and Ward (2005) in soccer, and Müller and Abernethy (2006) in cricket.

Although it is evident that skilled performers are more successful at using advanced kinematic information for anticipation, there is inconsistent evidence as to the range of cues used by skilled verse less-skilled performers. Research conducted by Huys et al. (2008) in tennis revealed that skilled players relied on different body regions through the use of the spatial occlusion paradigm, whereas less-skilled players focused merely on the arm-racket area. This indicates that skilled players utilize a more global information pick-up strategy as opposed to the less-skilled players who rely primarily on local end-effector information (Loffing & Hagemann, 2014). The kinematic cues used, as well as the contribution of each selected body area, are likely to vary across sports and even between tasks in the same sport (Loffing & Cañal-Bruland, 2017).

When examining the gaze behaviour of cricket batsmen, it has been found that skilled batsmen make more fixations and spend more time viewing the bowler’s arm and the anticipated ball release area, as well as the more central areas of the bowler’s body such as trunk-hips and head-shoulder compared to less-skilled batsmen. These results indicate that the perception and usage of information from specific body areas can lead to greater anticipatory predictions (Ford, Low, McRobert & Williams, 2010); however, the factor limiting skilled anticipation is the ability to interpret available information from the relevant cues (Müller & Abernethy, 2012).

Although kinematic cues can be used to facilitate performance, deception and disguise are strategies used by opponents to impair performance (Müller, Abernethy, Eid, McBean & Rose, 2010). The goal of deception is to minimize the potential for anticipation to occur through the manipulation of the performer's own movement pattern (Müller et al., 2010). For example, bowlers can adjust their kinematics in such a way that false or irrelevant cues are presented to the opponent thus attracting attention away from the critically informative cues (Müller et al., 2010). The use of kinematic information as a way of disguising intention has been examined in a number of sports. These include handball (Cañal-Bruland & Schmidt, 2009), rugby (Jackson, Warren & Abernethy, 2006), and tennis (Rowe, Horswill, Kronvall-Parkinson, Poulter & McKenna, 2009).

In a study conducted by Müller et al. (2010) in cricket, groups of high (n=14), intermediate (n=12), and low-skilled (n=15) cricket batsmen took part in an experiment to examine the pick-up of kinematic information. Temporal and spatial occlusion methodologies were used to isolate particular kinematic cues of the bowler's movement pattern. The typical order in which the particular kinematic cues became available in a bowler's action was varied and the results on a prediction task were examined. The results revealed that adjusting the order in which kinematics were typically presented to batsmen, thus presenting false or irrelevant cues, negatively influenced performance. Manipulating the kinematics in such a way that false cues were presented to the opponent was found to be an effective strategy in detracting attention away from the most informative cues and thus impairing performance. Therefore, it is vital that performers are able to distinguish between relevant and irrelevant stimuli through selective attention for successful anticipation (Müller & Abernethy, 2012). Through extensive experience, skilled batsmen develop the ability to pay attention to the most relevant cues from a bowler's action and develop a more refined knowledge base (Renshaw & Fairweather, 2000). However, even skilled batsmen may struggle when bowlers deliver different types of deliveries using similar movement patterns (Renshaw & Fairweather, 2000).

The skilled performer's advantage of attending to and processing information from the kinematics of an opponent has been well documented; however, the significance of non-kinematic cues has only received minimal attention (Mann et al., 2014; Murphy et al., 2018). In a study conducted by Murphy, Jackson, Cooke, Roca, Benguigui and Williams (2016), the importance of non-kinematic information (situational probability information) was examined. Skilled (n=16) and less-skilled tennis players (n=20) were required to verbally indicate the depth and direction of the ball bounce location while swinging the racquet as if they were to execute a return shot. Participants viewed 180 trials split into two different conditions (normal video and animated footage). In the animated footage, sequences were presented using player movement and projectile motion information (kinematic information was removed to isolate non-kinematic information). In the normal condition, both kinematic and non-kinematic information was presented. Results revealed that during the animated condition, both skill groups predicted higher than chance. This finding demonstrates that non-kinematic information can be used by performers to make accurate anticipation judgements. When the animated condition was compared to the normal condition, results revealed that performers were more accurate when both kinematic and non-kinematic cues were presented. These findings conclude that while non-kinematic information can be used to anticipate future outcomes, kinematic information makes a significant additional contribution to anticipatory skill.

2.4.3. Situational Probability Information

It has been argued that non-kinematic sources of information used in time-constrained tasks provide added value to current kinematic and projectile motion information (Loffing et al., 2016). Apart from kinematic and projectile motion information, players rely on situational probability information that allows for early estimation of the likely action outcome in a particular situation (Loffing & Hagemann, 2014; Mann et al., 2014; Loffing et al., 2016; Loffing & Cañal-Bruland, 2017; Murphy et al., 2018). Probabilities allow the quantification of future actions and assist in the decision-making process(Levitin, 2016). The concept of situational probability encompasses situation recognition, and mobilisation of knowledge to effectively attract an athlete's attention to relevant information (Milazzo et al., 2016).

The importance of situational probability information was first examined in a study conducted by Alain and Proteau (1980). In the study, rallies of badminton, squash, and tennis players in match situations were presented back to the players that were filmed. Players assigned subjective probabilities to the occurrence of different types of serves executed by their opponents. Results revealed that serves that were assigned higher probabilities were associated with a greater frequency of anticipatory movements on court. This implies that a strong relationship exists between the participants' subjective assessment and the subsequent anticipatory movements. Accurate knowledge of probabilities is, therefore, a potentially powerful source of information for skilled performers.

An expert advantage exists prior to the availability of any kinematic information from the opponent's movement pattern implying that the expert advantage is due to expert's superior knowledge of the probabilities associated with each movement option of the opponent (Abernethy et al., 2001). Following the research conducted by Alain and Proteau (1980), Abernethy et al. (2001) conducted a study in which the expert advantage in using situational probability information was confirmed. Furthermore, the study identified that situational probabilities could be utilised to successfully predict action outcomes in the absence of an opponent's movement information. In the study, skilled (n=6) and less-skilled (n=6) squash players were required to complete a squash stroke when their vision was occluded using remotely triggered liquid-crystal spectacles. The prediction accuracy of the performers was assessed, and results revealed that the skilled performers were superior to their less-skilled counterparts when vision was occluded prior to the pre-contact preparatory movements of the opponent. The skilled performer superiority is credited to the perception and usage of situational probability information related to the opponent's pattern of play.

Utilization of situational probability information varies across different stages of an opponent's developing action; however, it is used predominantly in the early stages when uncertainty regarding the action-outcome is high (Loffing et al., 2016). The expert advantage associated to the use of situational probability information exists before kinematic information becomes available (Loffing et al., 2016). This is the case as situational probability information is typically presented well before the opponent initiates their movement (Cañal-Bruland & Mann, 2015). As more kinematic information becomes available, the use of situational probability information decreases (Loffing et al., 2016).

Superior advance knowledge of event probabilities may enable earlier movements in sport given that the probability of making anticipatory movements has been shown to be linearly related to the subjective probability performers give to any action's occurrence (Abernethy et al., 2001; Mann et al., 2014). It has been well documented that if one particular stimulus option is more probable than another, the amount of information processed and the amount of uncertainty is reduced and performance is adjusted accordingly (Abernethy et al., 2001).

Performer's actions are embedded in task and sport-specific contexts. In any particular sport setting, there are likely to be a number of different sources of situational probability information, alongside the kinematic information derived from the movement pattern of the opponent, that performers can use to facilitate their anticipatory responses (Cañal-Bruland & Mann, 2015). Research has been conducted to identify different sources of situational probability information including patterns related to game score (Farrow & Reid, 2012), exposure to an opponent's action preferences (Mann et al., 2014); and exposure to previous sequences of action outcomes (Loffing et al., 2015). The different sources were found to be integrated in the anticipatory process and positively affect anticipation of the opponent's intentions (Loffing et al., 2015).

The opponent against whom the performer is competing is the most abundant source of situational probability information (Loffing & Cañal-Bruland, 2017). The strengths and weaknesses of the opponent, the tendencies and predispositions of the opponent, the skill level and experience of the opponent, and the relative position of the opponent are a few sources of situational probability information that have been identified that emanate from the opponent during performance (Loffing & Cañal-Bruland, 2017). Performers often know their opponents through previous competitions and/or performance profiles (Loffing & Cañal-Bruland, 2017). When a performer is familiar with an opponent, knowledge of sequential probabilities of their patterns of play allows for successful anticipation of the opponent's intentions and organization of his/her own movement response (Abernethy et al., 2001). Extensive training and competition allows for skilled players to become more aware of and more likely to include situational probability information about their opponents into their anticipatory predictions (Loffing & Hagemann, 2014).

In elite sport, performers are able to access and retrieve model situations in relatively short timeframes through their knowledge stored in long-term memory acquired through long-term working memory (LTWM) (Milazzo et al., 2016). This ability allows skilled performers to overcome the limitations of short-term working memory through the use of retrieval cues kept in short-term memory that are associated with the appropriate decisions in long-term memory (McRobert et al., 2011; Farrow & Reid, 2012; Milazzo et al., 2016). The retrieval structures allow skilled performers access to task-relevant options, which can be evaluated to inform an accurate prediction rather than merely prescribing a fixed action response. Skilled performers are thought to adjust their action outcome expectancies according to situational probability information that is presented in conjunction with later-occurring kinematic information (McRobert et al., 2011; Milazzo et al., 2016).

Skilled and less-skilled performers access, perceive and use information in different ways (Farrow & Reid, 2012). A difference has also been found in the ability of younger and older performers to use situational probability information (Farrow & Reid, 2012; Loffing & Hagemann, 2014). Older performers are able to use situational probability information to facilitate anticipation, whereas, younger performers are not. The difference in ability is due to the younger performers' lack of awareness that such information exists and can be explained by examining the knowledge structures and retrieval processes of younger performers. Through examining these processes, it is seen that youth "experts" do not build profiles relating to an opponent's strengths, weaknesses, and tendencies. One possible reason behind this is that such information is not required for skilled performance in younger performers, because the temporal constraints have not reached the point where anticipation is required. Another reason is that younger "experts" have not gained enough experience to use situational probability information and the final possible reason to explain the large difference between young and older expert's capability to use situational probability information is that due to the younger performers' lower level of performance, situational probability information may not exist or is too unpredictable to rely on (Farrow & Reid, 2012).

There is a clear advantage in anticipating upcoming action outcomes when situational probability information is used correctly; however, situational probability information, may in some circumstances be detrimental to performance (Loffing et al., 2015). The ability to use situational probability information facilitates performance through the improvement of response time and response accuracy. However, this might not always be the case as it has been argued that anticipation is based on uncertain information and therefore can in some instances lead to incorrect decisions (Mann et al., 2014). Firstly, research has shown that response time, response accuracy, and/or response timing may be impaired when action outcomes are incongruent with expectations derived from situational probability information (Levi & Jackson, 2018). If the expected outcome is congruent with the actual outcome (and the kinematic information), then the use of situational probability information should facilitate an advantage that is better than that possible if only kinematic information was relied upon. In contrast, if the expected outcome differs from that derived from the kinematic information then it seems rational to expect that situational probability information may decrease rather than improve anticipatory performance. As an example, in a study conducted by Mann et al. (2014), two groups of skilled handball goalkeepers anticipated the direction of penalties thrown by opponents prior to and after a training intervention that provided situational probability information in the form of action preferences. One group took part in a training intervention that consisted of two throwers that had a strong preference to throw in a specific direction and the other group took part in training that included throwers possessing no action preference. Results revealed that exposure to opponents that did possess the action preference during the training phase resulted in improved anticipatory response if the opponent continued to bias their throws according to their action preferences, but decreased performance resulted if the opponent did not continue with their action preferences. Similar findings have been found in research conducted by Runswick, Roca, Williams, McRrobert and North (2019) and (Murphy, Jackson & Williams, 2015) in cricket, Gray (2002) and Canãl-Bruland, Filius and Oudejans (2015) in baseball, and Loffing et al. (2015) in volleyball. The studies revealed that when an opponent's action outcomes were incongruent with expectations derived from situational probability information, a decrease in anticipatory performance occurred. Confirmation bias is a possible way in which the positive and negative effects of anticipation can be explained. This infers that once a decision has been made, performers have a tendency to use supporting information rather than conflicting information regarding event outcome. For an example in cricket, if batsmen develop event outcome expectations based on early information (situational probability information), this could lead to confirmation bias and affect the use of later occurring information (kinematic and projectile motion information) (Runswick et al., 2019). In congruent events, a prediction is made based on early information and supported with later occurring information leading to accurate anticipatory performance. However, in incongruent events, the later occurring information may not be utilized as it is in contrast with earlier arising information and the originally initiated action response, therefore leading to impaired anticipatory performance (Runswick et al., 2019).

Another reason as to why situational probability information might impair performance is that information about the action-outcome might distract performers from making the well-learned responses that they are familiar with (Mann, Schaefers & Cañal-Bruland, 2014). More specifically, skilled performers develop their expertise through the use of advance kinematic information to facilitate their motor responses, and they are thought to do this without having explicit knowledge of why or how the motor action was performed (Mann et al., 2014). Therefore, by attracting attention to specific outcomes of sources of information, additional information pertaining to the likely outcome may distract skilled performers from utilizing the kinematic patterns that they would typically use to anticipate correctly (Mann et al., 2014).

2.4.3.1. Types of Probability

In any particular sport setting, there are likely to be a few different sources of situational probability information in addition to the kinematic information derived from the movement pattern of the opponent (Cañal-Bruland & Mann, 2015). The types of situational probability information relevant to the study include sequencing information and pattern information and will be discussed in the sections to follow. Action preference information is another type of situational probability information that facilitates anticipation; however, it is not included in the scope of the study and therefore will not be elaborated on (see a study conducted by Mann et al. (2014) for a better understanding regarding action preferences and the anticipation of event outcomes).

2.4.3.1.1. Sequencing

There is abundant evidence available that shows performers use informational sources pertaining to sequences such as the history of previous deliveries/pitches and/or the counting of pitches to facilitate anticipation of the location and speed of arrival of the ball (Gray, 2002). Performers are aware of sequence information and are continuously searching for sequences and relying on them to guide future actions (Loffing et al., 2015). Skilled performers are more capable than less-skilled performers at identifying repeated sequences in an opponent's action and using this information to enhance anticipation (Murphy et al., 2018). The use of sequence information and the associated expert advantage was investigated in a study conducted by Milazzo et al. (2016) in 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 scenarios were presented was altered to provide situational probability information. Specifically, one of the attacks was repeated every four actions. Response accuracy and initial movement time of the fighters was required for the investigation, with eye-tracking and verbal report information providing a more in-depth understanding of the perceptual-cognitive skills used. Results revealed that skilled, but not less-skilled performers, were faster at blocking an opponent's attack when situational probability in the form of a repetitive attacking sequence was available. Additionally, the decision time and accuracy results corresponded to the statements made by the skilled performers in the verbal reports which stated that the skilled performers were aware of the repeated use of the same attack after the fifth and sixth time the attack was repeated. Furthermore, results revealed that the less-skilled performers were unaware of the sequence information. The superiority in response accuracy of skilled fighters was attributed to the ability to use sequence information to facilitate anticipation. The findings of the study are in alignment with similar research that suggests that in a natural performance setting skilled performers benefit from the knowledge of specific sequences in sport (see Farrow & Reid, 2012).

A study conducted by Murphy et al*.* (2018) in tennis revealed the advantage that skilled performers have over less-skilled performers with regards to the use of sequence information, but more interestingly the study found that the most useful information was contained in the shots immediately prior to the critical event rather than shots earlier in the performance. This finding seems to be logical as the situation, in dynamic sports such as tennis, seems to change drastically from one shot to the next. Although the most useful information was contained in the shots immediately prior to the critical event in tennis, different task constraints require the performer to focus on different sources of information to varying extents and in different ways (Murphy et al., 2018). Therefore, the use of sequence information may differ from one sport to the next.

The use of sequencing as a source of situational probability information has been examined in a variety of sports. Research has proven the importance of sequencing as a source of advance information in baseball (Gray, 2002), volleyball (Loffing et al., 2015), and Karate (Milazzo et al., 2016). Although the importance of sequence information has been proven in many sports, the number of trials between the occurrence of the sequence is a topic that has been rarely discussed and should be focused on in future research. Research conducted by Gray (2002) and Farrow and Reid (2012) presented sequence information at set instances in performance such as at specific pitch counts in baseball or on the first point of each game in tennis. Findings of both studies revealed the ability of skilled athletes to use the sequence information to improve performance. The same findings were observed for studies conducted by Milazzo et al. (2016) and Loffing et al. (2015) who presented sequence information on every fourth and sixth trial respectively. These results imply that the number of trials or amount of time between the occurrence of sequence information does not influence the effectiveness of the sequence information in facilitating anticipation, but without research being conducted on the topic, no conclusions can be drawn.

2.4.3.1.2. Pattern Recognition

The second source of situational probability information to be discussed is the presentation of pattern information. Pattern information refers to information emanating from the position of a single object/opponent in a display such as the positioning of an opponent on a tennis court (Loffing & Hagemann, 2014), or the configuration of a number of objects/opponents in a display such as the placement of fielders in a cricket match (Runswick et al., 2019). Superior recognition and recall of domain-specific patterns are well recognized as defining characteristics of skilled performers (Abernethy, Baker & Côté, 2005). It has been well documented that skilled performers are able to rapidly and accurately recognise meaningful patterns in situations; whereas, their less-skilled counterparts are unable to (Abernethy et al., 2005; Farrow, McCrae, Gross & Abernethy, 2010; Afonso et al., 2012). This advantage is apparent and is true regardless of whether the presented patterns are static or dynamic, whether the patterns presented are visual or auditory, and whether the elements of the pattern to be recalled are opposing player positions in a team sport or external layouts such as the placement of balls on a snooker table (Abernethy et al., 2005; Farrow et al., 2010).

In cricket, a batsman's future action is determined based on pattern information emanating from the placement of fielders. For example, a batsman may look around at the fielding positions before preparing himself for the subsequent delivery (Cotterill, 2014). The importance of field placements in cricket was investigated by Runswick et al. (2019) while examining the effect of congruency between contextual information and event outcome. In the study, the congruency between the information available and the event outcome was examined. In order to examine the congruency between the information and the event outcome, the relationship between situational probability information (field placement and game situation) and the final ball location in a cricket-batting task was manipulated. Skilled (n=18) and less-skilled (n=18) cricket batsmen were required to anticipate deliveries during a temporally occluded video-based task. Each batsman in the study was presented with 36 trials. Within these trials, 18 trials were congruent (trials in which the ball location was tactically appropriate to the game situation and field placement) and 18 trials were incongruent (trials in which the ball location was not tactically appropriate to the game situation and field placement). Results of the study revealed that skilled batsmen were able to use information emanating from field placement information and game situation information to anticipate correctly when the information was congruent with the action outcome; however, skilled batsmen were negatively affected when information presented was incongruent to action outcome. Additionally, an expertise advantage in the use of pattern information to facilitate anticipation was identified.

A performer's decision-making and the selection of appropriate responses in domain-specific tasks are limited by their level of expertise in the specific domain, as well as previous exposure to the stimulus and the context-specific information related to the situation (Williams et al., 2006; McRobert et al., 2011; Murphy et al., 2018). For example, the provision of context in chess, such as the meaningful pattern of chess pieces, aids to the ability of skilled performers to encode and recall, the configuration (pattern) of the chess pieces (McRobert et al., 2011; North et al., 2011). The skilled performer's advantage in pattern recall appears also to be reproduced in their ability to recognize previously experienced patterns. Skilled performers are more proficient than their less-skilled counterparts in their ability to differentiate between previously encountered and novel patterns (Abernethy et al., 2005). The expert advantage with regards to using patterns of play to facilitate anticipation was further uncovered in a study conducted by Williams and Davids (1995) in soccer. In the study, experienced skilled soccer players (n=12) and experienced less-skilled soccer players (n=12) were presented with test film and were required to anticipate pass direction. Performers were presented with a grid of the field with numbers representing different sections of the field. When performers were presented with a pattern of play, they were required to anticipate to which section of the field the final pass would be delivered. Performers were required to state as quickly and as accurately as possible the section of the field anticipated as the final pass destination in both structured and unstructured patterns of play. The structured clips contained offensive plays that concluded with a pass into the attacking third of the field or a shot at goal, whereas, the unstructured clips of film contained non-task-specific passages of play such as players walking onto and off of the pitch, teams warming up before the game, or a stoppage in play while injured players received treatment. Results revealed that the skilled defenders were more accurate and quicker than their less-skilled counterparts with regards to recognizing structured patterns. The skilled defenders also demonstrated superior performance when unstructured patterns were presented. This suggests that even in unstructured clips, there is some element of structure in the display which skilled performers can use to facilitate recognition. Similar findings were observed in a study conducted by Allard et al. (1980) in basketball. The results of the study corroborated the results of Williams and Davids (1995) in that skilled performers were superior at recognising structured patterns when compared to less-skilled athletes; however, the study also revealed, in contrast, that no difference between skilled and less-skilled athletes was found when unstructured patterns were presented.

In 2011, Gorman, Abernethy and Farrow (2011) conducted a similar study in basketball to the study conducted by Williams and Davids (1995); however, patterns were displayed through the use of presented video recordings as well as schematic images.

A total of 46 male basketball players were allocated into four groups including an expert group (n=12), a recreational group (n=12), a soccer group (n=10) and a novice group (n=12). In each trial, either two static images or two video presentations were presented to performers one second apart from each other and performers were required to distinguish whether the presented patterns were the same or different from one another by pressing a certain key on a keyboard. The results revealed that both expert and novice basketball players are able to anticipate the evolution of a complex pattern from their specific domain when displayed in a dynamic manner (moving videos); however, only expert performers have the depth of understanding required to produce the same anticipatory encoding for patterns presented as schematic images. When static images of complex patterns from a specific domain are displayed, a basic understanding of human motion is not sufficient to produce the anticipatory response. Rather, based on the results of the expert and novice basketball players in the study, it seemed that the performer is required to have an intricate knowledge of the interrelationships between the players within the pattern before representational momentum can occur.

In conjunction with being able to outperform their less-skilled counterparts in differentiating novel from previously encountered patterns, skilled performers possess the knowledge to derive information about the successive stages of a match. This knowledge is used very early on in visual perception (Gorman et al., 2011). Therefore, for skilled performers who have developed an understanding of the patterns of play that typically occur in their specific domain of expertise, the ability to rapidly evaluate a visual display and make an anticipatory prediction as to what is going to occur next is influenced by the depth of their knowledge as well as the anticipatory nature of the memory trace (Gorman et al., 2011).

The recall superiority possessed by skilled performers holds consistently for situations containing domain-specific structure but is either reduced or lost completely in situations where the general domain-specificity is disturbed (Abernethy et al., 2005; Farrow et al., 2010). The specific domain-specific knowledge structures that are linked to the expert advantage are stored and retrieved efficiently from long term memory (Farrow et al., 2010; North et al., 2011; Murphy et al., 2018). Skilled performers are able to encode the available information and associate it with a retrieval cue in short term memory, which allows access to information in long term memory with regards to the relationship between the perceived information and potential situation outcomes. These retrieval structures allow skilled performers access to task-relevant options, which can be examined to infer an accurate prediction rather than merely generating a set response (Murphy et al., 2018). In contrast, less-skilled performers have inadequate memory structures due to their lack of domain-specific experience. Therefore, these performers are unable to predict and evaluate events and react only when stimuli become available in the situation rather than planning ahead based on anticipated future events (North et al., 2011). The process of perceiving specific sporting patterns as chunks rather than single items, such as individual opponents, allows a skilled performer to process the patterns quicker. Theories have added templates to the concept of chunks so that additional variables, such as the situations next likely state, are taken into account. This content is linked to anticipation and is related to the pattern perception of skilled performers (Farrow et al., 2010).

2.4.3.2. Interaction of Different Sources of Situational Probability

In an opinion paper by Cañal-Bruland and Mann (2015), a call was made to broaden the understanding of the role situational probability information plays in anticipation in sport. Additionally, Runswick et al. (2017) stated that future researchers should manipulate access to each source of information presented in order to quantify the degree to which each influences anticipation in a specific task. The call was made as the degree to which each source of situational probability influences anticipation and the interaction between different sources of situational probability had not been elaborated on. The findings of this kind of research would be beneficial as it would help researchers identify the most relevant source/s of information used by performers to successfully anticipate an opponent’s intention.

2.5. Summary

The information obtained from literature has provided relevant awareness of the role that anticipation plays in sport, more specifically the role situational probability information plays in fast-ball sports such as cricket. Research conducted on the demands of fast-ball sports, information processing and decision-making, and the different sources of information used to anticipate were reviewed and will be considered when elaborating on the findings of the study, helping provide possible reasons as to why certain results were obtained.

The chapter to follow contains all the relevant information regarding the methods and procedures that were followed to conduct the study. The steps taken to obtain reliable results will be covered in detail.

Chapter 3: Method and Procedures

3.1. Introduction

The review of literature highlighted the empirical evidence in the field and therein numerous methods for investigating sources of information. In this chapter, the focus is on providing details regarding the methods and procedures utilized in the current study.

The chapter begins by outlining the research design and describing the participants and appropriate sampling methods to recruit those participants. A large part of this chapter is dedicated to explaining the test set up, measuring instruments, and the data collection and testing procedures. Data coding and analysis are highlighted towards the end of this chapter with a section on the consideration of ethics to finish.

3.2. Research Design

The study is classified as a quasi-experimental research design as it involves the manipulation of an independent variable without the random assignment of participant (De Vos, 2005). A within-subject design with multiple conditions was employed as each individual was exposed to the same conditions. A variety of conditions were presented to participants including a control condition (De Vos, 2005).

3.3. Participants and Sampling Technique

Skilled cricket batsmen (n=15), who matched the inclusion criteria, were included in the study. The mean age of the batsmen was 21.42 ± 2.71 years with the age range being between 18 and 27 years. The mean years of experience was 16.71 ± 3.02 with the range being between 11 and 21. Of the 15 participants, 13 played provincial cricket; whereas the remaining two participants played club cricket alone. According to a study conducted by Weissensteiner and colleagues (2008), cricket batsmen do not make use of anticipation before the age of 17, therefore batsmen younger than 17 were excluded from participation in this study.

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

- Be a male.
- Be a batsman that bats in the top six of the batting order.
- Be a member of one of the top five senior cricket clubs in Port Elizabeth at the end of the 2017/2018 cricket season.
- Be injury-free.
- Be able to attend testing.
- Be over the age of 18.

This study made use of non-probability, purposive and convenient sampling. A non-probability, purposive sampling technique was applied as skilled performers were required because only skilled performers possess such perceptual-cognitive skills. Convenient sampling was utilized because of logistical reasons. Budget constraints on the part of the researcher and access to highly skilled batsmen throughout the country was not possible, but the use of situational probability information could still be investigated with local players using the senior club league's log system to identify skilled batsmen. The participants were chosen from five of the top senior clubs in Nelson Mandela Bay as ranked on the previous club-cricket season's log.

3.4. Pilot Testing

Prior to the initiation of data collection, two pilot testing sessions took place. The first session was conducted to check the testing setup, more specifically, the velocity at which the bowling machine delivered the balls was observed. Different bowling machine settings were used in order to test which settings would project the balls at the desired velocity which was between 100 and 120 kilometres per hour (km/hr) (medium pace). A video camera (Hero 6 Black Gopro Video Camera, China) was set up at an outdoor cricket net in such a position as to capture both the release point of the bowling machine as well as the probable stance position of the batsman. The video camera was used to record the delivery and video analysis software (Version 9.0 Dartfish Video Solution) was used to identify the velocity of the ball. Consistent with Müller et al. (2009), velocity was calculated using the formula, velocity(m/sec) = distance(m)/time(s). The distance was 17.68 meters (m) from the bowling machine's release point to the batsman's probable stance position. The Travel time of the ball was calculated through a frame by frame analysis and converted to seconds.

The second pilot session was conducted to familiarise the researcher and research assistant with the testing setup and data collection procedure. The entire data collection procedure was conducted with a volunteer that matched the inclusion criteria of the study. The results of the participant in the pilot testing did not form part of the results in the study.

3.5. Testing Setup

Prior to the arrival of the participants at the testing venue, the pitch was rolled to improve the condition of the pitch, and the correct testing setup was prepared.

A bowling machine (220-volt Jugs Cricket Bowling Machine) was used to deliver the cricket balls as it isolates situational probability information by eliminating the kinematic information emanating from the bowler. Furthermore, the machine in conjunction with a laser pointer (500 MW HY 303 Assassin Laser Pointer) ensured that each delivery landed in precisely the correct position on the pitch. The laser pointer was mounted to the bowling machine and set up so that when shining, it aligned with where the ball would pitch.

The bowling machine was set up on the popping crease, over the wicket (just to the right of the wicket when viewed from the batsman's perspective), on one side of an outdoor-net cricket pitch with the batsman standing on the opposite side of the pitch at a distance of 17.68m away from the bowling machine (see Figure 3.1). The positioning of the pitch and bowling machine was such that environmental conditions (wind and sunshine) did not affect results. On the odd occasion that it rained, covers were placed on the pitch and testing was postponed to the next available time. The speed of the bowling machine was set with balls delivered from the machine varying between 100 and 120km/hr depending on the length of the delivery. The height at which the bowling machine delivered the ball was 2.10m as the average ball release height of male cricketers is in the range between 1.91m and 2.27m (Worthington, 2010). To ensure that participants did not use the positioning of the bowling machine to predict the line and length of a delivery, a sheet of material was used to block the participants sight of the machine with a small hole cut out of the sheet to allow for the ball to pass through from the bowling machine without altering the ball path (see Figure 3.2). The balls that were used in the study were Kookaburra bowling machine balls. These balls were used as they negate the effects of swing and seam movement that would occur if regular cricket balls were used. This was important as response accuracy results may have been affected by swing and/or seam movement if they had not been negated. In order to identify initial movement time and reassess response accuracy, a camera was set up on the off-side of the batsman in such a position as to capture both the release point of the bowling machine and the batsman making contact with the ball. These events are important as they were used in determining the initial movement time of the batsman.

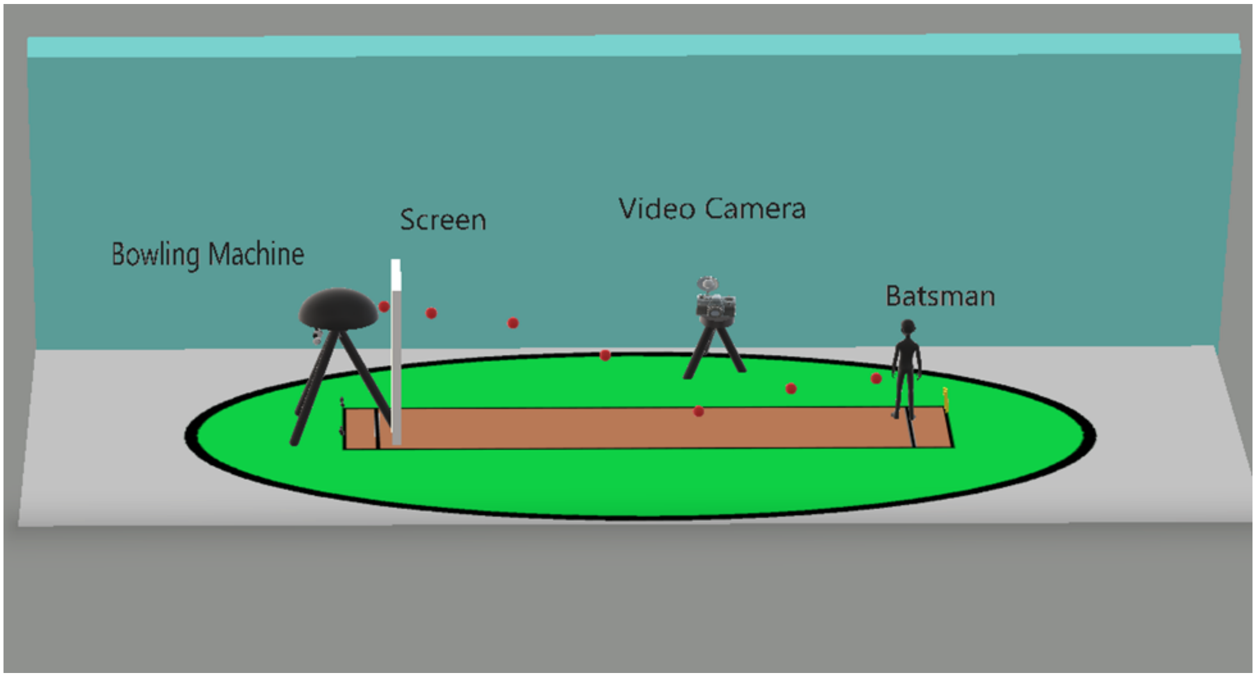


Figure 3.1 - Setup of the testing procedure

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

In order to determine the interaction between different sources of situational probability information used by skilled cricket batsmen to predict an upcoming cricket delivery, an in-situ test was performed. The test comprised of skilled cricket batsmen being exposed to 10 overs (60 balls) of bowling delivered by a bowling machine with the researcher asking the participant a number of questions to assess prediction accuracy, level of certainty associated with prediction accuracy, and the source of situational probability used to make the decision prior to each trial. Participants were encouraged to make successful bat-ball contact and play in an attacking manner during each trial.

In order to predict the line and length of the upcoming delivery, participants were provided with two sources of situational probability information. Participants were informed of the sources used and that they could be used to anticipate the landing position of the upcoming delivery. The two sources of situational probability information that were provided were bowling sequence and field placement information.

The bowling sequence that was used was the delivery of a full and straight delivery on the first and last ball of the over. Although a full and straight ball was not always present on the first and last ball of each over, it occurred more than any other type of delivery on the first and last ball of the over. On the first and last balls of the over, the full and straight delivery occurred 50% of the time; whereas, the remaining 50% was made up of short and straight deliveries (25%), short and wide deliveries (15%), and full and wide deliveries (10%). The deliveries that were presented between the second and fifth ball of each over, did not contain the bowling sequence.

The field placement information that was available was the placement of fielders in such a way that would suggest that a full and straight delivery was going to be bowled in the upcoming delivery. Prior to each delivery being bowled, the researcher provided the batsman with a diagram with the field placement that was implemented for the upcoming delivery. The diagram provided to batsmen included each field placement for right-handed batsmen, as well as for left-handed batsmen. The field placements used in the study were decided upon through the input of three level-three cricket coaches.

The two sources of situational probability information included in the current study were tested both together and independently of each other in order to compare the importance that participants assigned to them. In order to be able to describe and compare the use of field placement and bowling sequence/pattern information, by cricket batsmen to predict the bowler's intention, four different conditions existed. These conditions included:

- Control trials – no source of situational probability information was available to participants.
- Sequence alone – bowling sequence information was the only source of information available to participants.
- Field placement alone – field placement information was the only source of information available to participants.
- Both sources of information – both bowling sequence and field placement information was available to participants.

The different conditions were further categorised through the addition of a category of congruency. The categories of congruency included:

- Congruent – A trial was termed congruent if the delivery bowled (action-outcome) was tactically appropriate to the condition of situational probability information available.
- Incongruent - A trial was termed incongruent if the delivery bowled (action-outcome) was not tactically appropriate to the condition of situational probability information available.
- No congruency – A trial in which no congruency existed as no source of information was made available to the participant. Field placement information presented during these trials was random and provided no advance information pertaining to the event outcome of the upcoming delivery. These were the control trials.

Categories of congruency were included in order to create realistic hypothetical game situations in which competition existed between the batsman and the bowler. In cricket, the congruency of the action-outcome is related to two factors. These are whether the bowler intends to deceive the batsman or whether the bowler is able to execute the intended action outcome in relation to the source of situational probability available. For example, a congruent trial would exist if the field placement set out infers that a short ball will be bowled and then the bowler bowls a short ball. And an incongruent trial would exist if the field placement set out infers that a short ball will be bowled but the bowler bowls a full ball, either because of a poor delivery or as a deceptive tactic.

Once the different categories of congruency were added to the different conditions, the following combinations existed:

- Control trials – no congruency
- Sequence alone – congruent trials
- Sequence alone – incongruent trials
- Field placement alone – congruent trials
- Field placement alone – incongruent trials
- Both sources – congruent trials
- Both sources – incongruent trials

In order to ensure that each combination was presented in the testing procedure, a number of different deliveries were bowled and a number of different field placements were used. Deliveries were regarded as full if they pitched closer than 6.00m to the batsmen and short if they pitched further than 6.00m away from the batsman. Furthermore, deliveries were regarded as leg-side if the ball pitched on the leg-side of the off-stump and were regarded as off-side if they pitched on the off-side of the off-stump. A full and straight delivery (a delivery that pitched full, on the leg-side) was included in the study as the type of ball that the sequence comprised of. In addition to the full and straight delivery, three different random types of deliveries were bowled to ensure that no situational probability information, with regards to bowling sequence, was available. The three random deliveries included full and wide deliveries, short and wide deliveries and short and straight deliveries. The three random deliveries, along with the position on the pitch where each delivery landed, can be seen in Figure 3.3. The inverse of Figure 3.3 was used for left-handed batsmen.

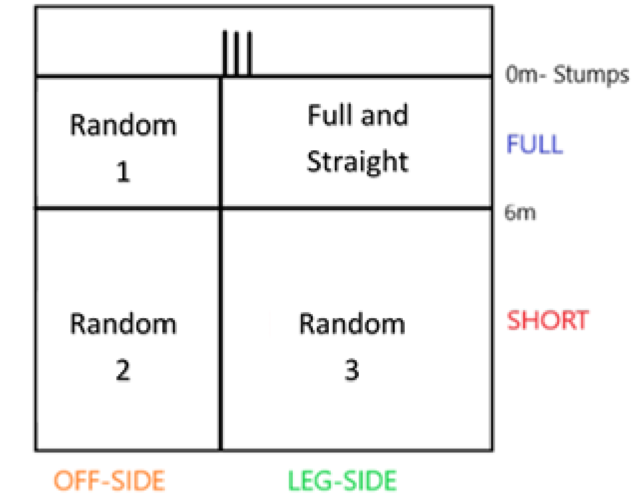


Figure 3.3- Landing position of deliveries included in the current study.

Four different field placements, authorised by three level-three coaches, were used in the study. One of the field placements used suggested the delivery of the ball aligned to the sequence (full and straight ball). The remaining three field placements were random and were used to ensure that no situational probability information with regards to field placement was available. The three random field placements, along with the field placement aligned with the sequence, are included in Appendix 4.

The type of delivery and field placement of each trial was distributed according to Table 3.1 and Table 3.2. This distribution ensured that the different conditions (no situational probability information, field placement information only, bowling sequence information only, bowling sequence and field placement information) were presented in such a way that they could be compared in terms of prediction accuracy. Two different variations of the full sequence of trials were used with an example of the full sequence being illustrated in Appendix 7. 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. The trials were created in such a way that there was an equal number of trials for each type of condition.

Table 3.1 - Different condition and congruency combinations in the first and last balls of each over (1&6)

Different combinations of bowling sequence and field placement and the distribution thereof - ball 1&6				
Condition	**Congruency**	**Ball**	**Field**	**Number of trials**
Sequence alone	Congruent	Full & straight	Random	5
	Incongruent	Random	Random	5
Sequence & field placement	Congruent	Full & straight	Full & straight	5
	Incongruent	Random	Full & straight	5

Table 3.2 - Different condition and congruency combinations in the second to the fifth ball of each over (2-5)

Different combinations of bowling sequence and field placement and the distribution thereof - ball 2-5				
Condition	**Congruency**	**Ball**	**Field**	**Number of trials**
No sources	None	Random	Random	30
Field placement alone	Congruent	Full & straight	Full & straight	5
	Incongruent	Random	Full & straight	5

3.6. Measuring Instruments

Four different measuring instruments were utilised in order to facilitate successful data collection. The following components were assessed: prediction accuracy, level of certainty associated with prediction accuracy, response accuracy, and initial movement time.

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 the situational probability information provided. The participants responded by verbally answering the questions and the researcher recorded the answers on a data collection sheet (see Appendix 6). The researcher asked the following questions:

1) What do you predict the line of the following ball to be?

The following options were given as the two possible answers to this question:

a) Off-side
b) Leg-side

2) What do you predict the length of the following ball to be?

The following options were given as the two possible answers to this question:

a) Short
b) Full

A prediction was regarded as successful if both the line and length of the delivery were correctly predicted by the participant.

3) How certain are you that your prediction is correct?

Notes were taken on the level of certainty associated with prediction accuracy. The following Likert scale was used by participants to express their level of certainty regarding prediction accuracy:

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

4) <u>What information did you use to make this decision?</u>

Participants were required to inform the researcher which source of information was used to make their decision. Possible answers included field placement, sequence, both or other (e.g. previous delivery).

The responses to the above-mentioned questions were recorded by the researcher through communication with the batsman. The batsman's responses were scribed onto the data collection sheet (see Appendix 6) prior to each trial.

3.6.2. Response Accuracy

For each trial that was conducted, batsmen were physically required to make bat-ball contact (movement response) given the in-situ nature of the test. Following each trial, notes were taken on the accuracy of the batsman's response, more specifically on the quality of bat-ball contact. The researcher and research assistant determined the response accuracy. The researcher and research assistant did not have any formal qualification in cricket but had 15 years of playing experience and an adequate knowledge of cricket batting. Furthermore, each trial was digitally recorded with a video camera and the footage was reviewed by the researcher and research assistant to assess the response accuracy of the participants.

Values representing the quality of bat-ball contact on each trial were assigned by the researcher in conjunction with the research assistant. The values represented bat-ball contact as follows:

0: unsuccessful trial – failure to make bat-ball contact or bat-ball contact that resulted in the ball not travelling in the desired direction with reference to the direction of the face of the bat. As the participants were encouraged to play in an attacking manner, if no attempt was made to play the ball, it was regarded as an unsuccessful trial.

1: successful trial – bat-ball contact made, and the ball travelled in the desired direction with reference to the direction of the face of the bat.

3.6.3. Initial Movement Time

For each ball delivered to the batsmen, initial movement time was identified through the use of a video camera (GoPro Hero 6 Black, China) that was set up so that both the bowling machine as well as the batsman were in the field of view. The frame rate used (100 frames per second) meant that if a 1 frame error occurred it would lead to an error of 0.01 seconds. The initial movement time of the batsman referred to the length of time between the projection of the ball from the machine and the first recorded foot movement of the batsman excluding trigger movements (routine preparatory movements made by the batsman significantly prior to ball release). Trigger movements of each participant were identified by the researcher and research assistant during the familiarisation trials prior to data collection. The initial movement time information was useful in determining whether or not the use of situational probability information lead to earlier initiation of movements. It was essential to have both the batsman and the bowling machine in view as the point of the ball exiting the machine (see Figure 3.4 – label A) was the point of reference and the batsman's initial foot movement (see Figure 3.4 – label B) excluding trigger movements was determined as the initial movement. The first frame in which the ball appeared from the machine was used as the first marker and the first observed movement of the feet excluding trigger movements was used as the second marker. The time between the two markers was regarded as the initial movement time. In alignment with Navia, Van der Kamp and Ruiz (2013), movements that occurred prior to the ball leaving the machine had negative movement times, whereas movements that occurred following the ball leaving the machine represented positive movement times. The initial movement time was utilised to corroborate the prediction accuracy of the delivery that was gathered prior to each delivery.

Figure 3.4 - Frame analysis depicting zoomed images of the bowling machine and participant. Label A refers to a zoomed image of the head of the bowling machine and label B refers to a zoomed image of the batsman.

3.7. Data Collection and Testing Protocol

Testing was organised with participants according to when they were available. Testing took place either late morning, midday or early afternoon to account for sufficient light levels. Participants were tested individually and in separate sessions so that the order of deliveries could not be identified. Upon the arrival of the participant to the testing venue, an informed consent form (refer to Appendix 2) was required to be filled out. Following the completion of the consent form, the researcher explained the testing procedure to the participant, as well as answered any queries that the participant might have had. Thereafter, the participant was instructed on how to give a verbal report as this required an unconscious task to become more cognitive in nature. The participant was then required to equip themselves with the appropriate protective gear and familiarise themselves with the testing procedure. The familiarisation period included 20 familiarisation trials (20 deliveries) in which the participants familiarized themselves with the speed of the ball machine and the process of providing verbal responses.

Following the familiarisation period, the participants were explicitly informed of the bowling sequence that would be present on the first and last delivery of the over (1st and 6th balls of the over) and that the remaining deliveries (2nd – 5th balls of the over) would not contain any bowling sequence. Participants were also explicitly informed that field placement could be used to predict the line and length of the upcoming delivery; however, participants were not told specifically what type of delivery could be anticipated from the field placement/s, nor which field placement could be used to anticipate the upcoming delivery. The test was then initiated, and trials were recorded on the data collection sheet.

The research assistant shone the laser and positioned the bowling machine to ensure the ball would pitch in the correct quadrant of the pitch. This was done while the participant had their back turned and was providing verbal responses to the researcher. The time taken by the participant to complete the verbal report for the subsequent delivery was the same for each delivery and served as a way to keep the fore period before each delivery consistent. Thereafter, the ball was held up in the air by the research assistant so that the batsmen could clearly see the ball and know that the trial was about to commence. The ball was then placed into the bowling machine. 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. This ensured that early occurring situational probability information and later occurring projectile motion information were the only sources of information available to batsmen to anticipate the delivery outcome.

The researcher recorded the verbal responses of the participant and following each delivery, the response accuracy of the trial was recorded. Following the initiation of the test, breaks were enforced. The breaks replicated the change of over in a cricket match while affording the research assistant time to fetch balls for the upcoming trials. These breaks provided the participants with time to drink some water and mentally refocus for the trials ahead. Upon completion of the testing procedure, a debrief was performed in which the researcher thanked the batsman for his participation.

3.8. Data Coding

Data coding was required to identify initial movement time results. The initial step of the coding process was to download the video from start to finish of each respective batsman from the video camera used. The second step was to analyse each video clip frame by frame using Dartfish to determine the initial movement time of the respective batsmen for each trial conducted. An example of the frame analysis using Dartfish video solution version 9.0 software can be seen in Figure 3.4. It is worth noting that Dartfish software has zoom options in order to get a clear image of the release of the ball from the machine (see Figure 3.4 – label A) as well as the initial movement time of the batsman (see Figure 3.4 – label B). The researcher conducted the coding and is a certified Dartfish technologist. A level-three coach was also consulted to assist in determining when trigger movements ended and when genuine initial movement occurred.

3.9. Data Analysis

The help of a qualified statistician based at the Nelson Mandela University was enlisted for the current study. Prediction and response accuracy statistics were run according to overall participant data; whereas, initial movement time statistics were run according to all valid trials. Descriptive statistics including the mean, standard deviation, minimum score, quartile 1, median, quartile 3 and maximum score were used to describe prediction accuracy, response accuracy, and initial movement time results. Graphical representations were also used in the form of bar graphs to present the prediction accuracy, response accuracy, and initial movement time results. Frequency distribution tables and graphs were used to illustrate the distribution of the different levels of certainty associated with prediction accuracy, as well as depict the distribution of sources of situational probability information used by batsmen to inform the prediction of the upcoming delivery. Chance-level was set at 25% for prediction accuracy as there were four possible options when making a prediction of the upcoming delivery and 50% for response accuracy as there were two possible outcomes when attempting to make contact with the ball.

Parametric inferential statistics were employed to test the statistical difference between categories of congruency, conditions of situational probability, and between combinations of congruency and conditions. In order to test for significant difference between chance level and prediction or response accuracy means, a one-sample t-test was conducted. Cohen's *d* values were used to indicate practical significance. The size of the practical significance was classified as follows:

- Small: $0.2 <= d < 0.5$
- Moderate: $0.5 <= d < 0.8$
- Large: $d >= 0.8$

A One-way analysis of variance (ANOVA) was conducted to compare control trials to all other combinations for prediction accuracy, response accuracy, and initial movement time. The confidence level was set at 95%. This was followed by a Dunnett post-hoc test in order to identify where statistically significant differences were present. A One-way ANOVA was also employed to compare the conditions of situational probability information with each other, as well as to compare the categories of congruency with each other for response accuracy, and initial movement time. Control trials were included in the categories of congruency, as well as the conditions of situational probability information for the One-way ANOVA conducted. A Tukey honestly significant difference (HSD) test was conducted to determine where statistically significant differences were present. With regards to the comparison between conditions and categories of congruency for prediction accuracy results, homogeneity of variances was not found; therefore, a Welch's ANOVA was conducted. A Games-Howell post-hoc test was conducted to determine where statistically significant differences were present.

A two-way ANOVA was used to test for the interaction between congruency and condition of situational probability for response accuracy and initial movement time. The confidence level was set at 95% A two-way ANOVA was not run for prediction accuracy as results from Levene's test for homogeneity of variances revealed violations of the assumptions of the test. Additionally, the assumption of normality was violated, therefore, a Kruskal-Wallis test was run to compare the distributions of the different combinations of congruency and condition of situational probability for prediction accuracy.

The alpha level was set at 0.05 to identify statistical difference. The partial eta squared statistic was derived in order to determine the practical significance of the mean prediction accuracy, response accuracy, and initial movement time differences between categories of congruency, conditions of situational probability, and between combinations of congruency and conditions. The partial eta squared statistic was only reported on in cases where statistical difference occurred. The size of the practical significance was classified as follows:

- Small: $\eta^2 < 0.09$
- Moderate: $0.09 <= \eta^2 < 0.25$
- Large: $\eta^2 >= 0.25$

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 was H18-HEA-HMS-005. 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. Safety measures were considered in the event that a participant was injured. For example, a Health and Safety officer was present at the facilities on the days of testing.

All participation in this study was voluntary and all participants completed informed consent forms prior to their participation in the study. The informed consent form provided all necessary information regarding the procedures of the testing, as well as the advantages, disadvantages and risks associated with being included in the study. Furthermore, participants were not forced to participate in the study, their privacy was respected at all time, and their personal details and results were kept confidential.

The chapter to follow contains the results collected during the data collection procedures.

Chapter 4: Results

4.1. Introduction

The purpose of this study was to determine the interaction of different sources of situational probability information used by cricket batsmen to anticipate a bowler's intention in cricket. The focus of this chapter is to report on the results obtained from the research conducted. The chapter includes the prediction accuracy of batsmen, the level of certainty associated with prediction accuracy, the verbal report data, the response accuracy of batsmen, and the initial movement time of batsmen. Note prediction accuracy and response accuracy means of conditions, categories of congruency, and combinations of condition and congruency will be stated as mean ± standard deviation when written in text.

4.2. Prediction Accuracy

The prediction accuracy results obtained in the study will be elaborated on in the section to follow.

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

	Overall
Number of participants	15
Mean	26.67
Standard deviation	7.43
Minimum	13.33
Quartile 1	23.33
Median	25.00
Quartile 3	29.17
Maximum	40.00

According to Table 4.1, the overall mean prediction accuracy of batsmen when anticipating the upcoming delivery was 26.67 ± 7.43%. A one-sample t-test was conducted and the results revealed that the overall mean prediction accuracy of batsmen was not significantly different to the chance level ($t(14)=0.87$, $p=0.399$). An interesting finding was that the median was 25.00% which is the same as the chance level for prediction accuracy.

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

	Control trials	Sequence alone	Field placement alone	Both sources
Number of participants	15	15	15	15
Mean	22.89	30.67	30.00	30.67
Standard deviation	4.52	16.68	14.64	14.86
Minimum	13.33	0.00	10.00	10.00
Quartile 1	20.00	20.00	20.00	20.00
Median	23.33	30.00	30.00	30.00
Quartile 3	26.67	45.00	40.00	40.00
Maximum	30.00	50.00	50.00	60.00

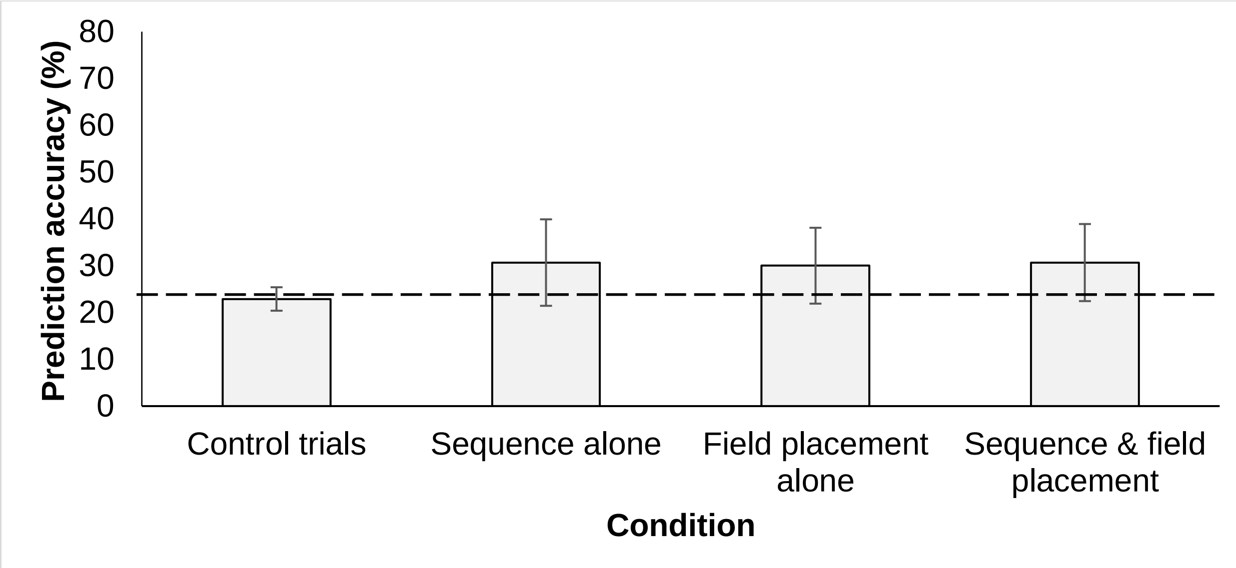


Figure 4.1- Bar graph indicating prediction accuracy (%) of batsmen when anticipating the upcoming delivery for each condition of situational probability regardless of congruency. Error bars indicate a 95% confidence interval. The dashed gridline represents the chance level (25%) for predicting the line and length of the delivery correctly.

A one-sample t-test was conducted with results revealing no significant differences between the chance level and any of the conditions (control: $t(14)=-1.81$, $p=0.092$, sequence alone: $t(14)=1.32$, $p=0.209$, field placement alone: $t(14)=1.32$, $p=0.207$, both sources: $t(14)=1.48$, $p=0.162$) for prediction accuracy. Additionally, a Welch's ANOVA was employed and results revealed no significant difference between the control trials and any other condition of situational probability presented. Furthermore, no significant differences between conditions of situational probability information presented were found ($F(3,26)=2.746$, $p=0.063$).

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

	Control trials	**Congruent trials**	**Incongruent trials**
Number of participants	15	15	15
Mean	22.89	51.56	9.33
Standard deviation	4.52	25.88	7.89
Minimum	13.33	20.00	0.00
Quartile 1	20.00	33.33	3.33
Median	23.33	46.67	6.67
Quartile 3	26.67	63.33	13.33
Maximum	30.00	100.00	26.67

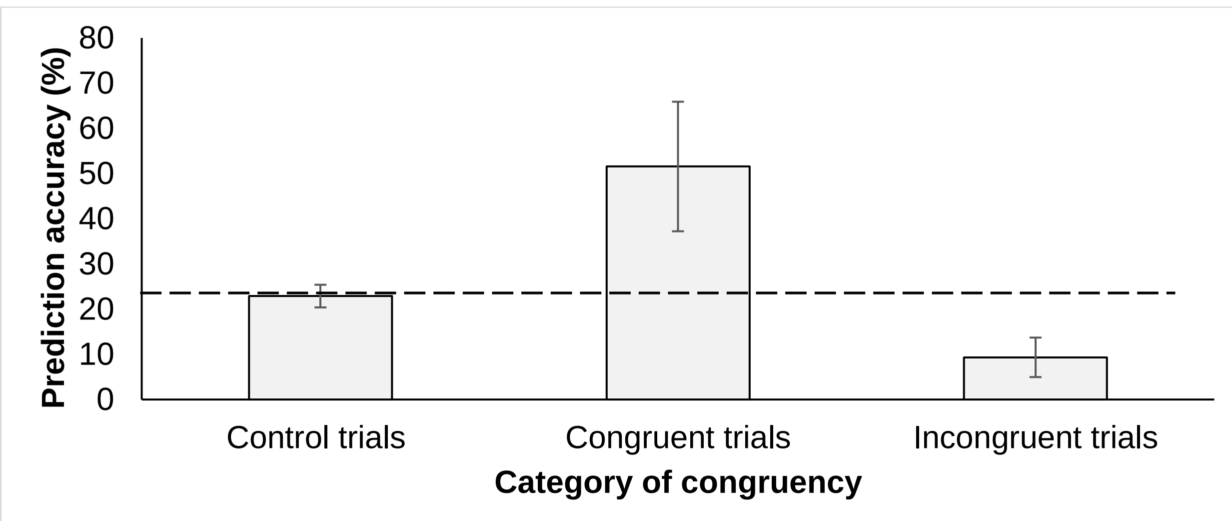


Figure 4.2- Bar graph indicating the prediction accuracy (%) of batsmen when anticipating the upcoming delivery for control trials, as well as trials from each category of congruency regardless of the condition of situational probability information presented. Error bars indicate a 95% confidence interval. The dashed gridline represents the chance level (25%) for predicting the line and length of the delivery correctly.

According to the one-sample t-test results as seen in Table 4.3, congruent trials had a prediction accuracy mean (51.56 ± 25.88%) significantly higher (t(14)=3.97, p=0.001, d=1.03) than the chance level for prediction accuracy; whereas, incongruent trials had a prediction accuracy mean (9.33 ± 7.89%) significantly lower (t(14)=-7.69, p<0.001, d=1.99) than the chance level for prediction accuracy.

A Welch's ANOVA was employed and the prediction accuracy results revealed significant differences between categories of congruency regardless of the condition of situational probability information presented (F(2,23)=27.123, p<0.001). Therefore, a Games-Howell test was conducted to determine where statistically significant differences were present. Congruent trials had a prediction accuracy mean (51.56 ± 25.88%) significantly higher (p=0.002) than the prediction accuracy mean for control trials (22.89 ± 4.52%); whereas incongruent trials had a prediction accuracy mean significantly lower (p<0.001) than the prediction accuracy mean for control trials. Additionally, congruent trials had a prediction accuracy mean significantly higher (p<0.001) than the prediction accuracy mean for incongruent trials (9.33 ± 7.89%).

Table 4.4 - Descriptive statistics for prediction accuracy (%) of batsmen when anticipating the upcoming delivery for control trials, congruent trials and incongruent trials for each condition of situational probability.

	Control trials	Sequence alone		Field placement alone		Both sources	
		Congruent	Incongruent	Congruent	Incongruent	Congruent	Incongruent
Number of participants	450	75	75	75	75	75	75
Mean	22.89	56.00	5.33	42.67	17.33	56.00	5.33
Standard deviation	4.52	33.97	11.87	34.53	14.86	31.35	11.87
Minimum	13.33	0.00	0.00	0.00	0.00	0.00	0.00
Quartile 1	20.00	20.00	0.00	20.00	0.00	40.00	0.00
Median	23.33	60.00	0.00	40.00	20.00	60.00	0.00
Quartile 3	26.67	80.00	0.00	70.00	20.00	80.00	0.00
Maximum	30.00	100.00	40.00	100.00	40.00	100.00	40.00

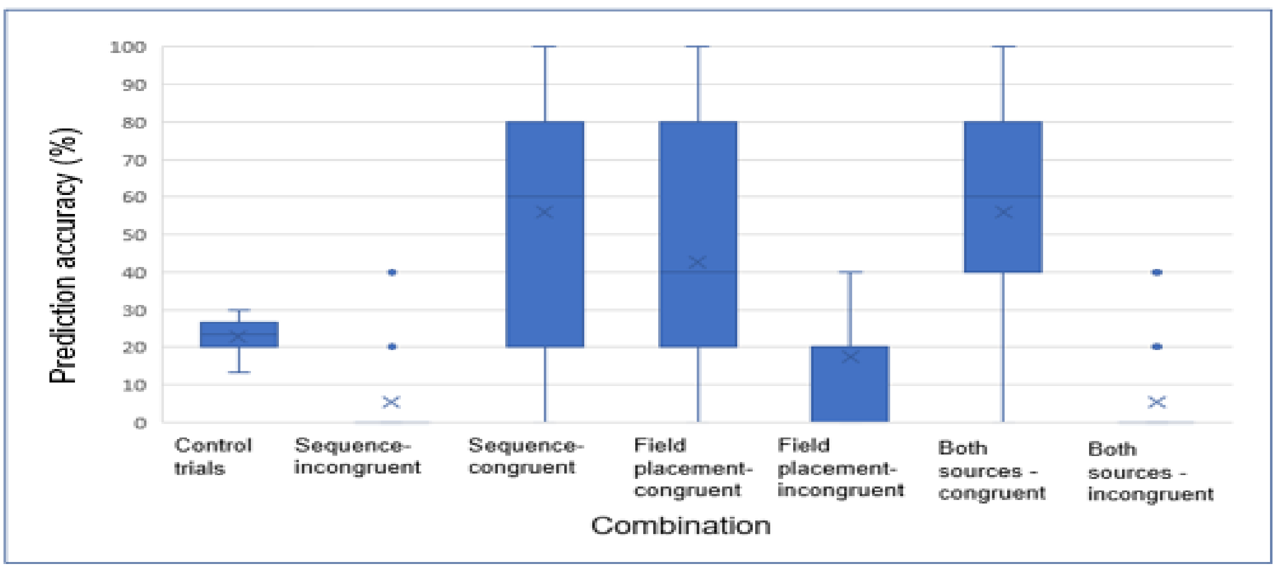


Figure 4.3 - Boxplot indicating the distribution of prediction accuracy for control trials, as well as for each combination of condition and congruency. Error bars indicate the range of each condition, the crosses (x) indicate the mean of each condition, the dots indicate data points, and the line within the box indicates the median of each condition.

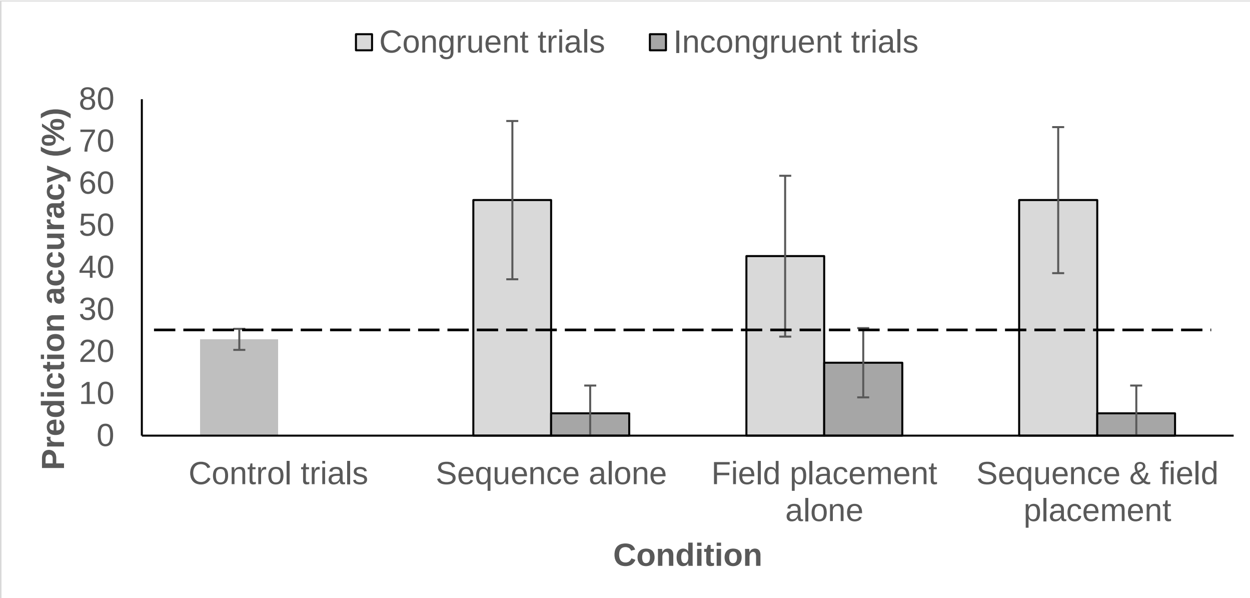


Figure 4.4- Bar graph indicating prediction accuracy (%) of batsmen when anticipating the upcoming delivery for each condition of situational probability, as well as each category of congruency. Error bars indicate a 95% confidence interval. The dashed gridline represents the chance level (25%) for predicting the line and length of the delivery correctly.

In Figure 4.3, the incongruent sequence alone combination and the incongruent both sources combination consisted of only three data points (0, 20, 40). There are only three data points as there were a minimal number of these types of trials per participant. In addition, the information during these trials is misleading therefore the data points are consistently low. The dots in the figure represent the data points.

According to Table 4.4, congruent trials that consisted of sequence information alone had the same prediction accuracy mean (56.00 ± 33.97%) as congruent trials that consisted of both sources of information (56.00 ± 31.35%), and incongruent trials in which sequence information alone was presented (5.33 ± 11.87%) had the same prediction accuracy mean as incongruent trials in which both sources of information were presented (5.33 ± 11.87%). An interesting finding was that the maximum prediction accuracy of batsmen for all the conditions in the congruent trials were 100%;

whereas, the maximum prediction accuracy of batsmen for all the conditions in the incongruent trials was 40%.

A one-sample t-test was then conducted and results revealed that congruent trials in which sequence information alone was presented ($t(14)=3.53$, $p=0.003$, $d=0.91$) and both sources of information were presented ($t(14)=3.83$, $p=0.002$, $d=0.99$) had prediction accuracy means significantly higher than the chance level for prediction accuracy: whereas congruent trials in which field placement information alone was presented had a prediction accuracy mean not significantly different ($t(14)=1.98$, $p=0.067$) to the chance level for prediction accuracy (see Figure 4.4). Within the incongruent category of congruency, sequence alone trials ($t(14)=-6.42$, $p<0.001$) and both sources trials ($t(14)=-6.42$, $p<0.001$) had prediction accuracy means significantly lower than the chance level; whereas, the field placement alone trials had a prediction accuracy mean that was not significantly different to the chance level ($t(14)=-2.00$, $p=0.065$).

One-way ANOVA results revealed that congruent sequence alone trials ($p=0.037$) and congruent both sources trials ($p=0.020$) had prediction accuracy means significantly higher than the control trials; whereas incongruent sequence alone trials ($p<0.001$) and incongruent both sources trials ($p<0.001$) had prediction accuracy means significantly lower than the control trials. Both congruent ($p=0.502$) and incongruent field placement trials ($p=0.955$) had prediction accuracy means that were not significantly different to the control trials.

A two-way ANOVA was not run for prediction accuracy as results from Levene's test for homogeneity of variances revealed violations of the assumptions of the test. Additionally, the assumption of normality was violated, therefore, a Kruskal-Wallis test was run to compare the distributions of the different combinations of congruency and condition of situational probability for prediction accuracy. According to Figure 4.3, within the congruent category, the distribution of the both sources condition was significantly different to the field placement alone condition ($p=0.040$). Within the incongruent category, the distribution of the field placement alone condition was significantly different to the sequence alone condition (*p*=0.007) and the both sources condition (*p*=0.007). Between the categories of congruency, the distribution of the sequence alone incongruent combination is significantly different to the sequence alone congruent combination (*p*<0.001). And the distribution of the both sources incongruent combination is significantly different to the both sources congruent combination (*p*<0.001).

4.3. Level of Certainty Associated with Prediction Accuracy

Results pertaining to the level of certainty associated with prediction accuracy will be elaborated on in the section to follow.

Table 4.5 – Distribution (%) of the level of certainty associated with prediction accuracy for the conditions of situational probability.

Certainty	Control trials	Sequence alone	Field placement alone	Both sources
1 – Not at all certain	9.56	6.67	2.67	1.33
2 – Slightly certain	15.11	11.33	16.67	8.67
3 – Somewhat certain	38.44	27.33	41.33	35.33
4 – moderately certain	24.00	33.33	27.33	34.67
5 – extremely certain	12.89	21.33	12.00	20.00

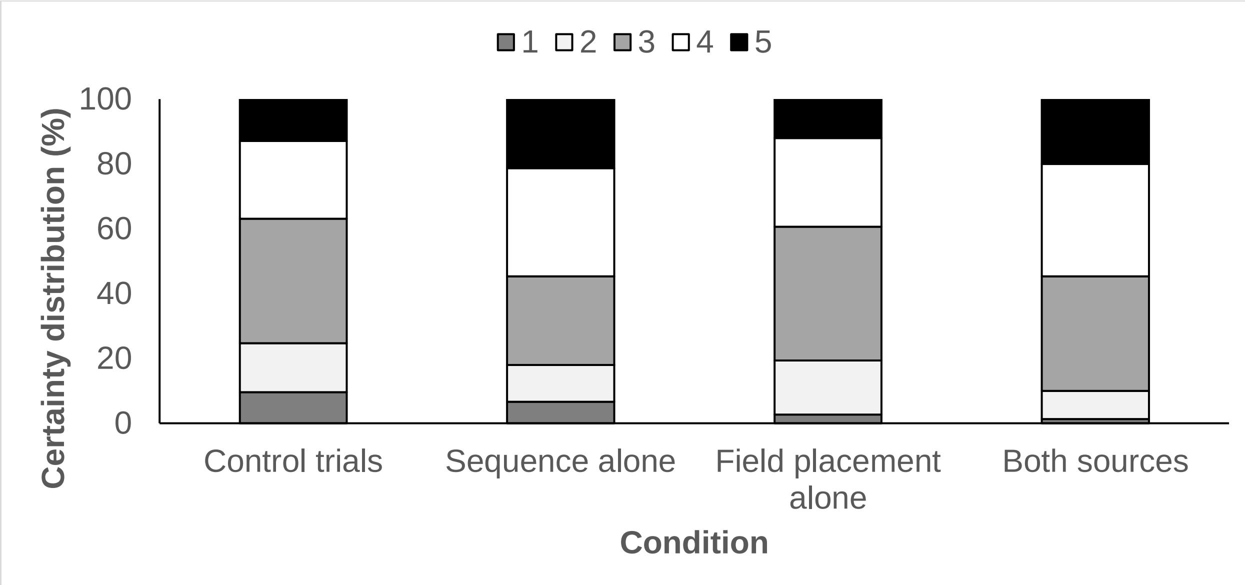


Figure 4.5 – Bar graph indicating the distribution (%) of the level of certainty associated with prediction accuracy for the conditions of situational probability.

According to Table 4.5, the most frequently occurring level of certainty associated with prediction accuracy of batsmen was “somewhat certain” for the control trials (38.44%), for the field placement alone condition (41.33%), and for the both sources condition (35.33%). The sequence alone condition was the only condition in which “somewhat certain” (27.33%) was not the most frequently occurring certainty level of batsmen and instead “moderately certain” (33.33%) was the most frequently occurring certainty level. An interesting finding was that in 21.33% of the trials in which sequence information alone was presented, and in 20.00% of the trials in which both sources of information were presented, participants were “extremely certain” of their prediction accuracy.

4.4. Verbal Report Associated with Prediction of Delivery Outcome

Results pertaining to the verbal report associated with prediction accuracy will be elaborated on in the section to follow.

Table 4.6 - Distribution of the sources of situational probability information used to predict the delivery outcome for each condition of situational probability obtained through the verbal report.

Verbal Reports	**Control trials**	**Sequence alone**	**Field placement alone**	**Both sources**
Sequence	1.11	10.67	1.33	9.33
Field placement	83.56	59.33	82.67	54.67
Both sources	0.44	22.67	0.00	31.33
Other source	14.89	7.33	16.00	4.67

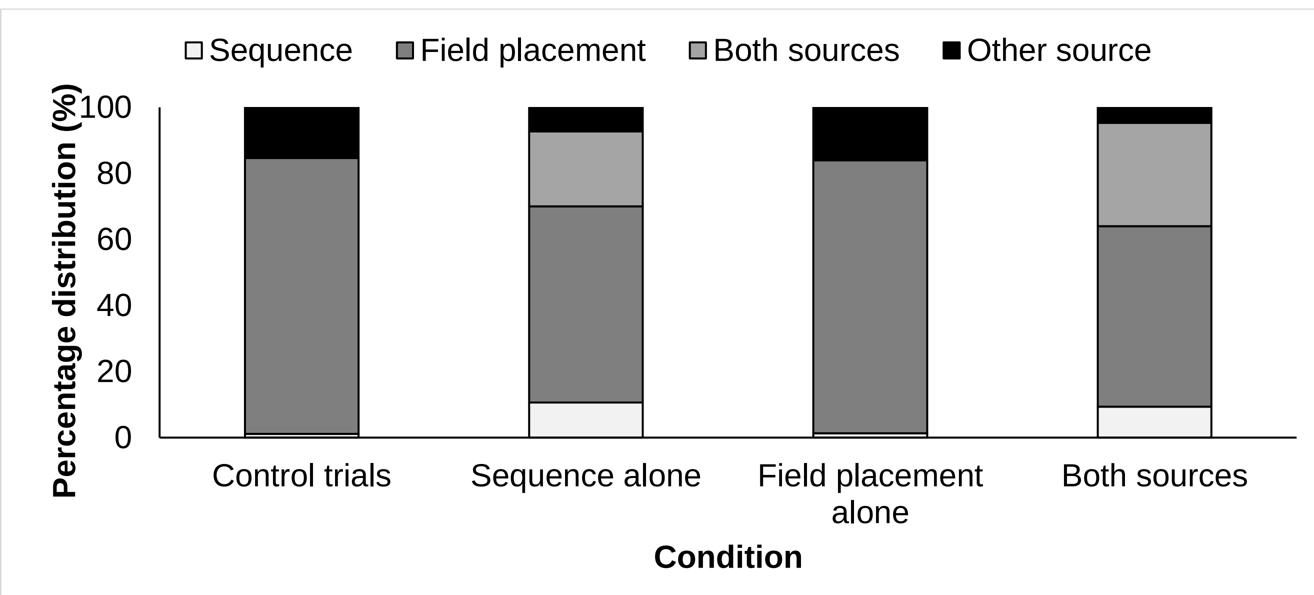


Figure 4.6 – Bar graph indicating the distribution of the sources of situational probability information used to predict the delivery outcome for each condition of situational probability obtained through the verbal report.

As seen in Table 4.6, the most frequently used source of information by batsmen to make a prediction regarding the ball's landing position according to the verbal report data was field placement information. Field placement information was the most frequently used source of information by batsmen for control trials (83.56%), for trials in which sequence information alone (59.33%) was presented, for trials in which field placement information alone (82.67%) was presented, and for trials in which both sources of information (54.67%) were presented. Another observation was that each specific source of situational probability information presented was highest in the condition in which it was presented. For example, the use of sequence information was most frequently used in the sequence alone condition (10.67%), the use of field placement information was most frequently used in the field placement alone condition (82.67%), and the use of both sources of information was most frequently used in the both sources condition (31.33%).

In addition to the sources of information provided, batsmen reported that they used "other sources". These included outcome of the previous delivery and stage of the innings. The use of "other sources" can be seen in Table 4.6.

4.5. Response Accuracy

The response accuracy results obtained in the study will be elaborated on in the section to follow.

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

	Overall
Number of participants	15
Mean	66.44
Standard deviation	7.04
Minimum	53.33
Quartile 1	61.67
Median	66.67
Quartile 3	70.83
Maximum	80.00

A one-sample t-test was conducted to test for significant difference between the chance level and the overall response accuracy mean. According to Table 4.7, the response accuracy of batsmen for all the trials in the study was 66.44 ± 7.04% which was significantly higher ($t(14)=9.04$, $p<0.001$, $d=2.34$) than the chance level set for response accuracy. An interesting finding was that although the study comprised of incongruent and control trials, a maximum response accuracy of 80.00% was achieved.

Table 4.8- Descriptive Statistics regarding the response accuracy (%) of batsmen for each condition of situational probability regardless of congruency.

	Control trials	Sequence alone	Field placement alone	Both sources
Number of participants	15	15	15	15
Mean	64.00	70.67	72.67	63.33
Standard deviation	9.86	13.87	14.86	14.47
Minimum	40.00	50.00	50.00	40.00
Quartile 1	60.00	65.00	60.00	55.00
Median	66.67	70.00	70.00	60.00
Quartile 3	70.00	80.00	80.00	80.00
Maximum	80.00	90.00	100.00	80.00

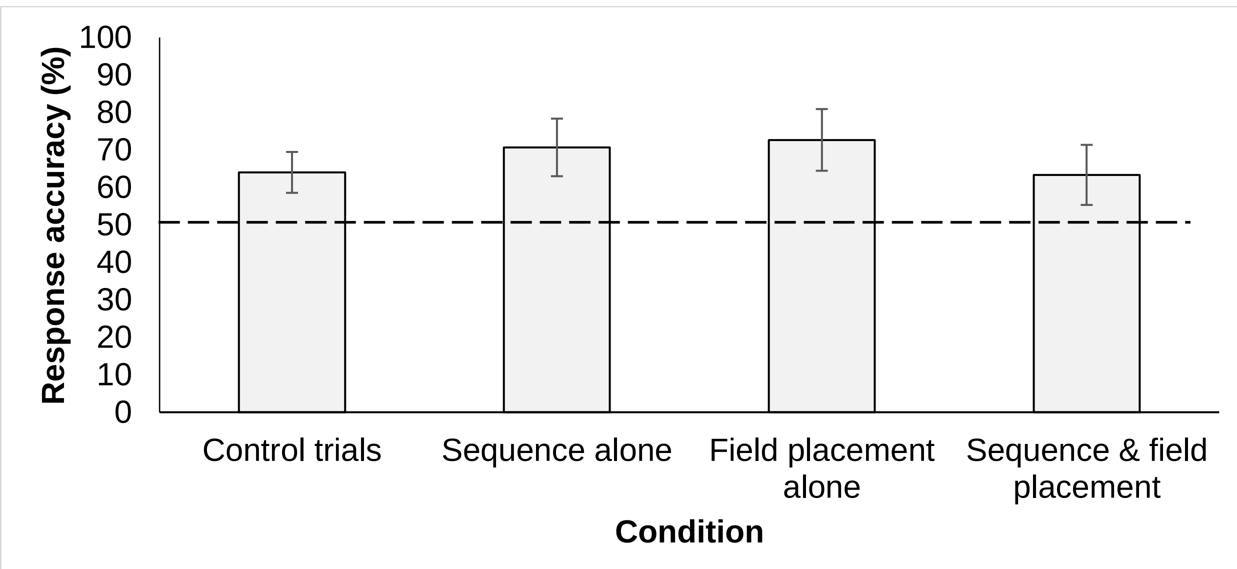


Figure 4.7- Bar graph indicating response accuracy (%) of batsmen for each condition of situational probability regardless of congruency. Error bars indicate a 95% confidence interval. The dashed gridline represents the chance level (50%) for response accuracy.

A one-sample t-test was conducted and the results revealed that the means for the control condition ($t(14)=5.50$, $p<0.001$, d=1.42), sequence alone condition ($t(14)=5.77$, *p*<0.001, *d*=1.49), field placement alone condition (*t*(14)=5.91, *p*<0.001, *d*=1.53) and the both sources condition (*t*(14)=3.57, *p*=0.003, *d*=0.92) were significantly higher than the chance level for response accuracy.

One-way ANOVA results revealed no significant differences between the control trials and any condition of situational probability information presented. Additionally, no significant differences between conditions of situational probability information presented to batsmen were found (*F*(3,56)=1.840, *p*=0.150).

Table 4.9- Descriptive statistics for response accuracy (%) of batsmen for control trials, as well as trials from each category of congruency regardless of the condition of situational probability information presented.

	Control trials	**Congruent trials**	**Incongruent trials**
Number of participants	15	15	15
Mean	64.00	72.89	64.89
Standard deviation	9.86	15.83	14.13
Minimum	40.00	46.67	46.67
Quartile 1	60.00	63.33	53.33
Median	66.67	73.33	60.00
Quartile 3	70.00	83.33	73.33
Maximum	80.00	93.33	93.33

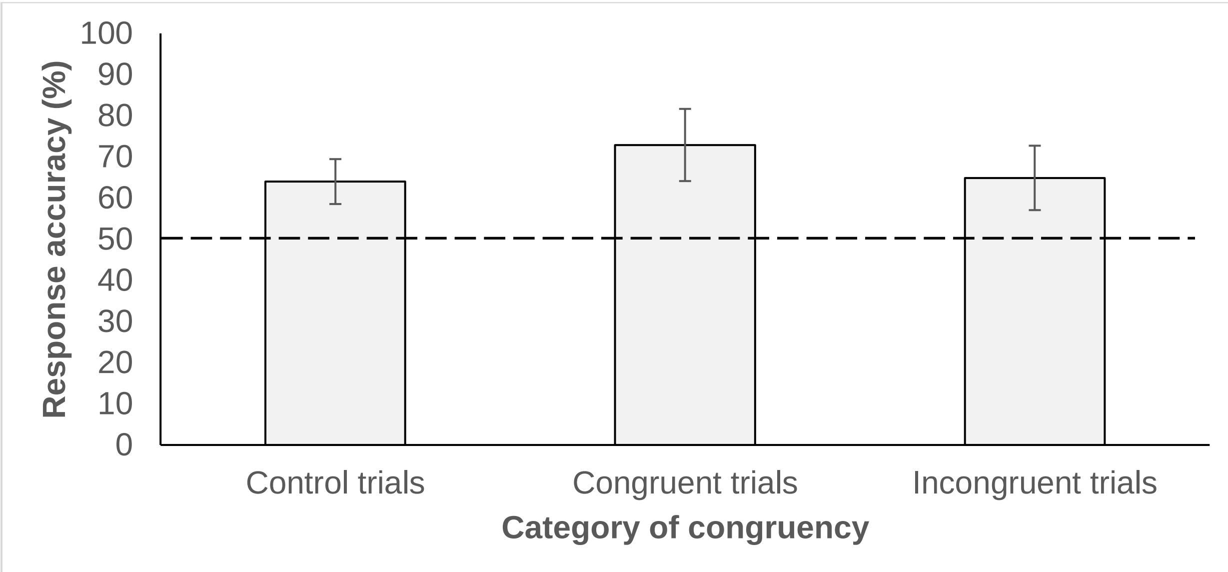


Figure 4.8- Bar graph indicating response accuracy (%) of batsmen for control trials, as well as trials from each category of congruency regardless of the condition of situational probability information presented. Error bars indicate a 95% confidence interval. The dashed gridline represents the chance level (50%) for response accuracy.

A one-sample t-test was conducted with results revealing that the response accuracy mean for control trials ($t(14)=5.50$, $p<0.001$, $d=1.42$), congruent trials ($t(14)=5.60$, $p<0.001$, $d=1.45$) and incongruent trials ($t(14)=4.08$, $p=0.001$, $d=1.05$) were significantly higher than the chance level.

One-way ANOVA results revealed that the response accuracy mean for the control trials was not significantly different to any other category of congruency. Furthermore, the response accuracy results of batsmen revealed no significant differences between categories of congruency regardless of the condition of situational probability information presented ($F(2,42)=1.970$, $p=0.152$). An interesting finding observed was that congruent trials and incongruent trials both had a maximum response accuracy of 93.33%.

Table 4.10- Descriptive Statistics regarding the response accuracy (%) of batsmen for control trials, congruent trials, and incongruent trials for each condition of situational probability.

	Control trials	Sequence alone		Field placement alone		Both sources	
		Congruent	Incongruent	Congruent	Incongruent	Congruent	Incongruent
Number of participants	15	15	15	15	15	15	15
Mean	64.00	80.00	61.33	70.67	74.67	68.00	56.00
Standard deviation	9.86	20.00	24.46	23.74	15.98	23.66	15.49
Minimum	40.00	40.00	20.00	40.00	40.00	20.00	40.00
Quartile 1	60.00	60.00	40.00	50.00	60.00	50.00	40.00
Median	66.67	80.00	60.00	80.00	80.00	80.00	60.00
Quartile 3	70.00	100.00	80.00	90.00	80.00	80.00	60.00
Maximum	80.00	100.00	100.00	100.00	100.00	100.00	80.00

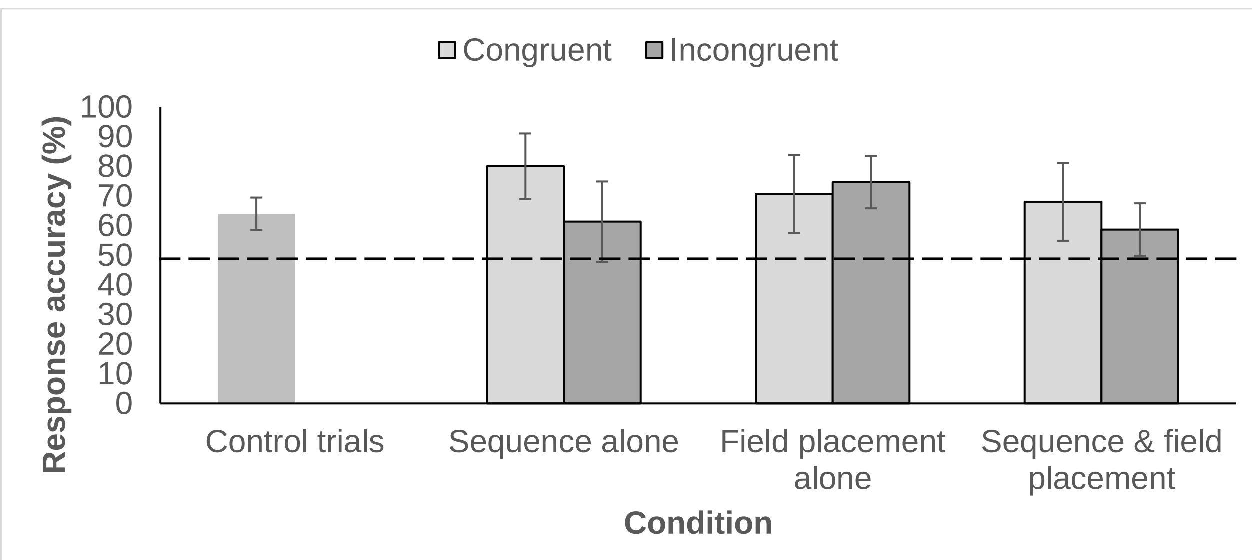


Figure 4.9 - Bar graph indicating response accuracy (%) of batsmen for each condition of situational probability, as well as each category of congruency. Error bars indicate a 95% confidence interval. The dashed gridline represents the chance level (50%) for response accuracy.

A one-sample t-test was conducted and results revealed that the response accuracy means for sequence alone congruent trials ($t(14)=5.81$, $p<0.001$, $d=1.50$), field placement alone congruent trials ($t(14)=5.77$, $p<0.001$, $d=1.49$), field placement alone incongruent trials ($t(14)=5.98$, $p<0.001$, $d=1.54$), and both sources congruent trials ($t(14)=2.95$, $p=0.011$, $d=0.76$) were significantly higher than chance level; whereas, the response accuracy means for sequence alone incongruent trials ($t(14)=1.79$, $p=0.094$) and both sources incongruent trials ($t(14)=2.10$, $p=0.054$) were not significantly different to the chance level.

One-way ANOVA results revealed no significant differences for the response accuracy of batsmen ($F(6,98)=2.198$, $p=0.050$, $\eta_p^2=.12$). Furthermore, a two-way ANOVA was conducted and results revealed no interaction effect between condition of situational probability information presented and category of congruency ($F(2,84)=2.219$, $p=0.115$). No significant differences between the combinations of condition and congruency were observed for response accuracy results.

4.6. Initial Movement Time

The initial movement time results obtained in the study will be elaborated on in the section to follow. Note that a number of trials were excluded as a result of invalid footage.

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

	Overall
Number of trials	876
Mean	69
Standard deviation	200
Minimum	-1185
Quartile 1	0
Median	134
Quartile 3	167
Maximum	480

According to Table 4.11, the mean initial movement time of batsmen for all the trials conducted in the study was 69 ± 200ms. The minimum initial movement time of batsmen was as early as -1185ms with the maximum initial movement time of batsmen being as late as 480ms resulting in a range of 1665ms.

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

	Control trials	Sequence alone	Field placement alone	Both sources
Number of trials	439	147	145	145
Mean	80	68	77	45
Standard deviation	67	73	82	107
Minimum	-121	-92	-145	-192
Quartile 1	53	37	43	18
Median	91	81	94	63
Quartile 3	122	120	149	122
Maximum	162	155	164	168

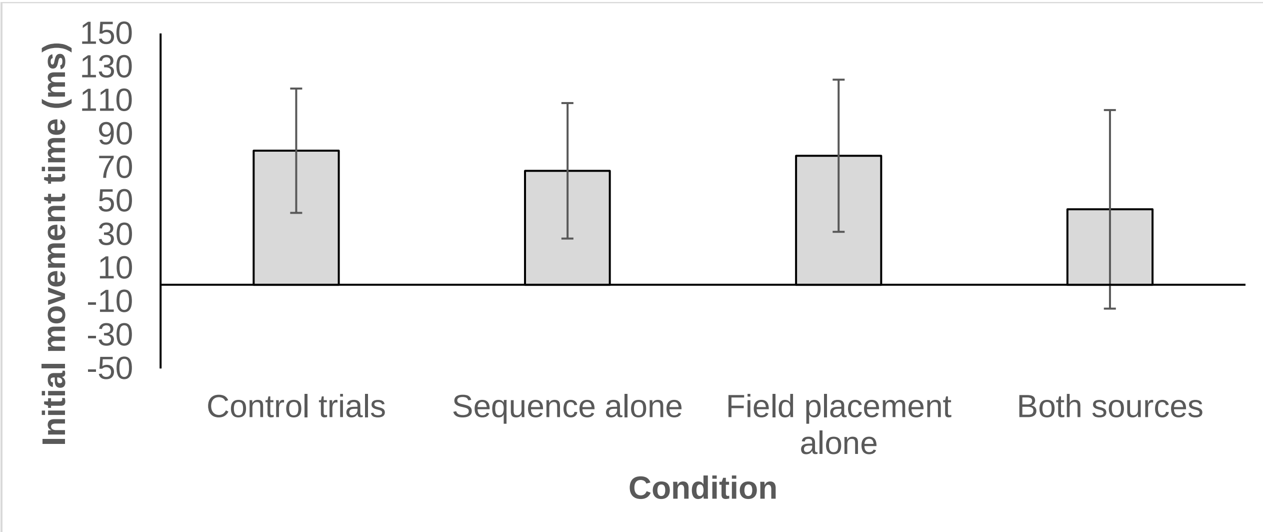


Figure 4.10 - Bar graph indicating the initial movement time (ms) of batsmen for all valid trials for each condition of situational probability regardless of congruency. Error bars indicate a 95% confidence interval.

According to Table 4.12, the initial movement time mean of batsmen for trials in which sequence information alone was presented was 68 ± 73ms and the mean for trials in which field placement information alone was presented was 77 ± 82ms, whereas the mean for trials in which both sources were presented was 45 ± 107ms.

A One-way ANOVA was conducted to and results revealed that no significant differences between the control trials and any other condition of situational probability information presented. Additionally, no significant differences were found between the different conditions of situational probability information presented to batsmen ($F(3,56)=0.541$, $p=0.656$).

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

	Control trials	Congruent trials	Incongruent trials
Number of trials	439	217	220
Mean	80	48	78
Standard deviation	67	101	73
Minimum	-121	-257	-113
Quartile 1	53	9	45
Median	91	67	88
Quartile 3	122	119	125
Maximum	162	149	181

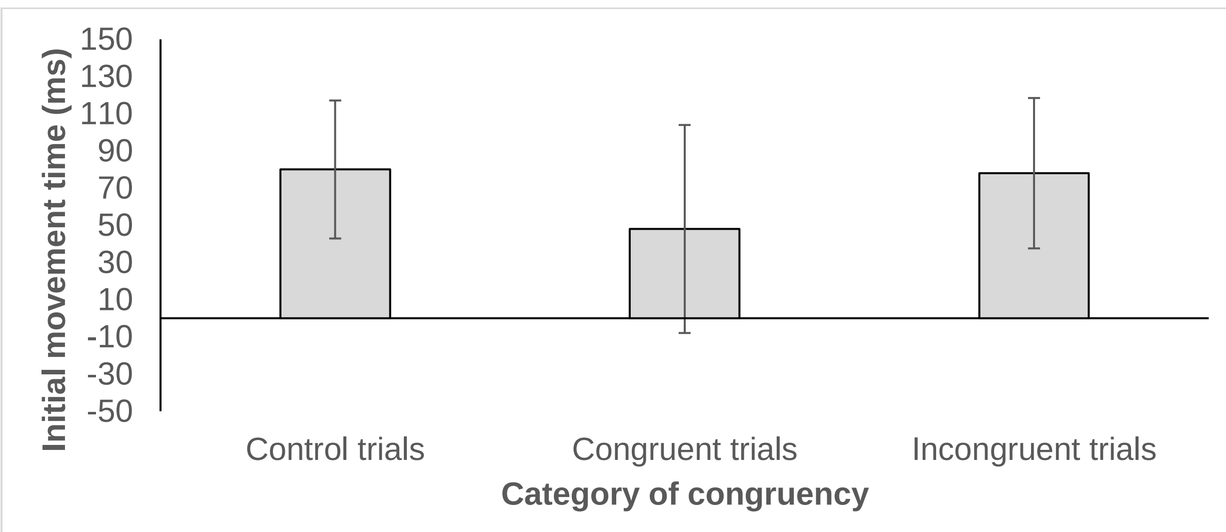


Figure 4.11 – Bar graph indicating the initial movement time (ms) of batsmen for all valid trials for control trials, as well as trials from each category of congruency regardless of the condition of situational probability information presented. Error bars indicate a 95% confidence interval.

According to Table 4.13, the mean initial movement time of batsmen for the control trials was 80 ± 67ms with the mean for congruent trials being 48 ± 101ms and the mean for incongruent trials being 78 ± 73ms.

One-way ANOVA results revealed no significant differences between the control trials and any category of congruency for initial movement time. Additionally, no significant differences were found between any categories of congruency regardless of the condition of situational probability information presented ($F(2,42)=0.690$, $p=0.507$).

Table 4.14 – Descriptive statistics regarding the initial movement time (ms) of batsmen for all valid trials for each condition of situational probability, as well as each category of congruency.

	No Sources	**Sequence alone**		**Field placement alone**		**Both sources**	
		Congruent	Incongruent	Congruent	Incongruent	Congruent	Incongruent
Number of trials	439	74	73	71	74	72	73
Mean	80	68	68	41	106	29	60
Standard deviation	67	55	110	160	75	122	112
Minimum	-121	-10	-224	-487	-50	-273	-237
Quartile 1	53	28	70	20	50	-15	15
Median	91	60	92	80	110	37	80
Quartile 3	122	122	140	132	166	125	143
Maximum	162	164	163	180	197	170	187

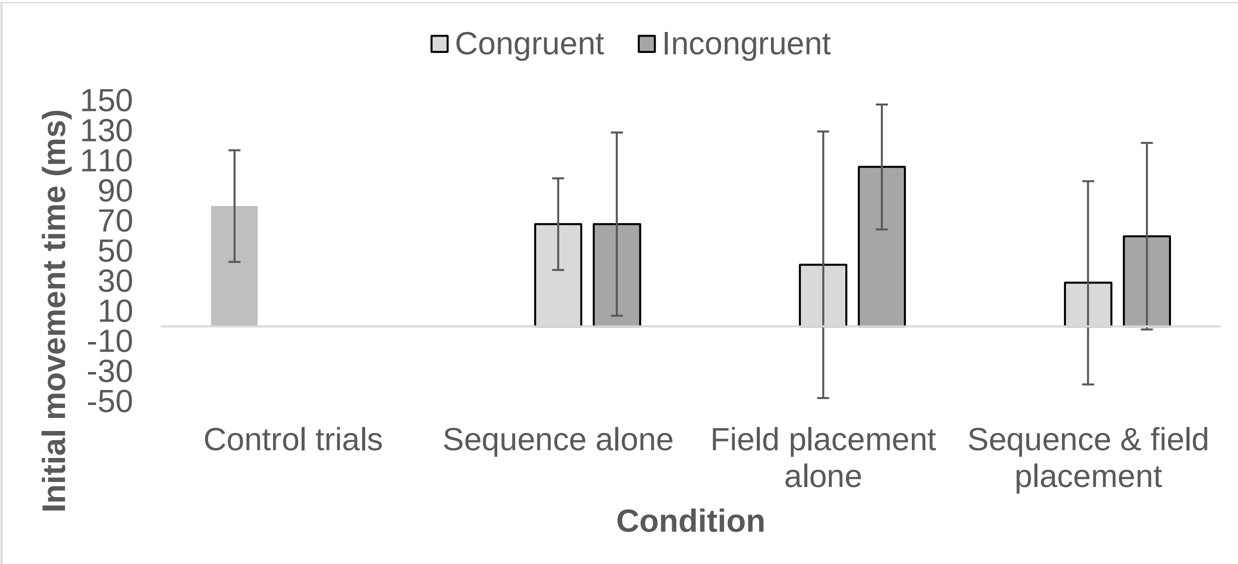


Figure 4.12 – Bar graph indicating the initial movement time (ms) of batsmen for all valid trials for each condition of situational probability, as well as each category of congruency. Error bars indicate a 95% confidence interval.

According to Table 4.14, the mean initial movement time of batsmen for control trials was 80 ± 67ms. In terms of the sequence alone condition, the mean for congruent trials was 68 ±55ms while the mean for incongruent trials was 68 ± 110ms. With regards to the field placement alone condition, congruent trials had a mean of 41 ± 160ms, while incongruent trials had a mean of 106 ± 75ms. Finally, in terms of the both sources condition, congruent trials had a mean of 29 ± 122ms, whereas incongruent trials had a mean of 60 ± 112ms. An interesting finding was that the minimum initial movement time of batsmen for field placement congruent trials was -487ms; whereas, for incongruent trials, the minimum was -50ms.

One-way ANOVA results revealed that when comparing the control trials to all other combinations, no significant differences were found for initial movement time of batsmen ($F(6,98)=0.857$, $p=0.529$).

The two-way ANOVA results revealed no interaction effect between the condition of situational probability information presented to batsmen and the category of congruency ($F(2,84)=0.640$, $p=0.530$). No significant differences between the combinations of condition and congruency were observed for initial movement time results.

The chapter to follow will provide a discussion and explanation of the results collected during the study.

Chapter 5: Discussion, Limitations, Conclusion, and Recommendations

5.1. Introduction

The current study sought to determine the interaction of different sources of situational probability information used by cricket batsmen to anticipate a bowler's intention. This chapter aims to discuss the results obtained from the study and is presented in nine sections. Prediction accuracy results and the level of certainty associated with prediction accuracy are elaborated on first. This is followed by a section on the verbal report associated with prediction accuracy. Response accuracy results are then elaborated on before reporting on the initial movement time of batsmen. The chapter concludes with the summary of findings, limitations, conclusion and recommendations for further research.

5.2. Prediction Accuracy

The purpose of this section is to address the results of the current study in terms of the prediction accuracy of cricket batsmen when anticipating the delivery outcome in an in-situ setting. In order to develop a better understanding of the prediction accuracy of batsmen, results were analysed according to the condition of situational probability information presented, the category of congruency, and the combination of condition and congruency.

The findings for the overall prediction accuracy conducted in the study, as illustrated in Table 4.1, revealed that the mean was 26.67 ± 7.43% and the median was 25.00%. The overall prediction accuracy mean in the study was not significantly different ($t(14)=0.87$, $p=0.399$) to the chance level (25%) set for prediction accuracy. A possible reason to explain the low prediction accuracy scores and the similarity between the mean prediction accuracy and the chance level is that the current study comprised mostly of control and incongruent trials. Control trials made up 50% of all trials, whereas the remaining 50% included an equal split of congruent and incongruent trials. Congruent trials were trials in which the delivery bowled (event outcome) was tactically appropriate to the condition of situational probability information available; whereas, control trials and incongruent were trials in which the delivery bowled (event outcome) was not tactically appropriate to the information available. Recent empirical evidence has shown that anticipatory performance is improved when advance information is tactically appropriate to the action-outcome (congruent trials), but when advance information is not tactically appropriate to the action-outcome (control and incongruent trials) anticipatory performance is impaired (Gray, 2002; Mann et al., 2014; Murphy et al., 2016). Therefore, the large number of control and incongruent trials could have led to low overall prediction accuracy scores as the advance information presented was not tactically appropriate to the event outcome on 75% of the trials.

In order to develop a better understanding of the prediction accuracy of batsmen, results were divided into the four conditions of situational probability (no sources, sequence alone, field placement alone, and both sources) and analysed accordingly.

No significant differences were found between the chance level and any of the conditions of situational probability information presented for prediction accuracy. These results are in contrast to previous findings that suggest the presentation of sequence information, field placement information, and the combination of sequence and field placement information facilitates successful anticipatory performance. For example, results from previous research has revealed that performers have improved performance when situational probability in the form of sequence information was presented (Gray, 2002; Loffing *et al.*, 2015). With regards to field placement information, Runswick et al. (2019) revealed that when field placement information that was congruent with the event outcome was presented to batsmen, improvement in anticipation of event outcome occurred. And when both sequence and field placement information was available, a study conducted by Runswick et al. (2017) revealed that sequencing and field placement information was used to predict the delivery outcome. Furthermore, results revealed that skilled performers were able to integrate sources of situational probability including field placement, sequence, and game situation information to facilitate performance. A possible reason as to why the results of the current study are in contrast to previous studies is that for each condition of situational probability information presented (sequence, field placement and both) an equal number of congruent and incongruent trials were presented. With the current study comprising of an equal split of congruent and incongruent trials, the improvement of prediction accuracy produced by congruent trials was nullified by the impairment of prediction accuracy caused by incongruent trials; therefore, leading to no significant differences being found between the chance level and any of the conditions of situational probability information presented for prediction accuracy.

Trials containing no source of information (control trials) had a prediction accuracy mean of 22.89 ± 4.52% which can be explained through the fact that no source of situational probability information was available during these trials and there were only four possible options for batsmen to choose from regarding the upcoming delivery's landing position. As there was no source of situational probability available to batsmen during the control trials, it would be expected that the prediction accuracy mean would be near the chance level and as stated previously, the chance level was 25%. As seen above, the prediction accuracy mean for control trials (22.89 ± 4.52%) is similar to the chance level (25%). Furthermore, results revealed that control trials were not significantly different to any other condition of situational probability information presented to batsmen. The results infer that the addition of the different conditions of situational probability information did not eliminate the uncertainty regarding the upcoming delivery's landing position. This is an interesting finding as it was expected that batsmen would be able to use the situational probability information to inform their predictions of the upcoming delivery outcomes. The finding is in contrast to previous research regarding the use of situational probability as Murphy et al*.* (2016), revealed that skilled tennis players made anticipatory judgements that were better than chance when only situational probability information was presented (Murphy et al*.*, 2016). A possible reason as to why the results of the current study occurred could be that only situational probability information was presented. Although situational probability information is important in the anticipatory process in cricket, it is only one of the three types of information used by cricket batsmen. In a typical cricket delivery, situational probability information is presented in conjunction with kinematic and projectile motion information. Performers rely predominantly on situational probability information at the early stages and then predictions become more refined as kinematic information and projectile motion information become available (Loffing & Hagemann, 2014; Loffing et al., 2016). The integration of advance (situational probability and kinematic) and projectile motion information facilitates a reduction in the uncertainty of the opponent's movement and guides successful interception (Müller & Abernethy, 2012). Therefore, a possible reason that the control trials were not different to any of the conditions of situational probability presented could be that although situational probability information was presented, the nonexistence of kinematic and projectile motion information meant that uncertainty regarding the upcoming delivery was not reduced and therefore predictions were not as refined as they could have been.

The prediction accuracy null hypothesis set for the current study was PA H_0: $PA\mu_1 = PA\mu_2 = PA\mu_3 = PA\mu_4$. The prediction accuracy results of batsmen revealed no significant main effect for the condition of situational probability information to batsmen ($F(3,26)=2.746$, $p=0.063$). Therefore, the null hypothesis cannot be rejected and is consequently accepted for prediction accuracy.

No significant difference between conditions of situational probability presented to batsmen was observed for prediction accuracy results. These results reveal that batsmen value field placement information and bowling sequence equally. Additionally, when the two conditions are presented concurrently, enhanced prediction accuracy does not occur. It was interesting that the both sources condition prediction accuracy was not significantly higher than the sequence alone condition or the field placement alone condition as previous research conducted by Müller and Abernethy (2012), Rosalie and Müller (2013), Loffing et al. (2016), Murphy et al. (2016), and Murphy et al.

(2018) has revealed that the addition of sources of information leads to better anticipatory performance. The results of the current study 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. This statement is in alignment with research conducted by Savelsbergh et al*.* (2005) which stated that prediction accuracy is dependent on the nature of the information presented rather than the amount of information presented. Performers draw upon more pertinent information variables according to the relevance to the task at hand.

Another possible reason as to why no significant differences were found between conditions of situational probability information presented could be that the way in which the conditions of situational probability were presented. They were possibly not as task-specific as possible. According to the LTWM theory, when a domain-specific situation is presented, skilled performers have access to more task-relevant and less task-irrelevant information, which leads to more accurate predictions. Therefore, a possible reason as to why no significant differences between the conditions were discovered, is that not enough task-relevant information was presented or too much task-irrelevant information was presented.

It is vital that the conditions presented in studies closely mimic that of performance and a possible reason as to why no significant differences were found in the current study could be the way in which both types of situational probability information were presented. For example, the sequence used in the study was the delivery of a full and straight delivery on the first ball of the over. Although the participants were explicitly made aware of the sequence, they did not trust the information. Additionally, it is not a frequently occurring sequence in the game of cricket. In terms of the field placement information provided to batsmen, some field placements have distinct deliveries associated with them while other field placements have a variety of possible deliveries associated with them (may be a more conservative field placement in case of poor execution by the bowler). The particular delivery and associated field placement in this study may have been too general (conservative) and less distinct and therefore yielded a non-significant result.

Following the discussion of the effect of condition on prediction accuracy, the effect of the category of congruency will be discussed.

According to Table 4.3, congruent trials had a prediction accuracy mean (51.56 ± 25.88%) significantly higher ($t(14)=3.97$, $p=0.001$, $d=1.03$) than the chance level for prediction accuracy; whereas, incongruent trials had a prediction accuracy mean (9.33 ± 7.89%) significantly lower ($t(14)=-7.69$, $p<0.001$, $d=1.99$) than the chance level for prediction accuracy.

The prediction accuracy results revealed a significant main effect for congruency ($F(2,23)=27.123$, $p<0.001$). When compared to the control trials, congruent trials had a prediction accuracy mean (51.56 ± 25.88%) significantly higher ($p=0.002$) than the prediction accuracy mean for control trials (22.89 ± 4.52%); whereas incongruent trials (9.33 ± 7.89%) had a prediction accuracy mean significantly lower ($p<0.001$) the prediction accuracy mean for control trials. Additionally, Congruent trials had a prediction accuracy mean significantly higher ($p<0.001$) than the prediction accuracy mean for incongruent trials. The results above reveal that the batsmen anticipated more accurately when the information presented was aligned to the event outcome (congruent trial) and anticipated less accurately when the information presented was not aligned to the event outcome (incongruent trial).

The results highlight that the congruency of situational probability information to event outcome is crucial for anticipation and are in alignment with the results of previous research. In a study conducted by Runswick et al. (2019) in cricket, the congruency between the information available and the event outcome was examined. Results of the study revealed that skilled batsmen anticipated more accurately when field placement information available was congruent to the event outcome and less accurately when field placement information available was incongruent to the event outcome. With regards to sequence information, research conducted by Gray (2002), revealed that the previous sequence of pitches in baseball batting was a useful source of information in terms of prediction accuracy when congruent with the event outcome. Similarly, research by Mann et al. (2014) revealed that handball goalkeepers improved anticipatory performance when opponent throwers continued to throw in accordance to their action preference; however, when the opponent throwers did not continue with their action preference, anticipatory performance decreased.

The low prediction accuracy mean for incongruent trials can be explained through the information presented to the batsmen. In the incongruent trials, information was presented to the batsmen that did not tactically align to the specific upcoming delivery. In cricket, deliveries that are bowled that do not tactically align to the game situation are delivered either as a deceptive strategy or poor execution. In the current study, a bowling machine was used; therefore, the incongruent trials were not delivered due to poor execution, but rather as a deceptive strategy. As seen, the incongruent trials prediction accuracy mean is lower than the chance level. This infers that the batsmen made use of the deceptive information, leading to a low prediction accuracy. Deception (presentation of false cues) and disguise (delayed onset of informative cues) are strategies used by opponents to minimize the benefits of anticipation (Müller & Abernethy, 2012). Previous research has shown that when an opponent's action outcomes are incongruent with expectations derived from situational probability information, a decrease in anticipatory performance occurs. For example, in a study conducted by Mann et al. (2014), two groups of skilled handball goalkeepers anticipated the direction of penalties thrown by opponents prior to and after a training intervention that provided situational probability information in the form of action preferences. One group took part in a training intervention that consisted of two throwers that had a strong preference to throw in a specific direction and the other group took part in training that included throwers possessing no action preference. Results revealed that exposure to opponents that did possess the action preference during the training phase resulted in improved anticipatory response if the opponent continued to bias their throws according to their action preferences, but decreased performance resulted if the opponent did not continue with their action preferences. Similar findings have been found in research conducted by Runswick, Roca, Williams, Mcrobert and North (2019) and (Murphy *et al.*, 2015) in cricket, Gray (2002) and Canãl-Bruland, Filius and Oudejans (2015) in baseball, and Loffing et al. (2015) in volleyball.

Following the discussion of the effect of condition and congruency on prediction accuracy, the effect of the interaction between condition and congruency on prediction accuracy will be discussed.

Congruent trials in which sequence information alone was presented ($t(14)=3.53$, $p=0.003$, $d=0.91$) and congruent trials in which both sources of information were presented ($t(14)=3.83$, $p= 0.002$, $d=0.99$) had prediction accuracy means significantly higher than the chance level for prediction accuracy: whereas incongruent trials in which sequence information alone was presented ($t(14)=-6.42$, $p<0.001$, $d=1.66$) and incongruent trials in which both sources of information were presented ($t(14)=-6.42$, $p<0.001$, $d=1.66$) had prediction accuracy means significantly lower than the chance level for prediction accuracy. When compared to control trials, results revealed that congruent sequence alone trials ($p=0.037$) and congruent both sources trials ($p=0.020$) had prediction accuracy means significantly higher than the control trials; whereas incongruent sequence alone trials ($p<0.001$) and incongruent both sources trials ($p<0.001$) had prediction accuracy means significantly lower than the control trials. Both congruent ($p=0.502$) and incongruent field placement trials ($p=0.955$) had prediction accuracy means that were not significantly different to the control trials. Once again, these results highlight that the congruency of situational probability information to event outcome is crucial for anticipation. Congruent trials led to higher prediction accuracy means; whereas, incongruent trials led to lower prediction accuracy means. What is interesting is that, although congruent trials for the sequence alone and the both sources conditions were significantly higher than the chance level and their incongruent trials were significantly lower than the chance level, field placement congruent and incongruent trials were both not significantly different to the chance level. A possible reason for this is that a full and straight delivery does not have a distinct field placement associated with it. Therefore, batsmen were not able to use the field placement information to predict the upcoming delivery. Additionally, when a full and straight delivery is to be bowled, captains often place a number of players in positions on the field as a defensive strategy in case the bowler is not able to execute the delivery appropriately. This implies that not all the fielders in a specific field placement provide information as to where the upcoming delivery will pitch. Rather certain field placements provide advance information regarding the landing position of the subsequent delivery.

The results of the Kruskal-Wallis test conducted, as seen in Figure 4.3, were in alignment with the results and discussion above in terms of the distribution comparisons between the combinations.

5.3. Level of Certainty Associated with Prediction Accuracy

The purpose of this section is to address the level of certainty associated with the prediction accuracy of cricket batsmen when anticipating the delivery outcome in an in-situ setting.

In prediction tasks, such as the anticipation task in the current study, high levels of accuracy associated with high confidence ratings indicate subjective awareness of the information used to make accurate predictions, whereas low confidence ratings associated with high levels of accuracy indicate a lack of subjective awareness (Murphy et al., 2018). Confidence ratings and accuracy scores collected in conjunction can, therefore, provide information regarding the relevance of the information presented (Chan, 1992; Murphy et al., 2018). In the current study, the most frequently occurring level in terms of the batsmen's certainty of prediction accuracy was "somewhat certain" for the control trials (38.44%), the field placement alone condition (41.33%), and the both sources condition (35.33%). Although the frequency difference was only slight, the sequence alone condition was the only condition in which "somewhat certain" (27.33%) was not the most frequently occurring certainty level of batsmen and instead "moderately certain" (33.33%) was the most frequently occurring certainty level.

A possible reason as to why “somewhat certain” was the most occurring certainty level is that each condition consisted of an equal number of congruent and incongruent trials. Therefore, for each congruent trial that might have led the batsmen to be more certain in trials later in the study, there was an identical incongruent trial that led to batsmen being less certain. With there being an equal split of congruent and incongruent trials, the influence of each category of congruency cancelled each other out and the “neutral” certainty level was the most common.

Another possible reason as to why “somewhat certain” was the most occurring certainty level is because batsmen might have taken a conservative approach when batting in the study. The “somewhat certain” certainty level was the “neutral” certainty level. This means that the batsmen were not extremely certain when choosing this certainty level; however, there was some degree of certainty. This might have been the case because participation in cricket batting is constrained by the rules of the game. Batsmen in limited-overs cricket only get one opportunity to bat; therefore, a single skill error could lead to the end of their innings (Müller & Abernethy, 2008). For this reason, batsmen might take a conservative approach in order to prolong their participation in the match.

An interesting finding observed was that for trials in which sequence information alone was presented and trials in which both sources were presented, participants stated that they were “extremely certain” in 21.33% and 20.00% of the trials respectively. The finding for the both sources condition can be explained through research conducted by Murphy et al. (2018) in tennis which revealed that when two sources of information were presented in conjunction with each other, confidence ratings were higher than when the sources were presented independently of each other. However, it is interesting that the sequence alone also had a high frequency distribution for the “extremely certain” category. A possible reason as to why this occurred is that the sequence used in the study could only be used on the first and last ball of the over as this was when sequence information was made available. With the sequence information being limited to these trials and batsmen being made aware of that, they were more certain of their prediction accuracy.

5.4. Verbal Report Associated with Prediction of Event Outcome

The purpose of this section is to address the verbal report associated with the prediction accuracy of cricket batsmen when anticipating the event outcome in an in-situ setting.

As seen in Table 4.6, the most frequently used source of information by batsmen to make a prediction regarding the ball's landing position according to the verbal report data was field placement information. Field placement information was the most frequently used source of information by batsmen for control trials (83.56%), for trials in which sequence information alone (59.33%) was presented, for trials in which field placement information alone (82.67%) was presented, and for trials in which both sources of information (54.67%) were presented. A possible reason to explain these findings is that during a game of cricket, for each delivery bowled, field placement information is available; whereas, other forms of advance information, such as sequence information, are not. In the current study, field placement information, although not always congruent to event outcome, was present during each trial of the study whereas bowling sequence information was not. Therefore, batsmen always had the option to try and derive meaningful information from the field placement. Although the current study revealed that field placement was used more than any other type of source of information, Runswick et al. (2017) revealed that when bowling sequence information, field placement information, game situation information, and the bowler's kinematic information was presented, a balanced use of all these sources were used to facilitate successful anticipation.

Another finding observed in the current study was that the use of sequence information was most frequent in the sequence alone condition (10.67%), the use of field placement information was most frequent in the field placement alone condition (82.67%), and the use of both sources of information was most frequent in the both sources condition

(31.33%). These results reveal that when a source of information is provided, no matter which source of information is provided, batsmen use this information more than when no source of information is available (control trials). These results are supported by research conducted by Loffing et al. (2015) which stated that the use of sequence information facilitated anticipation; Runswick et al*.* (2019) which revealed that the use of field placement information facilitated anticipation; and Runswick et al*.* (2017) which found that the use of both sequence and field placement information was used in the anticipatory process.

5.5. Response Accuracy

The purpose of this section is to address the results of the current study in terms of the response accuracy results of cricket batsmen when responding to a delivery in an in-situ setting. In order to develop a better understanding of the response accuracy of batsmen, results were analysed according to the condition of situational probability information presented, the category of congruency, and the combination of condition and congruency.

The findings for the overall response accuracy conducted in the study, as illustrated in Table 4.7, revealed that the mean for all trials was 66.44 ± 7.04% and the maximum response accuracy obtained was 80.00%. The overall response accuracy was also significantly higher ($t(14)=9.04$, $p<0.001$, $d=2.34$) than the chance level (50%). These results were higher than expected seeing that trials comprised mostly of control and incongruent trials, meaning that either no prior situational probability information related to the action-outcome was available or deceptive information was available to batsmen during these trials. A possible reason as to why the overall response accuracy was significantly higher than the chance level could be that the action capabilities of the batsmen were of a high standard. This means that although their prediction might not have been correct, they were still able to make successful bat-ball contact. This is in alignment with Mann et al. (2014) who suggested that the strong perceptual-action coupling inherent in a motor response may be more resistant to interruption by situational probability information than a perceptual response, and therefore the action response of making successful bat-ball contact may be less affected by knowledge of field placement and sequence information. Another explanation might be that batsmen were able to utilise projectile motion information to react and rapidly correct their response. Research conducted by Runswick et al. (2019) revealed that once 80ms of projectile motion information is available, skilled batsmen switch from using situational probability information to using projectile motion information. The integration of advanced and projectile motion information facilitates a reduction in the uncertainty of the opponent's movement and guides successful interception (Müller & Abernethy, 2012; Rosalie & Müller, 2013). This statement was supported by Müller and Abernethy (2012), who stated that information perceived from projectile motion often provides either confirmatory information or information to update and fine-tune a general movement response selected from the earlier information perceived. Therefore, batsmen are able to make successful contact regardless of whether situational probability information is presented or not.

In order to develop a better understanding of the response accuracy of batsmen, results were divided into the four conditions of situational probability (no sources, sequence alone, field placement alone, and both sources) and analysed accordingly.

When the response accuracy means were compared to chance level (50%), the results revealed that the means for the control condition ($t(14)=5.50$, $p<0.001$, d=1.42), sequence alone condition ($t(14)=5.77$, $p<0.001$, $d=1.49$), field placement alone condition ($t(14)=5.91$, $p<0.001$, $d=1.53$) and the both sources condition ($t(14)=3.57$, $p=0.003$, $d=0.92$) were significantly higher than the chance level for response accuracy. Additionally, the response accuracy results of batsmen revealed no significant main effect for the condition of situational probability information presented to batsmen ($F(3,56)=1.840$, $p=0.150$). The response accuracy null hypothesis set for the current study was RA H_0: $RA\mu_1 = RA\mu_2 = RA\mu_3 = RA\mu_4$. Therefore, the null hypothesis cannot be rejected and is consequently accepted for response accuracy.

With regards to the condition of situational probability information presented to batsmen, it was expected that the knowledge of situational probability information would lead to significant differences in response accuracy between conditions; however, the response accuracy results of batsmen revealed no significant main effect for condition of situational probability information (no sources, sequence alone, field placement alone, both sources) presented to batsmen. These results are interesting as research has found that the use of advanced information, such as sources of situational probability information, is crucial for batsmen to judge when and where the ball will arrive. This, in turn, provides the batsmen with additional time to respond accurately (Müller & Abernethy, 2008; Williams, 2009; Rosalie & Müller, 2013; Triolet et al., 2013). Therefore, it was expected that the response accuracy for the field placement alone, sequence alone, and both sources conditions would be significantly greater than the response accuracy for the control trials. However, research has also shown that, although the use of situational probability information is crucial in judging where and when the ball will arrive, different sources of information are weighted differently in terms of their facilitation of anticipation depending on the stage of the opponent's action (Loffing & Hagemann, 2014; Loffing et al., 2016). A performer's prediction relies predominantly on situational probability information at the early stages, but as kinematic and projectile motion information arises, the role of situational probability information decreases (Loffing & Hagemann, 2014; Loffing et al., 2016). Therefore, the appearance of projectile motion information in the study could have provided the batsmen with enough information to make successful bat-ball contact regardless of which condition of situational probability information was presented and regardless of whether or not their prediction was correct.

Following the discussion of the effect of condition on prediction accuracy, the effect of the category of congruency will be discussed.

The response accuracy mean for congruent trials ($t(14)=5.60$, $p<0.001$, $d=1.45$) and the response accuracy mean for incongruent trials ($t(14)=4.08$, $p=0.001$, $d=1.05$) were significantly higher than the chance level. Furthermore, the response accuracy results of batsmen revealed no significant main effect for congruency ($F(2,42)=1.970$, $p=0.152$).

The response accuracy results with regards to congruency are in contrast to a large body of literature that states that many situations in sport occur in which the kinematic and situational probability information presented are incongruent with the actual event outcome, leading to negative consequences (Runswick et al., 2019). The ability to use situational probability information facilitates performance through the improvement of response time and response accuracy. However, this might not always be the case (Mann et al., 2014). Research has shown that response accuracy may be impaired when action outcomes are incongruent with expectations derived from situational probability information (Levi & Jackson, 2018). If the expected outcome is congruent with the actual outcome (and the kinematic information), then the use of situational probability information should facilitate an advantage that is better than that possible if only kinematic and projectile motion information was relied upon (Levi & Jackson, 2018). In contrast, if the expected outcome differs from that derived from the kinematic or projectile motion information then it seems rational to expect that situational probability information may decrease rather than improve anticipatory performance (Levi & Jackson, 2018). This statement is supported by research conducted by Mann et al. (2014) in handball which revealed that exposure to opponents that did possess an action preference resulted in improved anticipatory response if the opponent continued to bias their throws according to their action preferences, but decreased performance if the opponent did not continue with their action preferences.

Although the results of the current study are in contrast to a large body of literature, the current study made use of an action response in an in-situ setting; whereas, the contrasting body of literature does not. Research conducted by Mann et al. (2014) can be used to explain why no significant difference occurred between congruent and incongruent trials for the response accuracy in the current in-situ study. Mann et al. (2014) suggested that the strong perceptual-action coupling inherent in a motor response may be more resistant to interruption by situational probability information than a perceptual response, and therefore the action response of making successful bat-ball contact may be less affected by knowledge of field placement and sequence information.

Following the discussion of the effect of condition and congruency on response accuracy, the effect of the interaction between condition and congruency on response accuracy will be discussed.

When the control trials were compared to all other combinations of condition and congruency, a significant main effect for response accuracy of batsmen was found ($F(6,98)=2.198$, $p=0.049$, $\eta_p^2=.12$). However, post-hoc tests revealed no significant difference between the control trials and any combination of condition and congruency. Furthermore, no interaction effect was found between the condition of situational probability information presented and the category of congruency ($F(2,84)=2.219$, $p=0.115$). Action capabilities could once again be a possible reason as to why these results occurred. No matter which combination of condition of situational probability and congruency was presented, batsmen had the action capabilities to respond correctly to the delivery bowled and therefore, no single combination was significantly different to the control trials.

5.6. Initial Movement Time

The purpose of this section is to address the results of the current study in terms of the initial movement time results of cricket batsmen when responding to a delivery in an in-situ setting.

The initial movement time of the batsman referred to the length of time between the projection of the ball from the machine and the first recorded movement of the batsman. Positive initial movement time values represented trials in which the batsman initiated their movement following the projection of the ball from the bowling machine and negative values represented trials in which the batsman initiated their movement prior to the projection of the ball from the bowling machine (Peploe, King & Harland, 2014).

The findings for the overall initial movement time of batsmen conducted in the study, as illustrated in Table 4.11, revealed that the overall mean was 69 ± 200ms. Therefore, indicating that on average the batsmen initiated their movement following the release of the ball from the bowling machine. Research studies conducted have shown varying results in terms of the initial movement time of cricketers when facing a bowling machine.

A possible reason as to why the overall mean initial movement time was lower than the values identified by the studies conducted by Renshaw et al*.* (2007) and Pinder et al. (2009) is the use of advance information. The studies mentioned in the preceding sentence did not provide the batsmen with advance information, whereas the current study did. The presentation of advance information, such as the sources of situational probability information presented to batsmen in the current study, can lead to reductions in initial movement time by 50 to 150ms depending on the activity under investigation (Borysiuk & Sadowski, 2007). Research conducted by Borysiuk and Sadowski (2007), revealed that the presentation of advance information led to a 42ms decrease in initial movement time on a time anticipation test. Superior advance knowledge of event probabilities may facilitate earlier movements in sport given that the probability of making anticipatory movements has been shown to be linearly related to the subjective probability performers give to any action's occurrence (Abernethy et al*.*, 2001; Mann et al., 2014). It has been well documented that if one particular stimulus option is more probable than another, the amount of information processed and the amount of uncertainty is reduced and performance is adjusted accordingly (Abernethy et al*.*, 2001).

When compared to the control trials (80 ± 67ms), the initial movement time means of the sequence alone condition (68 ± 73ms), the field placement alone condition (77 ± 82ms), and the both sources condition (45 ± 107ms) were not significantly different. The initial movement time null hypothesis set for the current study is IMT H_0: $IMT_{\mu 1} = IMT_{\mu 2} = IMT_{\mu 3} = IMT_{\mu 4}$. The initial movement time results of batsmen revealed no significant main effect for the condition of situational probability information to batsmen ($F(3,56)=1.840$, $p=0.150$). Therefore, the null hypothesis cannot be rejected and is consequently accepted for initial movement time. Furthermore, initial movement time results revealed no significant differences between categories of congruency and no significant differences between the combinations of condition and congruency. The initial movement time results may be due to the use of a bowling machine. As kinematic cues used by batsmen are not presented as they would be in the natural batting task (Pinder et al., 2009; Cork et al., 2010). The operator of the bowling machine typically provides cues to the batsmen, such as raising their hand prior to feeding the ball through the machine; however, these cues are not representative of the natural batting task and do not give the batsmen precise pre-release information pertaining to when the ball will be delivered (Cork et al., 2010). The uncertainty as to when the ball would leave the machine could, therefore, lead to batsmen either responding very early or very late to the delivery, thus leading to varying results and consequently, no significant differences between conditions of situational probability presented or between the congruency of trials. The large range found for initial movement time results corroborates the statement that the use of a bowling machine causes uncertainty as to when the ball will be delivered. The minimum initial movement time of batsmen was as early as -1185ms with the maximum initial movement time of batsmen being as late as 480ms resulting in a range of 1665ms.

5.7. Summary of Findings

The summary of the findings of the study for prediction accuracy, response accuracy, and initial movement time will be discussed in the section to follow.

5.7.1. Prediction Accuracy

- There was no significant difference ($F(3,26)=2.746$, $p=0.063$) between conditions of situational probability information for prediction accuracy of cricket batsmen when anticipating the delivery outcome which is presumably caused by the number of incongruent trials or alternatively, that batsmen value the sources of situational probability in the current study equally.
- There were significant differences ($F(2,23)=27.123$, $p<0.001$) between categories of congruency for prediction accuracy of cricket batsmen when anticipating the delivery outcome. This is presumably caused by the alignment of information to action outcome.
- The most frequently occurring level in terms of the batsmen's certainty of prediction accuracy was "somewhat certain". The results possibly occurred as batsmen may have taken a conservative approach.
- The most frequently used source of information by batsmen to make a prediction regarding the ball's landing position according to the verbal report data was field placement information. The results possibly occurred because during a game of cricket, for each delivery bowled, field placement information is available; whereas, other forms of advance information, such as sequence information, are not.

5.7.1. Response Accuracy

- The response accuracy of cricket batsmen when anticipating the delivery outcome in an in-situ setting was not influenced by the condition of situational probability information presented ($F(3,56)=1.840$, $p=0.150$), the congruency between the information presented and the event outcome ($F(2,42)=1.970$, $p=0.152$), or the interaction between the condition and congruency ($F(2,84)=2.219$, $p=0.115$). The strong perceptual-action coupling inherent in a motor response may be more resistant to interruption by situational probability information than a perceptual response, and therefore the action response of making successful bat-ball contact was less affected by knowledge of field placement and sequence information. Additionally, another possible reason to explain the response accuracy results could be that batsmen were able to utilise projectile motion information to react and rapidly correct their response.

5.7.1. Initial Movement Time

- The initial movement time of cricket batsmen when anticipating the delivery outcome in an in-situ setting was not influenced by the condition of situational probability information presented ($F(3,56)=0.541$, $p=0.656$), the congruency between the information presented and the event outcome ($F(2,42)=0.690$, $p=0.507$), or the interaction between the condition and congruency ($F(2,84)=0.640$, $p=0.530$). The results achieved can be explained by the fact that a bowling machine was used (kinematic information was removed). The uncertainty as to when the ball would leave the machine could lead to batsmen either responding early or late to the delivery, thus leading to mean initial movement times that were not significantly different to each other.

5.8. Limitations

Despite the positive results, there were a few limiting factors that could have affected the outcome of the study. These include:

- A quasi-experimental research design was used which meant that the study was limited with the greatest disadvantage being that randomization was not used.
- Cognitive and visual deficits were not considered when determining the inclusion criteria.
- The sample size was limited due to the fact that the cricket clubs in the Port Elizabeth region are not situated in close proximity to the testing venue. The

sample size was also limited as only the top six batsmen in each club met the inclusion criteria to participate in the study.

- Environmental conditions were a limiting factor as the test conducted was in-situ and required the use of an outdoor cricket pitch. Environmental and pitch conditions varied from testing sessions and possibly led to differing difficulty levels when attempting to make contact with the ball. This may have had an effect on response accuracy.
- The slow nature of the cricket pitch used may have influenced response accuracy results. Due to the slow nature of the cricket pitches used, performers may have had additional time to make successful contact with the ball thus affecting response accuracy results.
- The verbal report questionnaire was not validated.
- A testing session was not conducted following data collection to assess whether or not the speed of the bowling machine remained consistent throughout the study.
- The sequence used in the study may not have been as distinct/task-relevant as other sequences which possibly led to sequence information not being used as much as the field placement information.
- A full and straight delivery does not have a specific field placement aligned to it which possibly led to reduced prediction accuracy results and certainty levels when using field placement informing.
- An equal number of congruent and incongruent trials were used. Although this was necessary for statistical purposes, it had a negative effect on prediction accuracy comparisons between conditions, level of certainty results, verbal report results and initial movement time results.

5.9. Conclusion

The conclusion for the current study aims to summarize all the aforementioned results and discussions to achieve the main aim and objective of the study.

The prediction accuracy results revealed that the batsmen equally value each source of situational probability information and that when sources were presented in conjunction with each other, no enhancement in anticipatory performance occurred. Batsmen were, however, able to make significantly better predictions on congruent trials when compared to control trials and incongruent trials due to the fact that information presented on congruent trials aligned to the delivery outcome; whereas, on incongruent trials, the information presented did not align to the delivery outcome.

The response accuracy results revealed that the batsmen have the required action capabilities to make successful bat-ball contact regardless of whether or not they correctly anticipate the upcoming delivery's landing position. Additionally, batsmen were able to utilise projectile motion information to react and rapidly correct their response thus leading to results being similar for different conditions, categories of congruency, and combinations of condition and congruency.

The initial movement time results achieved can be explained by the fact that a bowling machine was used. The uncertainty as to when the ball would leave the machine could lead to batsmen either responding early or late to the delivery, thus leading to mean initial movement times that were not significantly different to each other.

5.10. Recommendations for Further Research

For future studies, it is recommended that:

- The current research is repeated to confirm the findings of this study, and the following be considered:
    - Increase the sample size and number of trials.
    - Conduct testing on a synthetic indoor cricket pitch to negate varying environmental conditions.
    - Do not present information explicitly as it leads to batsmen not relying on the information.

    - Use sequence information that is more specific to the game of cricket, such as, the delivery of a short ball following a boundary.
    - Include action preferences as an additional type of situational probability information.
- The effect of prediction accuracy on the response accuracy of making contact with the ball be examined.

List of References

1. Abernethy, B. & Zawi, K. 2007. Pickup of essential kinematics underpins expert perception of movement patterns. *Journal of Motor Behavior*. 39(5):353–367.
2. Abernethy, B., Gill, D.P., Parks, S.L. & Packer, S.T. 2001. Expertise and the perception of kinematic and situational probability information. *Perception*. 30(2):233–252.
3. Abernethy, B., Baker, J. & Côté, J. 2005. Transfer of pattern recall skills may contribute to the development of sport expertise. *Applied Cognitive Psychology*. 19(6):705–718.
4. Afonso, J., Garganta, J. & Mesquita, I. 2012. Decision-making in sports: The role of attention, anticipation and memory. *Revista Brasileira de Cineantropometria e Desempenho Humano*. 14(5):592–601.
5. Alain, C. & Proteau, L. 1980. Decision making in sport. *Psychology of motor behaviour and sport*. 1979:465–477.
6. Allard, F., Graham, S. & Paarsalu, M.E. 1980. Perception in Sport: Basketball. *Journal of Sport Psychology*. 2(1):14–21.
7. Borysiuk, Z. & Sadowski, J. 2007. Time and Spatial Aspects of Movement Anticipation. *Biology of Sport*. 24.
8. Brenton, J., Muller, S. & Mansingh, A. 2016. Discrimination of Visual Anticipation in Skilled Cricket Batsmen. *Journal of Applied Sport Psychology*. 28(4):483–488.
9. Canãl-Bruland, R., Filius, M.A. & Oudejans, R.R.D. 2015. Sitting on a fastball. *Journal of Motor Behavior*. 47(4):267–270.
10. Cañal-Bruland, R. & Mann, D.L. 2015. Time to broaden the scope of research on anticipatory behavior: A case for the role of probabilistic information. *Frontiers in Psychology*. 6(OCT):1–3.
11. Cañal-Bruland, R. & Schmidt, M. 2009. Response bias in judging deceptive movements. *Acta Psychologica*. 130(3):235–240.
12. Cañal-Bruland, R., van Ginneken, W.F., van der Meer, B.R. & Williams, A.M. 2011. The effect of local kinematic changes on anticipation judgments. *Human*

Movement Science. 30(3):495–503.

13. Chan, C. 1992. Implicit cognitive processes : theoretical issues and applications in computer systems design. *Unpublished doctoral dissertation*.
14. Cork, A., Justham, L. & West, A.A. 2010. Batter's behaviour during training when facing a bowling machine and when facing a bowler. *Proceedings of the Institution of Mechanical Engineers, Part P: Journal of Sports Engineering and Technology*. 224(3):201–208.
15. Cotterill, S.T. 2014. Developing decision-making for performance: A framework to guide applied practice in cricket. *Journal of Sport Psychology in Action*. 5(2):88–101.
16. Croft, J.L., Button, C. & Dicks, M. 2010. Visual strategies of sub-elite cricket batsmen in response to different ball velocities. *Human Movement Science*. 29(5):751–763.
17. De Vos, A.., Strydom, H., Fouche, C.. & Delport, C.S.. (2005). Book review: Research at grass roots: For the social sciences and human services professions. SA Journal of Industrial Psychology. 30(1):355–450.
18. Dicks, M., Davids, K. & Button, C. 2010. Individual differences in the visual control of intercepting a penalty kick in association football. *Human Movement Science*. 29(3):401–411.
19. Elmurr, P. 2011. The relationship of vision and skilled movement-A general review using cricket batting. *Eye and Contact Lens*. 37(3):164–166.
20. Farrow, D. & Reid, M. 2012. The contribution of situational probability information to anticipatory skill. *Journal of Science and Medicine in Sport*. 15(4):368–373.
21. Farrow, D., McCrae, J., Gross, J. & Abernethy, B. 2010. Revisiting the Relationship between Pattern Recall and Anticipatory Skill. *International Journal of Sport Psychology*. 41.
22. Ford, P.R., Low, J., McRobert, A.P. & Williams, A.M. 2010. Developmental Activities That Contribute to High or Low Performance by Elite Cricket Batters When Recognizing Type of Delivery from Bowlers' Advanced Postural Cues. *Journal of Sport and Exercise Psychology*. 32(5):638–654.
23. Gibson, J.. 1979. *The Ecological Approach to Visual Perception*. 1st ed. New

York: Taylor & Francis Group.

24. Glossary of Cricket Terms and Cricket Terminology. (2020). Available: http://www.cricker.com/glossary/ [2019 , August 17].
25. Gorman, A.D., Abernethy, B. & Farrow, D. 2011. Investigating the anticipatory nature of pattern perception in sport. *Memory and Cognition*. 39(5):894–901.
26. Gray, R. 2002. Behavior of College Baseball Players in a Virtual Batting Task. *Journal of Experimental Psychology: Human Perception and Performance*. 28(5):1131–1148.
27. Hagemann, N., Strauss, B. & Cañal-Bruland, R. 2006. Training Perceptual Skill by Orienting Visual Attention. *Journal of Sport and Exercise Psychology*. 28(2):143–158.
28. Hepler, T.J. & Feltz, D.L. 2012. Take the First Heuristic , Self-Efficacy , and Decision-Making in Sport. *Journal of Experimental Psychology: Applied*. 18(2):154–161.
29. Huys, R., Smeeton, N.J., Hodges, N.J., Beek, P.J. & Williams, A.M. 2008. On the dynamic information underlying visual anticipation skill. *Perception and Psychophysics*. 70(7):1217–1234.
30. Jackson, R.C., Warren, S. & Abernethy, B. 2006. Anticipation skill and susceptibility to deceptive movement. *Acta Psychologica*. 123(3):355–371.
31. Klein, G. 1993. A Recognition-Primed Decision (RPD) Model of Rapid Decision Making. *Decision making in action: Models and methods*. (January 1993):139–147.
32. Land, M.F. & McLeod, P. 2000. From eye movements to actions: Batsmen hit the ball. *Nature Neuroscience*. 3(12):1340–1345.
33. Levi, H.R. & Jackson, R.C. 2018. Contextual factors influencing decision making: Perceptions of professional soccer players. *Psychology of Sport and Exercise*. 37(July 2017):19–25.
34. Levitin, D.J. 2016. *A Field Guide to Lies*. 1st ed. New York: Peguin Random House LLC.
35. Loffing, F. & Cañal-Bruland, R. 2017. Anticipation in sport. *Current Opinion in Psychology*. 16(16):6–11.

36. Loffing, F. & Hagemann, N. 2014a. Skill differences in visual anticipation of type of throw in team-handball penalties. *Psychology of Sport and Exercise*. 15(3):260–267.
37. Loffing, F., Stern, R. & Hagemann, N. 2015. Pattern-induced expectation bias in visual anticipation of action outcomes. *Acta Psychologica*. 161:45–53.
38. Loffing, F., Sölter, F., Hagemann, N. & Strauss, B. 2016. On-court position and handedness in visual anticipation of stroke direction in tennis. *Psychology of Sport and Exercise*. 27:195–204.
39. Mann, D.L., Abernethy, B. & Farrow, D. 2010. Action specificity increases anticipatory performance and the expert advantage in natural interceptive tasks. *Acta Psychologica*. 135(1):17–23.
40. Mann, D.L., Schaefers, T. & Cañal-Bruland, R. 2014. Action preferences and the anticipation of action outcomes. *Acta Psychologica*. 152:1–9.
41. Mann, D.Y., Williams, A.M., Ward, P. & Janelle, C.M. 2007. Perceptual-cognitive expertise in sport: A meta-analysis. *Journal of Sport and Exercise Psychology*. 29(4):457–478.
42. McRobert, A.P., Ward, P., Eccles, D.W. & Williams, A.M. 2011. The effect of manipulating context-specific information on perceptual-cognitive processes during a simulated anticipation task. *British Journal of Psychology*. 102(3):519–534.
43. Milazzo, N., Farrow, D., Ruffault, A. & Fournier, J.F. 2016. Do karate fighters use situational probability information to improve decision-making performance during On-Mat tasks? *Journal of Sports Sciences*. 34(16):1547–1556.
44. Müller, S. & Abernethy, B. 2006. Batting with occluded vision: An in situ examination of the information pick-up and interceptive skills of high- and low-skilled cricket batsmen. *Journal of Science and Medicine in Sport*. 9(6):446–458.
45. Müller, S. & Abernethy, B. 2008. Skill Learning from an Expertise Perspective: Issues and Implications for Practice and Coaching in Cricket. *The Sport Psychologist's Handbook: A Guide for Sport-Specific Performance Enhancement*. 245–261.
46. Müller, S. & Abernethy, B. 2012. Expert anticipatory skill in striking sports: A

review and a model. *Research Quarterly for Exercise and Sport*. 83(2):175–187.

47. Müller, S., Abernethy, B. & Farrow, D. 2006a. How do world-class cricket batsmen anticipate a bowler's intention? *Quarterly Journal of Experimental Psychology*. 59(12):2162–2186.
48. Müller, S., Abernethy, B., Reece, J., Rose, M., Eid, M., McBean, R., Hart, T. & Abreu, C. 2009. An in-situ examination of the timing of information pick-up for interception by cricket batsmen of different skill levels. *Psychology of Sport and Exercise*. 10(6):644–652.
49. Müller, S., Abernethy, B., Eid, M., McBean, R. & Rose, M. 2010. Expertise and the spatio-temporal characteristics of anticipatory information pick-up from complex movement patterns. *Perception*. 39(6):745–760.
50. Müller, S., Brenton, J. & Rosalie, S.M. 2015. Methodological considerations for investigating expert interceptive skill in in situ settings. *Sport, Exercise, and Performance Psychology*. 4(4):254–267.
51. Murphy, C.P., Jackson, R.C. & Williams, A.M. 2015. Cognitive processes underlying anticipation in a context-oriented task. *Psychology of Sport and Physical Activity*. (October):4–7.
52. Murphy, C.P., Jackson, R.C., Cooke, K., Roca, A., Benguigui, N. & Williams, A.M. 2016. Contextual information and perceptual-cognitive expertise in a dynamic, temporally-constrained task. *Journal of Experimental Psychology: Applied*. 22(4):455–470.
53. Murphy, C.P., Jackson, R.C. & Williams, A.M. 2018. The role of contextual information during skilled anticipation. *Quartely Journal of Experimental Psychology*.
54. Navia, J.A., Van der Kamp, J. & Ruiz, L.M. 2013. On the use of situation and body information in goalkeeper actions during a soccer penalty kick. *International Journal of Sport Psychology*. 45(3).
55. North, J.S., Ward, P., Ericsson, A. & Williams, A.M. 2011. Mechanisms underlying skilled anticipation and recognition in a dynamic and temporally constrained domain. *Memory*. 19(2):155–168.
56. Peploe, C., King, M. & Harland, A. 2014. The effects of different delivery methods

on the movement kinematics of elite cricket batsmen in repeated front foot drives. *Procedia Engineering*. 72:220–225.

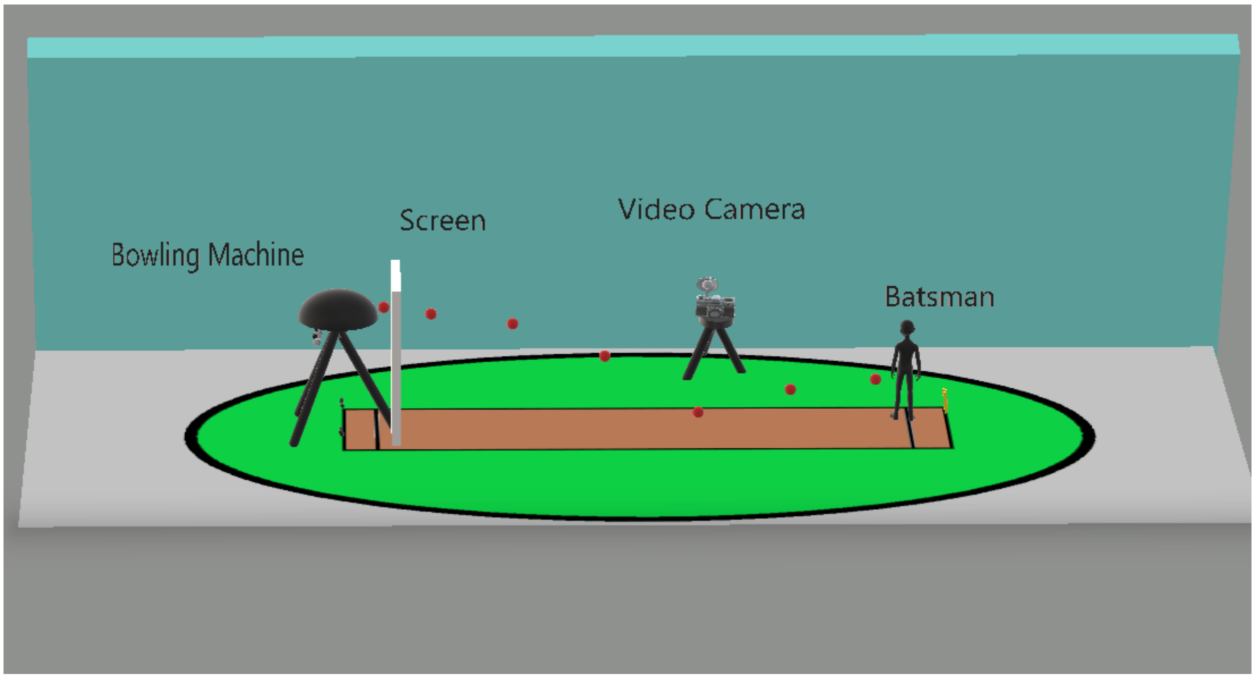
57. Pinder, R.A., Renshaw, I. & Davids, K. 2009. Information-movement coupling in developing cricketers under changing ecological practice constraints. *Human Movement Science*. 28(4):468–479.
58. Renshaw, I. & Fairweather, M.M. 2000. Cricket bowling deliveries and the discrimination ability of professional and amateur batters. *Journal of Sports Sciences*. 18(12):951–957.
59. Renshaw, I., Oldham, A.R.H., Davids, K. & Golds, T. 2007. Changing ecological constraints of practice alters coordination of dynamic interceptive actions. *European Journal of Sport Science*. 7(3):157–167.
60. Roca, A. & Williams, A.M. 2016. Expertise and the interaction between different perceptual-cognitive skills: Implications for testing and training. *Frontiers in Psychology*. 7(MAY):1–4.
61. Rosalie, S.M. & Müller, S. 2013. Timing of in situ visual information pick-up that differentiates expert and near-expert anticipation in a complex motor skill. *Quarterly Journal of Experimental Psychology*. 66(10):1951–1962.
62. Rowe Dr., R., Horswill, M.S., Kronvall-Parkinson, M., Poulter, D.R. & McKenna, F.P. 2009. The effect of disguise on novice and expert Tennis players' anticipation ability. *Journal of Applied Sport Psychology*. 21(2):178–185.
63. Runswick, O.R., Roca, A., Williams, M., Bezodis, N., McRobert, A.P. & North, J.S. 2017. The impact of contextual information and a secondary task on anticipation performance: An interpretation using Cognitive Load Theory. *Applied Cognitive Psychology*. 01:1–7. [Online], Available: http://www.albayan.ae.
64. Runswick, O.R., Roca, A., Williams, A.M., McRobert, A.P. & North, J.S. (2018). The temporal integration of information during anticipation. Psychology of Sport and Exercise. 37(November):100–108.
65. Runswick, O.R., Roca, A., Williams, A.M., McRobert, A.P. & North, J.S. 2019. Why do bad balls get wickets? The role of congruent and incongruent information in anticipation. *Journal of Sports Sciences*. 37(5):537–543.
66. Savelsbergh, G.J.P., Van der Kamp, J., Williams, A.M. & Ward, P. 2005.

Anticipation and visual search behaviour in expert soccer goalkeepers. *Ergonomics*. 48(11–14):1686–1697.

67. Takeuchi, T. & Inomata, K. 2009. Visual Search Strategies and Decision Making in Baseball Batting. *Perceptual and Motor Skills*. 108(3):971-980E.
68. Triolet, C., Benguigui, N., Le Runigo, C. & Williams, M. 2013. Quantifying the nature of anticipation in professional tennis. *Journal of Sports Sciences*. 31(8):820–830.
69. Ward, P., Williams, A.M. & Bennett, S.J. 2002. Visual search and biological motion perception in tennis. *Research Quarterly for Exercise and Sport*. 73(1):107–112.
70. Weissensteiner, J., Abernethy, B., Farrow, D. & Müller, S. 2008. The development of anticipation: a cross-sectional examination of the practice experiences contributing to skill in cricket batting. *Journal of sport & exercise psychology*. 30(6):663–684.
71. What's The Difference Between Over & Around The Wicket? | Cricketers Hub. (2020). Available: https://cricketershub.com/difference-over-around-the-wicket/ [2019 , August 17].
72. What Is The Off Side And Leg Side In Cricket? | Cricketers Hub. (2020). Available: https://cricketershub.com/off-side-leg-side/ [2019 , August 07].
73. Williams, A.M. 2009. *Perceiving the intentions of others: how do skilled performers make anticipation judgments?* Vol. 174. Elsevier.
74. Williams, M. & Davids, K. 1995. Declarative Knowledge in Sport : A By-Product of Experience or a Characteristic of Expertise ? 259–275.
75. Williams, A.M., Hodges, N.J., North, J.S. & Barton, G. 2006. Perceiving patterns of play in dynamic sport tasks: Investigating the essential information underlying skilled performance. *Perception*. 35(3):317–332.
76. Williams, M., Huys, R., Cañal-Bruland, R. & Hagemann, N. 2009. The dynamical information underpinning anticipation skill. *Human Movement Science*. 28(3):362–370.
77. Worthington, P.J. 2010. A biomechanical analysis of fast bowling in cricket. [Online], Available: https://dspace.lboro.ac.uk/2134/6839.

List of Appendices

Appendix 1- Setup of Testing Procedure



Appendix 2- Consent Form

NELSON MANDELA UNIVERSITY

RESEARCHER'S DETAILS	
Title of the research project	Interaction between Situational Probability Information to Anticipate the Bowler's Intention in Cricket
Principal investigator	David-John Lilford
Address	30 Arkhon Street, Summerstrand, Port Elizabeth
Postal Code	6001
Contact telephone number (private numbers not advisable)	**********

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	David-John Lilford	
From	Faculty of Health Sciences	
of the Nelson Mandela University.		

THE FOLLOWING ASPECTS HAVE BEEN EXPLAINED TO ME, THE PARTICIPANT:					Initial
2.1	**Aim:**	The primary aim of this study is to determine the interaction between different sources (field placement and bowling sequence/pattern) of situational probability information to anticipate the bowler's intention in cricket.			
2.2	**Procedures:**	The participant will be required to undergo testing that will require them to face 16 overs (96 balls) delivered by a bowling machine. Prior to the delivery of each ball, the participant will also be required to provide a verbal report including the prediction of the upcoming ball, as well as what source of information was used to make the prediction.			
2.3	**Risks:**	The possibility of injury during the test will be low due to the fact that the participants will be wearing the appropriate protective equipment used in cricket.			
2.4	**Possible benefits:**	There is a lack of research on the information used by cricketers to predict the intention of the bowler, therefore this study will be conducted to fill this gap. Results of the study will be communicated with the participants of the study, as well as their coaches.			
2.5	**Confidentiality:**	The identity of the participant will not be revealed in any discussion, description or scientific publications by the researcher.			
2.6	**Access to findings:**	Should the participant be interested in the findings of this study, contact may be made with the head researcher whose details appear at the beginning of this document.			
2.6	**Voluntary participation /**	My participation is voluntary	YES	NO	

	refusal / discontinuation:	My decision whether or not to participate will in no way affect my present or future care/employment/lifestyle	**TRUE**	**FALSE**		

3. THE INFORMATION ABOVE WAS EXPLAINED TO ME/THE PARTICIPANT BY:									**Initial**
in	**Afrikaans**		**English**		**Xhosa**		**Other**		
and I am in command of this language, **or** it was satisfactorily translated to me by									
(name of translator)									
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 penalization.	

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 thumbprint of participant	Signature of witness:	
	Full name of witness:	

STATEMENT BY OR ON BEHALF OF INVESTIGATOR(S)									
I,	(name of interviewer)			declare that:					
1.	I have explained the information given in this document to			(name of patient/participant)					
	and / or his / her representative			(name of representative)					
2.	He/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		(name of translator)					
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

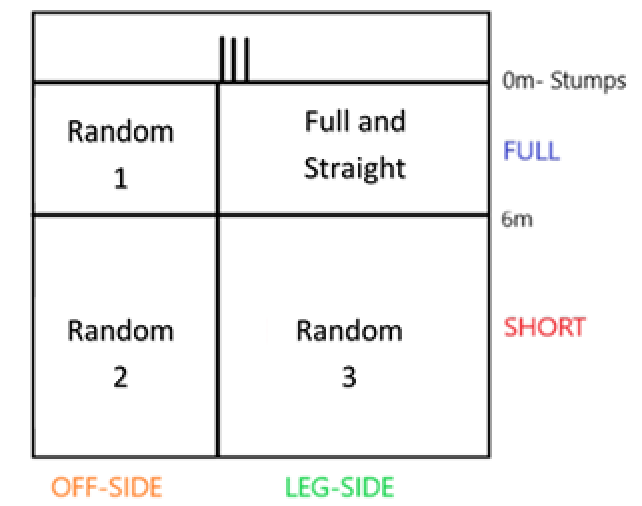
Thank you for your/the participant's participation in this study. Should, at any time during the study:

- an emergency arise as a result of the research, or
- you require any further information with regard to the study, or
- the following occur

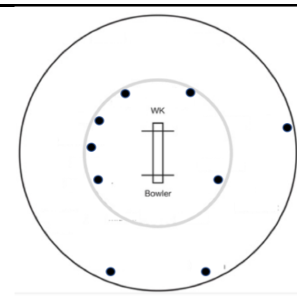
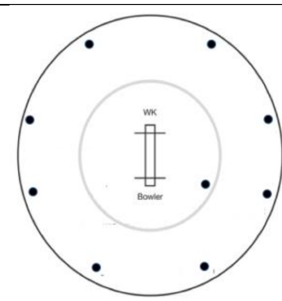
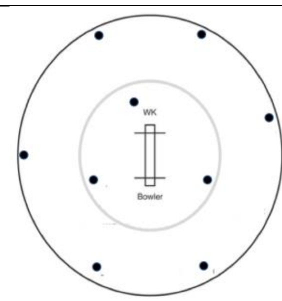
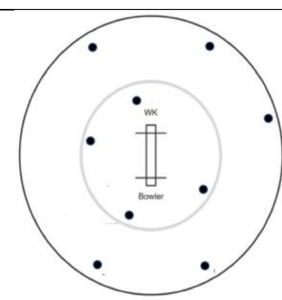
(indicate any circumstances which should be reported to the investigator)

Kindly contact	
at telephone number	(it must be a number where help will be available on a 24-hour basis, if the research project warrants it)

Appendix 3 – Pitch Map Indicating Different Landing Positions of Each Type of Delivery



Appendix 4- Different Field Placements used in Method

Field Placement Letter	Description	Field Placement
A – Full and straight	Field Placement presents situational probability information that infers that a full and straight delivery will be bowled	
B - Random	No situational probability information is presented by the field placement - random field	
C - Random	No situational probability information is presented by the field placement - random field	
D - Random	No situational probability information is presented by the field placement - random field	

Appendix 5 – Measuring Instrument Questions

5) What do you predict the line of the following ball to be?

The following options will be given as the two possible answers to this question:

a) Off-side
b) Leg-side

6) What do you predict the length of the following ball to be?

The following options will be given as the two possible answers to this question:

a) Short
b) Full

7) How certain are you that your prediction is correct?

The following Likert scale will be used by participants to express their level of certainty:

1 – Not at all certain

2 – Slightly certain

3 – Somewhat certain

4 – Moderately certain

5 – Extremely certain

8) What information did you use to make this decision?

9) Did you utilise any other additional information to make your decision and if so what information?

A prediction will be regarded as successful if both the line and length of the delivery are correctly predicted by the participant.

Appendix 6 – Data Collection Sheet

Data Collection Sheet											
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 7 – Entire Sequence of Trials

Entire Sequence of Trials						
	Ball 1	**Ball 2**	**Ball 3**	**Ball 4**	**Ball 5**	**Ball 6**
Over 1	BS, non-FP	BS, non-FP	non-BS, non-FP	non-BS, non-FP	BS, non-FP	BS, non-FP
Over 2	BS, FP	BS, FP	BS, non-FP	non-BS, FP	non-BS, non-FP	non-BS, non-FP
Over 3	non-BS, non-FP	non-BS, non-FP	non-BS, non-FP	non-BS, non-FP	non-BS, non-FP	BS, non-FP
Over 4	non-BS, FP	non-BS, FP	non-BS, non-FP	non-BS, non-FP	BS, FP	non-BS, FP
Over 5	non-BS, FP	non-BS, non-FP	BS, FP	non-BS, non-FP	non-BS, non-FP	BS, FP
Over 6	non-BS, non-FP	BS, non-FP	non-BS, non-FP	BS, non-FP	non-BS, FP	non-BS, non-FP
Over 7	BS, non-FP	non-BS, non-FP	non-BS, non-FP	non-BS, non-FP	non-BS, non-FP	BS, non-FP
Over 8	BS, FP	non-BS, non-FP	non-BS, non-FP	non-BS, non-FP	non-BS, non-FP	BS, FP
Over 9	BS, FP	BS, FP	non-BS, FP	non-BS, non-FP	non-BS, non-FP	non-BS, non-FP
Over 10	non-BS, FP	non-BS, FP	non-BS, non-FP	BS, FP	non-BS, non-FP	non-BS, FP

* BS – Ball sequence; FP – Field placement

Appendix 8 – Permission Letter

NELSON MANDELA UNIVERSITY

South Campus
Department of Human Movement Science
Tel. +27 (0)41 504 4754
S214046427@mandela.ac.za

Prof. Andrew Leitch
Deputy Vice-Chancellor
Tel: +27 41 504 2017

REQUEST FOR PERMISSION TO CONDUCT RESEARCH

Dear Prof. Leitch,

My name is David-John Lilford, and I am a Master of Arts: Human Movement Science (Research) student. The research I wish to conduct for my Master's dissertation involves the comparison of different sources of situational probability in club level cricket batsmen when facing a bowling machine. This project will be conducted under the supervision of Mr R. Raffan.

I am hereby seeking your consent to perform testing on approximately six university cricket batsmen that are from different faculties.

I have provided you with a copy of my dissertation proposal which includes copies of the measure and consent and assent forms to be used in the research process, as well as a copy of the approval letter which I received from the Faculty Postgraduate Studies Committee.

If you require any further information, please do not hesitate to contact me on cell: 0838957588.
Thank you for your time and consideration in this matter.

Yours sincerely,

David-John Lilford
Nelson Mandela University