Expertise in striking sports: The importance of visual anticipation for superior performance

by

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Student Declaration

I declare that this thesis is my own account of my research and contains as its main content work, which has not been previously submitted for a degree at any tertiary educational institution.

Khaya Morris-Binelli

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**Structure of the Thesis**

This thesis is structured as follows: (a) chapter 1 presents an up to date literature review of visual anticipation research in striking sports and investigates whether there have been any advancements in the literature which add to a model of expert visual anticipation by Müller and Abernethy (2012). The literature review was written in preparation for submission to the Canadian Journal of Behavioural Science (www.apa.org/pubs/journals/cbs/), (b) chapter 2 presents the experimental research conducted, which has been prepared in manuscript format in preparation for submission to the Journal of Sports Sciences (www.tandfonline.com/loi/rjsp20). The submission guidelines for this journal state that manuscripts should be in the range of 4,000 words and the experimental paper adheres to these guidelines. Both of these journals adhere to The Publication Manual of the American Psychological Association (6th edition; American Psychological Association, 2010). Due to the abovementioned structure of the thesis, there is unavoidable repetition.
Chapter 1

Abstract

Superior performance in striking sports such as baseball requires anticipatory skill due to constraints imposed on performers, which make it extremely difficult to achieve motor skills such as hitting a baseball. This paper provides an updated literature review of visual anticipation in striking sports and addresses whether there have been advancements in striking sport research which add to a model of visual anticipation proposed by Müller and Abernethy (2012). Firstly, this paper provides an overview of visual anticipation theory and methodologies used to study visual anticipation, followed by a review of recent empirical findings. Specifically, this review addresses advancements in the literature in relation to multiple factors influencing visual anticipation performance between varying skill levels. Furthermore, whether anticipatory skill can be learnt and whether anticipatory skill can transfer to similar or dissimilar domains is discussed. Subsequently, this review highlights that multiple factors contribute to anticipatory skill, as well as identifying viable methods to improve visual anticipation. Moreover, evidence that anticipatory skill can transfer to similar domains is discussed, but it is apparent further research is required, due to scarce research in this area. Collectively, this review provides an update of the research on visual anticipation in striking sports and highlights findings that further the understanding of expertise in striking sports.

**Keywords**: visual anticipation, perception, expertise, striking sports.
Advancements to the understanding of expert anticipatory skill in striking sports: A literature review

Visual anticipation is a major contributing factor to expertise in sport and is defined as the ability to make precise predictions from incomplete sources of visual information (Van Der Kamp, Rivas, Van Doorn, & Savelsbergh, 2008). Sports people must be able to identify the most vital information from their immediate environment, direct their attention accordingly and use this information to respond effectively (Williams, Ford, Eccles, & Ward, 2011). Adequate anticipatory skill is highly important in striking sports such as baseball, cricket and tennis, due to constraints imposed on performers (Müller & Abernethy, 2012).

A key constraint is the time pressure enforced by the speed of the game object (e.g. a baseball). Chronometric analyses of performer-opponent scenarios have shown that the total time to prepare and perform a striking skill takes longer than the total travel time of the object to be intercepted, with the object travel time approximately 500ms and the performers preparatory time approximately 900ms (Ripoll, 1991; Singer, 2000). Subsequently, there is a need for components of the skill to be initiated before ball flight for an adequate response, such as striking a pitched baseball (Williams et al., 2011). This time constraint has led to the notion that to be successful in such sports, information that arises before and during ball flight needs to be utilised to successfully complete the motor skill (Müller & Abernethy, 2012). Such information can include advance visual cues from the opponent’s movement patterns, known as kinematics, and situational probabilities, such as game tactics (Williams et al., 2011). By investigating the key information sources that contribute to anticipatory skill it is possible to explain how expertise in striking sports is obtained, and how experts perform so well under these demanding circumstances (Müller & Abernethy, 2012).
There are several methodologies that have been used to study anticipatory skill, and video-based temporal occlusion is one of the most common (Müller & Fadde, 2016). Using this method, an opponent (e.g., baseball pitcher) is filmed from the performers (e.g., baseball batter) perspective to simulate the visual information used when completing a motor skill (e.g., hitting a baseball; Abernethy, Gill, Parks, & Packer, 2001). The footage is then edited, and a black frame (i.e., occlusion) is applied at key kinematic events in the opponent’s action (e.g., the point of ball release) and during ball flight (Brenton, Muller, & Mansingh, 2016). Participants are then required to specify their prediction by making a written, button or verbal response (Brenton et al., 2016). Temporal occlusion is beneficial in studying striking sports as it provides information about the timing of information pick-up (Müller & Abernethy, 2012). A similar methodology is spatial occlusion, but rather than occluding the visual display at key time points along the opponent's movement pattern, occlusion is applied to specific body parts of the opponent (e.g., the arm; Jackson & Mogan, 2007). This enables the identification of which advance cues from the opponent’s kinematic movement pattern are important for anticipation (Müller & Abernethy, 2012). Additionally, point-light paradigms have been implemented, whereby an opponent’s movement pattern is represented by points of light corresponding to the locations of each of the opponent’s major joints, subsequently allowing the minimum amount of information needed for anticipation to be determined (Johansson, 1973). Recording eye movements through the use of eye trackers, which show the location of eye fixation points and their durations, is another method to investigate anticipatory skill, which provides information about the visual search strategies of performers as they anticipate actions (Shim, Carlton, & Kwon, 2006). Furthermore, neurophysiological methodologies such as functional resonance magnetic imaging (fMRI), transcranial magnetic stimulation (TMS) and
electroencephalogram (EGG) have been used to understand the neural processes that occur when one anticipates (Wright, Bishop, Jackson, & Abernethy, 2010).

Following concerns that video-based methodologies lack ecological validity, there has been an increase in in-situ research, meaning in its natural setting (Muller et al., 2009). The development of liquid occlusion glasses, which the performer wears during an anticipation task, has allowed temporal occlusion to be applied as it is in video-based designs but also allows a movement response (Muller et al., 2009). The researcher remotely triggers the glasses to occlude at various stages of the opponent’s movement and the performer has to respond by attempting to hit the object (e.g. a baseball) or by making a verbal response (Müller, Brenton, & Rosalie, 2015). Consequently, in-situ designs have allowed the ventral (responsible for the perception of objects) and dorsal (responsible for guiding movement) systems of the brain to be examined in tandem, thus increasing the ecological validity of anticipation research (Milner & Goodale, 1995). Despite this benefit, there are practical difficulties of in-situ designs, such as increased risk of fatigue and injury to participants and the extended length of in-situ trials (often two hours), which limit its applicability in certain settings, such as professional sporting teams (Müller, Brenton, & Rosalie, 2015).

Based on research using the above methodologies, Müller and Abernethy (2012) have devised a two-stage model of anticipation, providing an explanation for why experts in striking sports display such superior performance. This model states that as perceptual information progresses over time, there is an increase in the informational cues that can be used to achieve the skill (e.g., hitting a baseball; Müller & Abernethy, 2012). In the first stage, experts are capable of attaining perceptual information, such as kinematic and situational cues, before and during the opposition’s movement pattern, with this information serving as a guide to position their body for interception of the
object. In the second stage, ball flight information, which occurs later, is used to guide and fine tune interceptive movements (Müller & Abernethy, 2012). Alternatively, less-skilled individuals obtain kinematic and probability cues to position their bodies later, subsequently resulting in less time to respond to the moving object and thus poorer task performance (Müller & Abernethy, 2012). This model is supported by video-based occlusion studies in cricket, badminton and tennis, which have consistently shown that highly skilled performers, but not novices, can use information from their opponent’s early movement kinematics (e.g., the position of the wrist at the point of ball release), to improve their prediction accuracy of shot outcomes (Abernethy & Zawi, 2007; Farrow, Abernethy, & Jackson, 2005; Muller, Abernethy, & Farrow, 2006). Furthermore, an in-situ study by Mann, Abernethy, and Farrow (2010) found that early kinematic information from the opponent (i.e., cricket bowler) was used by skilled cricket batters, but not novices, to guide their lower body movements in preparation for interception of a cricket ball. Thereafter, ball flight information was used to position their upper body to intercept the ball. This movement pattern of interception resulted in significantly superior anticipatory prediction accuracy for skilled compared to novice participants.

Expert’s ability to utilise a wider array of informational sources when anticipating as proposed by Müller and Abernethy (2012) is further supported by eye movement studies, which show experts have significantly fewer eye fixations of longer durations, while novices have more fixations of shorter durations (Mann, Williams, Ward, & Janelle, 2007). As the ability to use information from a display is reduced during saccadic eye movements, frequent fixations of shorter durations is a less effective search strategy, and this is supported by higher anticipation accuracy for experts compared to novices (Mann et al., 2007). Moreover, neurophysiological studies suggest fine tuned activation of brain areas such as the action observation network
(AON) by experts, allows a greater array of informational sources to be utilised while anticipating (e.g., Wright et al., 2010; Yarrow, Brown, & Krakauer, 2009), therefore supporting Müller and Abernethy's (2012) model.

There are some aspects that need to be addressed to further develop this model of expert anticipation in striking sports (Müller & Abernethy, 2012). Firstly, a greater understanding of the role situational probability information plays in guiding or inhibiting the early phases of body positioning is required. Furthermore, it is unclear whether situational probability information stems from a wide or narrow range of contextual sources (Müller & Abernethy, 2012). Greater research is also needed to understand differences in anticipation abilities between striking sport performers of similar skill levels, while there is little knowledge of how anticipatory skill is learnt over time. Additionally, it is unclear whether anticipatory skill can transfer across sports, which are similar or dissimilar (Müller & Abernethy, 2012). Therefore, the purpose of this literature review is to identify whether any of these gaps in the model have been addressed by recent research. To achieve this, the review is structured into two key areas: performance studies, which discuss findings that further the understanding of visual anticipation performance between skill levels, and learning and transfer studies.

**Performance Studies**

**Situational probability.** Loffing and Hagemann (2014a) recently used point-light video-based temporal occlusion, with a button response, to test whether the on-court positioning of opponents in tennis affected skilled (16 years experience) and novice (no playing experience) tennis player’s anticipatory decisions. Results found only the skilled participants shot location expectations were altered relative to the position of the opponent on the court. Interestingly, this effect decreased as more
reliable cues, such as the opponent’s stroke kinematics, became available. The ability of situational probability information to guide anticipatory decisions is further supported by Farrow and Reid (2012). This study used video simulation of a tennis serve, with a touch response, and included older and younger junior tennis players from the Tennis Australia high-performance pathway. The older group was considered to be of greater skill as they had higher Australian and international tournament ranking points. Results of this study found that older players were able to detect the occurrence of a service pattern and use this information in conjunction with the opponent's pre-ball flight kinematic information, to anticipate the tennis serve location. This translated into higher prediction accuracy for the older participants. In comparison, younger players were unaware of a service pattern and were thus more reliant on later occurring ball flight information to guide their anticipatory responses (Farrow & Reid, 2012). The ability of expert performers to use situational probability information to guide anticipatory decisions has also been displayed in non-striking sports such as with goalkeepers in European handball (Mann, Schaefers, & Cañal-Bruland, 2014), elite karate performers (Milazzo, Farrow, Ruffault, & Fournier, 2016) and skilled volleyball players (Loffing, Stern, & Hagemann, 2015). Collectively, these findings suggest that with increased experience from training and competition, skilled performers are more aware of and can utilise situational probability information from their environment to shape their anticipatory decisions (Loffing, Stern, et al., 2015). Furthermore, situational probability information may be just as important as opponent kinematics in guiding experts anticipatory decisions (Loffing, Stern, et al., 2015).

**Disguise and deception.** The use of disguise is an essential tactic in sport to reduce the amount of useful information available to observers, while the use of deception aims to mislead an observer into making incorrect judgements (Jackson,
Warren, & Abernethy, 2006). Surprisingly, there are no studies investigating the effects of disguise and deception has on the ability to anticipate in striking sports. However, there are studies in other types of sports investigating this. Causer and Williams (2015) found (using video-based temporal occlusion, with a verbal response) that soccer uniforms designed to reduce the amount of information that could be extracted from the hip region (a key source of information when anticipating soccer penalties) reduced skilled goalkeepers ability to correctly anticipate penalty kicks. Additionally, Mori and Shimada (2013) found (using video-based temporal occlusion, with a button response) that college rugby players (nine years playing experience) and novices (no playing experience) ability to correctly anticipate the directional change of a running opponent, was negatively affected if the opponent used deceptive side-steps when running. Interestingly, college player’s anticipation of non-deceptive running actions (i.e., the opponent did not use side-steps) was worse than novices. Mori and Shimada (2013) state that this may be due to a judgement bias, where experienced players are expecting the use of deception by their opponents, as this is commonplace in rugby, and thus have poorer anticipatory performance when deception is not used. Collectively, these studies indicate that the use of disguise and deception have negative effects on the ability to anticipate, and therefore research is needed to examine the extent disguise and deception affect visual anticipation in striking sports.

**Handedness.** There are considerably fewer left-handers who compete in sport, but considerably more left-handers compete at elite levels in striking sports such as cricket, baseball and tennis, suggesting left-handers have an advantage in these domains (Loffing, Sölter, Hagemann, & Strauss, 2015). Despite this apparent advantage, there have been no recent studies in striking sports investigating the effect handedness has on the ability to anticipate. However, studies in European handball and volleyball have
examined this effect. Loffing, Sölter, et al. (2015), through the use of video-based temporal occlusion, with a button response, found experienced (16 years average competitive experience) and novice (no competitive experience) European handball goalkeepers prediction accuracy was significantly worse when they were predicting shots at goal from left compared to right-handed opponents. Similar findings of poorer anticipatory accuracy by expert volleyball players when predicting the outcomes of volleyball shots from left-handed opponents were found by Loffing, Hagemann, Schorer, and Baker (2015) and Loffing, Schorer, Hagemann, and Baker (2012). Loffing, Hagemann, et al. (2015) argue that the poor performance of experienced sportspeople against left-handers may be due to reduced perceptual-familiarity with the kinematics of left-handers, and thus a reduced ability to pick-up and use visual information with the same success as when anticipating from right-handed opponents. The findings from these studies highlight the negative effect handedness has on anticipatory ability, and therefore research is needed to examine the effect handedness has on individuals anticipatory performance in striking sports.

Anticipation and real world performance. Recent research has identified that there is a relationship between visual anticipation scores from occlusion tests and real-world match performance. Müller and Fadde (2016), using video-based temporal occlusion, with a written response, found that a group of professional baseball batters (single-A minor league players in the United States) anticipation scores of pitch types from an occlusion point prior to ball release (i.e., pitchers front foot touching the ground), positively correlated with two baseball match statistics, base-on-balls and on-base percentage. Pitch types are categorised by the amount of speed and curve a pitcher places on a baseball when throwing it towards a batter (e.g., fastball: a pitch with a fast and flat trajectory; curveball: a pitch with a slower and curved trajectory; and change-
up: a pitch that has a flat trajectory but is slower than a fastball; Müller & Fadde, 2016). Base-on-balls is how often a batter refrains from swinging at four pitches which the umpire deems as outside the strike zone, while on-base percentage is how often a batter reaches first base successfully via a safe hit or base-on-balls (Müller & Fadde, 2016). This study is one of the first to identify a vital element of sports expertise (e.g., visual anticipation) is linked to measures of real world performance in striking sports (Müller & Fadde, 2016). As such, this study helps to establish predictive validity of visual anticipation tests. However, further research is required to replicate these findings, as this is the only study investigating the relationship between visual anticipation scores and match statistics.

**Individual differences.** Two recent in-situ studies have investigated whether there are differences in the movement processes within samples of highly skilled participants in striking sports and whether this affects visual anticipation performance. This is a shift from the conventional expert-novice paradigm of examining anticipatory skill, where highly skilled and less skilled performers are compared (Müller, Brenton, Dempsey, Harbaugh, & Reid, 2015). Müller, Brenton, Dempsey, et al. (2015) compared the weight transfer and bat downswing initiation and completion of eight highly skilled cricket batsmen (Australian state level) using in-situ temporal occlusion, with a movement response. Results found significant differences between participants weight transfer and bat downswing initiation as well as their bat downswing completion. Despite these differences in participant's movements, there were no significant differences in their ability to successfully anticipate and thus hit the cricket ball.

Similarly, Müller, Lalović, Dempsey, Rosalie, and Harbaugh (2014) found that a highly skilled Major League Baseball batter had significantly earlier weight transfer and bat downswing compared to skilled Australian Baseball League participants. These studies
suggest that although highly skilled performers utilise visual information earlier than novices, within highly skilled samples of striking sport performers, individuals have differing preferences of how visual-perceptual information is used to guide movement in preparation for interception of an object (Müller, Brenton, Dempsey, et al., 2015).

**Neurophysiological studies.** Recent studies have used fMRI to further identify differences in brain activation between experts and novices while anticipating actions in striking sports. Olsson and Lundström (2013) found notable differences in brain regions used by professional and novice (no playing experience) ice hockey players during action observation and decision-making. When predicting shot direction towards goal (by completing a video-based temporal occlusion task), novices had substantial activation in regions of the visual cortex and the prefrontal cortex. Alternatively, experts primarily had activation in the premotor cortex and regions of the temporal lobe (Olsson & Lundström, 2013). Olsson and Lundström (2013) argue that novice’s recruitment of the visual and prefrontal cortex while anticipating suggests novices have to actively search for visual information to help guide their anticipatory decisions. In comparison, expert’s recruitment of the premotor cortex suggests that they have stored representations of complex motor actions. This allows faster anticipation, as experts do not have to visually search to the same extent as novices to acquire useful information each time they are anticipating an action, corresponding to better anticipatory accuracy (Olsson & Lundström, 2013). Similar utilisation of motor areas by experts during visual anticipation has been found in studies of tennis (Balser et al., 2014), volleyball (Balser et al., 2014) and soccer (M. Wright, Bishop, Jackson, & Abernethy, 2013).

Additionally, Ryu, Kim, Ali, Kim, and Radlo (2015) examined (using fMRI) whether an increase in the number of possible pitches: (1) fastball; (2) fastball and curveball; and (3) fastball, curveball and slider, resulted in different neural processes in
a group of skilled baseball batters (average of eight years experience). When participants viewed one pitch (by watching a video simulation of a pitcher), areas involved in action execution were significantly activated, suggesting participants were aware of the ball type in advance, and therefore areas involved in action execution were activated when a decision was not required (Ryu et al., 2015). However, when participants were presented with two and three pitch types, areas associated with judgement and decision-making were significantly activated. As there were no significant differences in the reaction times of participants as the number of pitches increased, these findings suggest that skilled batters utilise decision-making areas of the brain to assist their anticipation of multiple baseball pitches (Ryu et al., 2015). A limitation of this study, however, is that there was no comparison group (i.e., less skilled participants), and subsequently, it is unclear whether higher activation in decision-making areas is a component of expertise in striking sports. Interestingly, a recent EEG study found expert (U.S. division one standard), compared to novice (non-players) baseball batters had higher activity within motor regions of the brain coupled with faster reaction times in visual anticipation tasks (participants had to predict the trajectory of a baseball from a video simulation of a pitcher pitching; Muraskin, Sherwin, & Sajda, 2015). As reaction time is a component of decision making, this finding suggests that expert visual anticipation may be due in part to a tight coupling between motor response and decision-making areas of the brain (Muraskin et al., 2015). Thereby, using neurophysiological measures such as fMRI and EEG, it can be inferred that the motor and decision-making regions of the brain are necessary for superior anticipation, and their utilisation may be a distinguishing element of expertise in striking sports.
Learning and Transfer Studies

There is evidence that guided perceptual training and perceptual training using imagery, are effective methods to improve anticipatory skill in striking sports (Smeeton, Hibbert, Stevenson, Cumming, & Williams, 2013). Guided perceptual training involves participants being given explicit instructions of where to focus their attention during an anticipation task, while imagery training comprises of participants imagining an action (e.g. a cricket ball being bowled) once it has occurred during an anticipation task (Smeeton et al., 2013). Smeeton et al. (2013) tested whether guided and imagery perceptual training (via video-based temporal occlusion, with a button response) could improve the anticipatory ability of skilled junior cricket batters who played in the highest junior competitions in England and Wales. Participants were assigned to three experimental conditions: (1) video replay; player was told the ball direction and received advance cue instructions then watched the delivery again, (2) imagery no replay; player told the ball direction and received advance cue instructions then imagined the delivery again, and (3) outcome no replay; player told the ball direction only. Participants in all conditions significantly improved their anticipation performance from pre-test to post-test. Interestingly, the greatest improvement in anticipation skill was for the outcome no replay group followed by the imagery no replay and video replay groups. Despite participants in the outcome no replay group being provided with no additional instructions, they reported recreating a mental image of the delivery themselves. Therefore these results suggest that recreating a mental image of an action just observed (i.e., cricket ball delivery) facilitates the pick-up of useful information in movement patterns, which are then used to improve anticipation accuracy over time (Smeeton et al., 2013). Furthermore, providing participants with minimal directional information (i.e., outcome no replay) during the anticipation task may force the
participant to actively search for task-relevant information and mentally rehearse viewed actions, which significantly strengthens their familiarity with the task (Smeeton et al., 2013). Therefore, this study provides evidence that perceptual training using imagery may be just as useful or more effective than guided training (Smeeton et al., 2013). However, as this is the only study examining the use of imagery during anticipation training in striking sports, further research is required before definitive conclusions can be made.

A recent study has also investigated the effectiveness of training visual anticipation using in-situ temporal occlusion when it is either coupled with or without an interceptive movement response (Müller & Abernethy, 2014). Participants were intermediate cricket batsmen (competing in competition below Australian state level), and were assigned to one of three training groups: (1) in-situ training without a movement response; (2) in-situ training with an interceptive movement response (i.e. hitting a cricket ball); and (3) a control group only completing regular cricket training. Results of this study found only participants in the with-movement response condition significantly improved their anticipation accuracy of pitch types on a video-based anticipation task, after the training period (Müller & Abernethy, 2014). Furthermore, on an in-situ test of anticipation post-intervention, participants in the with and with-out movement response conditions, compared to control, significantly improved their ability to use advance information from the bowler to make appropriate foot movements when vision was occluded before ball release (Müller & Abernethy, 2014). Interestingly, only participants in the with-movement condition significantly improved their ability to make desirable contact with the ball (Müller & Abernethy, 2014). These findings suggest in-situ training with and without a movement response is more effective than conventional cricket training to improve anticipatory ability. Moreover,
these findings imply that perceptual training which closely matches the natural performance context is most effective to improve anticipatory skill (e.g., in-situ temporal occlusion with a movement response; Müller & Abernethy, 2014).

There is also evidence that perceptual training can significantly improve performance within a professional setting. Fadde (2016) integrated video and in-situ occlusion tasks into a college baseball teams standard training program during the 2014 season, with the aim to improve batters pitch recognition and thus the team's batting performance. In the 2013 season, the team was below the competition average for standard batting statistics. During the 2014 season, in which perceptual training was included, the teams batting statistics were significantly higher than the competition average. Furthermore, in 2015 continued improvement was observed. In comparison, another team who were not using perceptual training methods had no significant differences in batting performance. Therefore, improvements in batting performance are believed to be due to perceptual training, and not due to usually expected team improvement year to year (Fadde, 2016). Although the findings of this study are not generalisable beyond this sample and training program, the results are critical in attracting other baseball teams to implement pitch recognition training within their usual programs. Moreover, this study provides valuable evidence that perceptual training using video and in-situ occlusion can improve aspects of performance in professional settings (Fadde, 2016).

There has been very little research in striking sports of whether performers can transfer anticipatory skill across sports that are either similar or dissimilar to domains of expertise. For example, it is relatively unknown whether expert baseball batters can perform to the same superior level in cricket (similar domain) or volleyball (dissimilar domain), as they do in baseball. There is one recent study which suggests that
anticipatory skill can transfer to similar domains (Moore & Müller, 2014). Moore and Müller (2014) examined whether an expert group of baseball players (i.e., high division professionals), could transfer their anticipation skill in baseball to a cricket anticipation task (video-based temporal occlusion, with a written response). Expert participants significantly improved their prediction accuracy during pre-ball flight conditions in the cricket task. In comparison, near expert (i.e., low division professionals) and novice (i.e., undergraduate) baseball batters did not display any significant information pick-up in any of the pre-ball flight occlusion conditions for the cricket task. The identical elements theory serves as a potential explanation for why the transfer of anticipatory skill is observed across similar domains (Rosalie & Müller, 2014). This theory stipulates that similarities in a task are key in facilitating anticipatory transfer. Therefore, as baseball and cricket are relatively similar regarding sports type (i.e., they are both interceptive striking sports which use a ball and a bat), this may allow transfer of anticipatory skill (Rosalie & Müller, 2014). Furthermore, anticipatory transfer could be a product of expert’s in-depth understanding of the fundamental movement patterns of throwing that occurs in baseball (e.g., pitcher) and cricket (e.g., bowler; Moore & Müller, 2014). Interestingly, two studies investigating anticipatory transfer in non-striking sports support the identical elements theory. Firstly, Rosalie and Müller (2014) found expert and near expert participants could anticipate as accurately as taekwondo experts in a taekwondo anticipation task. Secondly, Müller, McLaren, Appleby, and Rosalie (2015) found expert, near expert and novice rugby players could not predict baseball pitch type above chance in an anticipation task. Therefore, these two studies further suggest that anticipatory skill transfer is dependent on similarities between tasks as proposed by the identical elements theory.
These findings are in contrast to Wimshurst, Sowden, and Wright (2016). Wimshurst et al. (2016) found that despite expert hockey player’s (club to international competition level) anticipatory ability being superior to novices (non-hockey players) during a hockey anticipation task (video-based temporal occlusion, with a button response), there were no significant differences between the participants anticipatory ability during a badminton anticipation task (i.e. no skill transfer between similar domains). Intriguingly, through the use of fMRI during the task, this study found when experts were anticipating outside their expertise domain (i.e., in the badminton task), they showed higher activation than novices in areas of the brain associated with visual processing, attention and working memory. This suggests that experts may be employing different neural strategies to novices when anticipating in a task in which they have no expertise. Wimshurst et al. (2016) propose that the utilisation of these areas may allow experts to require less perceptual and motor training in a new sport to significantly increase their performance, but this is speculative, and further research is required (Wimshurst et al., 2016).

**Advancements to the Model of Expert Anticipation**

Recent research has further strengthened the notion that experts anticipatory advantage over novices is in part due to the ability to use early occurring situational information to guide anticipatory decisions as specified in the model by Müller and Abernethy (2012). Situational probability information also appears to be of equal importance to kinematic cues for expert anticipation. Furthermore, this information seems to stem from multiple sources, such as an opponent's on-court position (e.g., Loffing & Hagemann, 2014a) and the service pattern of opponents (e.g., Farrow & Reid, 2012). Additionally, neurophysiological studies highlight the efficient use of motor and decision-making regions within the brain, as discriminating factors of
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anticipatory expertise (Olsson & Lundström, 2013; Ryu et al., 2015). Therefore, along with the ability to use a wide range of kinematic and situational cues as proposed by Müller and Abernethy's (2012) model, the utilisation of motor and decision-making regions of the brain are crucial for superior visual anticipation performance.

The findings that anticipation scores on video-based temporal occlusion tests correlate to baseball match statistics further supports Müller and Abernethy's (2012) model. The results suggest that as the pitcher's kinematic information unfolds towards the point of ball release, the anticipation of pitch type based on early pre-ball flight kinematic cues is related to a decision-making statistic (i.e., base-on-balls; Müller & Fadde, 2016). Subsequently, the anticipation of pitch type based on later kinematic cues at the point of ball release is related to a bat-ball interception statistic (i.e. on-base percentage; Müller & Fadde, 2016). This is coherent with the model, which indicates that early information guides decision-making, in-turn positioning the lower body whilst later information is used to guide upper body interception. Advancements to the anticipation test used by Müller and Fadde (2016) are required, however, to make it more representative of baseball batters in-game decisions, and thus improve the tests predictive validity of performance. This could be achieved by using match footage (e.g. from a baseball game) rather than choreographed footage, which was used by Müller and Fadde (2016). A new occlusion test should also include left-handed pitchers and a prediction of pitch location, which is more representative of the information used by baseball batters in a game to complete motor skills (Müller & Fadde, 2016).

There is a lack of research in striking sports investigating the effect disguise and deception used by opponents (e.g., baseball pitcher) has on performers (e.g., baseball batter) ability to anticipate in striking sports. As research from other sports has shown, disguise and deception (e.g., Mori & Shimada, 2013) and anticipating from left-handed
opponents (e.g., Loffing, Sölter, et al., 2015) greatly reduces the ability of experts to anticipate. This leaves a gap in the knowledge of expert anticipatory skill, and thus future research is needed in this area.

The finding by Müller, Brenton, Dempsey, et al. (2015) that highly skilled cricket players have different movement patterns while anticipating actions, does not negatively affect their ability to anticipate and thus perform, has implications for Müller and Abernethy's (2012) model. This finding suggests that a uniform model of visual anticipation, and thus movement initiation, may not apply to skilled performers. Moreover, the model may need to be changed to state that the pick-up of early visual information is used to guide lower body movement initiation, rather than the positioning of the lower body (which infers movement completion; Müller, Brenton, Dempsey, et al., 2015).

A small proportion of studies within the literature have displayed that anticipatory skill can be improved through training, therefore addressing a future research direction of Müller and Abernethy (2012). The results of the study by Müller and Abernethy (2014) support Müller and Abernethy's (2012) model, as in-situ temporal occlusion training led to improvements in the ability to use advance information to guide the gross positioning of the body, which led to improvements in the quality of upper body interception of a cricket ball. The relatively small number of learning studies in striking sports, however, calls for future research to further examine the most efficacious methods to improve anticipation. The scarce number of studies investigating anticipatory skill transfer makes it difficult to draw any definitive conclusions. Therefore, there is still a gap within the striking sport literature of whether anticipatory skill can transfer. However, from the little research that has occurred, it appears that anticipatory skill in striking sports can transfer between similar domains, supporting the
identical elements theory (e.g., baseball to cricket; Moore & Müller, 2014). As with learning studies, future research should heavily investigate anticipatory skill transfer to further understand mechanisms of anticipatory skill and thus further develop Müller and Abernethy's (2012) model of expert anticipation.

Summary

The literature reviewed demonstrates that recent research has strengthened the importance of situational probability information in guiding expert’s anticipatory decisions. Moreover, motor and decision-making regions of the brain appear critical in facilitating experts to use a broad range of informational sources to guide anticipation. However, it remains unclear the effect deceptive and disguising cues, as well as handedness, have on experts anticipation in striking sports. Additionally, there has been relatively little research investigating how anticipatory skill can be learnt and whether anticipatory skill can transfer, and this should be a focus of future studies. Finally, this review has identified that measures of visual anticipation are related to real-world performance in striking sports, which are exciting findings, but warrants future research.
Chapter 2

Abstract

Professional baseball batters \((N = 105)\) visual anticipation of pitch type and location combined, pitch type and pitch location were measured using a representative video-based temporal occlusion test, and correlated with their baseball batting statistics. Participants watched in-game footage of skilled baseball pitchers that was temporally occluded at the point of ball release, and at 80ms and 200ms after ball release. Participants then made written predictions of pitch type and location. The anticipation of pitch type and location 80ms after ball release significantly correlated with slugging percentage \((r = .21)\), whereas anticipation of pitch type 200ms after ball release significantly correlated with strikeouts \((r = -.28)\). Furthermore, prediction of pitch type 200ms after ball release significantly correlated with on-base percentage \((r = .23)\) and walk-to-strikeout ratio \((r = .25)\). These findings strengthen the role visual anticipation plays in baseball batting performance and support a recent model of expert anticipatory skill by Müller and Abernethy (2012). Moreover, this study emphasises the applicability of representative video-based occlusion tests as measures of performance in professional sporting settings. Therefore the inclusion of video-based visual anticipation tests in sporting teams training programs may serve as an advantage over the competition by serving as a training tool and a guide for player recruitment.

*Keywords*: visual anticipation, performance, baseball, striking sports.
Baseball batting performance: Is visual anticipation the key to success?

Baseball is one of the most attended and popular sports in the United States and around the world (Beneventano, Berger, & Weinberg, 2012). It is, therefore, no surprise that top-tier teams strive for any competitive advantage over their opponents. Consequently, there has been an influx in the use of sports analytics, which is the use of detailed predictive statistics to answer questions in sport, such as a player’s worth to a team, and which players a team should recruit (Rees, Rakes, & Deane, 2015). A branch of sports analytics unique to baseball is sabermetrics, which uses detailed performance data rather than conventional match statistics and qualitative data (e.g., players physical attributes) to rate and predict performance (Beneventano et al., 2012). Sabremetrics surge to popularity occurred after the Oakland Athletics baseball team, depicted in the book *Moneyball* (Lewis, 2003), were able to compete with the most successful teams in American baseball, such as the New York Yankees, and in 2002, go on to set the record for the second-most consecutive wins in Major League Baseball history (Lewis, 2003). This was achieved despite one of the smallest payrolls and a team that lacked elite players (Beneventano et al., 2012). Instead of drafting expensive star players, the Oakland Athletics targeted players with limited skill sets, but who excelled in key sabermetric performance indicators and thus were cheaper to recruit (Lewis, 2003). The Oakland Athletics successful use of sabermetrics has resulted in the use of sports analytics to guide decisions, such as player recruitment, at high-performance sporting organisations (Rees et al., 2015). Despite evidence that sport analytic techniques are effective in predicting performance and useful for economic recruiting (Kornspan, 2014), it is unclear as to whether perceptual measures can be used in a similar fashion to predict match performance, guide recruitment and improve training.
Investigating the perceptual skills of elite athletes who participate in striking sports such as baseball, may answer this question (Van Der Kamp et al., 2008). Striking sports require the athlete to intercept an object, often a ball, with high degrees of precision (Van Der Kamp et al., 2008). Achieving this action is difficult as the time taken for the ball to travel from the opponent to the performer (~500ms) is shorter than the time needed to react and move to intercept the object (~900ms; Williams et al., 2011). Additional constraints include deceptive visual cues used by the opposition, the spatial uncertainty of ball flight and minimal tolerance rules where errors in performance lead to immediate exclusion from the game (Müller & Abernethy, 2012). The ability of expert athletes to consistently perform under these constraints and to do so with such precision has led to the notion that information before ball flight, rather than the sole reliance on ball flight information, is critical for successful performance in these sports (Van Der Kamp et al., 2008). Therefore a component of perception, visual anticipation, which is the ability to make accurate predictions from incomplete sources of visual stimuli, has become a focal point of investigating expertise in striking sports (Van Der Kamp et al., 2008).

The expert-novice paradigm, where groups of experts and novices visual anticipation abilities are compared, is a predominant method in studying visual anticipation (Müller & Fadde, 2016). Expertise in sport is categorised as the level of competition reached by a performer in a given sport (Panchuk & Vickers, 2009). Video-based temporal occlusion is a commonly used methodology to investigate visual anticipation (Müller & Fadde, 2016). The opponent is filmed from the performers perspective while they carry out various play actions, such as pitching a baseball (Müller & Fadde, 2016). These videos are then occluded with blank displays at different points of key kinematic events, such as the moment of ball release. Participants are then
required to indicate the outcome of the viewed play by a button or written response (Mori & Shimada, 2013). Temporal occlusion is useful as it allows the determination of the timing of information pick-up (Williams et al., 2011). Results of temporal occlusion studies have consistently shown that experts are superior to novices in using visual information before ball flight to successfully predict the future location of objects (Loffing & Hagemann, 2014b; Müller & Abernethy, 2012). Unlike experts, novices rely more heavily on object flight information after object release, resulting in a rushed reaction, and therefore less accurate interceptive performance (Müller & Abernethy, 2012).

These findings in striking sports converge on the notion that expert anticipation is linked to the acquisition of essential kinematics of the action being viewed (Müller & Abernethy, 2012). Based on these findings, Müller and Abernethy (2012) proposed a model of expert anticipation explaining why experts have such superior performance in striking sports. In the process of intercepting a moving object, such as a baseball, experts are capable of acquiring perceptual information before and during the opponent's pre-contact movement pattern. This early information is then used to guide global positioning of the body. Later object flight is then used to fine-tune interception movements (Müller & Abernethy, 2012). In comparison, novices acquire information cues to guide body positioning and interception much later. This results in less time to respond and thus inferior task performance (Müller & Abernethy, 2012). Therefore, this model proposes that expert anticipation is not a product of information reduction, but rather the ability to use different, additional and earlier occurring sources of information to guide action (Müller & Abernethy, 2012).

More pertinent to the question of whether perceptual skill can be used in a similar fashion to sabermetrics in predicting performance, Müller and Fadde (2016)
used video-based temporal occlusion to see if professional baseball batters (single-A minor league) could anticipate three pitch types above guessing level based upon vision occluded prior to pitch release, and subsequently whether there is a relationship between these anticipation scores and their match statistics. The pitch types were fastballs (a pitch that is fast with a flat trajectory), curveballs (a slower pitch with a curved trajectory) and change-ups (a pitch with a slower speed than a fastball). Results found a significant positive correlation between the anticipation scores at the occlusion point of the pitcher's front foot touching the ground during the pitching motion (i.e., before ball release) and base-on-balls (how often a batter resists from hitting balls outside the strike zone) batting statistic. Furthermore, there was a significant positive correlation between the ability to predict a fastball/change-up at the point of ball release with base-on-balls and on-base percentage (how often a batter reaches first base successfully) statistics. This type of study is not unprecedented, as Gabbett, Jenkins, and Abernethy (2011) investigated relationships between laboratory measures and match statistics. Using rugby league as the sport, participant’s scores on recognition and memory tests correlated with some rugby match statistics. The findings of these studies are significant as they highlight the importance of perception and memory for performance in rugby and visual anticipation for performance in baseball. Furthermore, the study by Müller and Fadde (2016) helps in establishing the predictive validity of laboratory-based measures of visual anticipation. Moreover, investigating the link between visual anticipation and match statistics is imperative for applied sports psychologists to build a body of evidence that can be used to convince sporting organisations of the significant role visual anticipation plays in match performance (Müller & Fadde, 2016). To this end, it opens the possibility of visual anticipation to be used as a measure of potential performance to guide player recruitment and drafting decisions (Müller & Fadde, 2016).
Despite these benefits, there are limitations with the occlusion test used in the study by Müller and Fadde (2016), which restrict its ecological validity. Firstly, the test included one right-handed pitcher who was instructed to throw certain types of pitches, which is not representative of a real baseball match. Secondly, the test only included a prediction of pitch type and not a prediction of pitch location (the end location of a baseball that has been pitched relative to a batter), which is also a significant element of baseball batting (Müller & Fadde, 2016).

A recent study by Müller, Fadde, and Harbaugh (in press) developed a new video-based occlusion task which is more representative of the visual information a baseball batter would use in a game, to test whether professional baseball batters could adapt their anticipatory skill across different opponents. The new occlusion task included multiple right and left-handed baseball pitchers (who were filmed during a baseball game) and included predictions of pitch type as well as pitch location. Investigating the anticipatory ability of expert performers against left and right-handed opponents is imperative, as baseball batters can compete against pitchers with different handedness within a game (Müller et al., in press). Moreover, predictions of pitch type and pitch location are more representative of the required anticipatory skill of baseball batters within a game (Müller et al., in press). The results from this study found participants could anticipate pitch type and pitch location above chance when predicting from right and left-handed pitchers. Interestingly, participant’s ability to correctly anticipate pitch type and pitch location declined when they were predicting from left-handed opponents, but anticipation was still above chance level. As participants were able to use the visual information presented in the new occlusion task to anticipate above chance, the results validate this new representative occlusion test as a viable
measure of visual anticipation ability in baseball. Furthermore, this new task has
addressed the limitations of the anticipation test used in Müller and Fadde (2016).

Therefore, the purpose of the present study is to advance the work of Müller and
Fadde (2016) by using visual anticipation scores from the new representative occlusion
test developed and used in Muller et al. (in press), to replicate relationships between
visual anticipation scores and match statistics (Appendix A). Based on the literature,
and findings from Müller and Fadde (2016), it was hypothesised that there would be
significant relationships between visual anticipation scores of skilled baseball batters in
the occluded conditions and some of their batting match statistics.

**Method**

**Participants**

A sub-sample of 105 professional baseball batters (age: $M = 23$, $SD = 2.36$) from
Muller et al. (in press) were used as participants in this study. All participants had at
least 100 plate appearances ($M = 349.55$, $SD = 132.20$), which refers to the number of
times they have batted in competition (Müller & Fadde, 2016). 100 plate appearances
was set as the minimum number for inclusion in the study as this is an acceptable
standard to evaluate batting performance (Classé et al., 1997). Ethics approval was
provided by the Murdoch University ethics committee (2013/216; Appendices B and
C), and participants provided written informed consent once they acknowledged their
understanding of the research (Appendices D and E). A written summary of the project
has also been provided (Appendix F).

**Materials**

Participants visual anticipation scores were taken from Müller et al. (in press). In
Müller et al. (in press) study, multiple left and right-handed pitchers, who played at
minor league baseball level in the United States, were filmed during a baseball game. A
standard camera filming at 25 frames per second was placed behind the grandstand. The camera was adjusted to focus on the pitcher, but also included the batter and umpire in the foreground to provide a reference point to the strike zone, as the anticipation task required the prediction of pitch type and pitch location. Multiple pitches from each pitcher were filmed to provide adequate pitch type and pitch locations for the later creation of the temporal occlusion test. Pitches that were deemed representative of those thrown in Major League Baseball by an expert baseball coach were included and the footage was then edited to show varying amounts of visual information (Müller et al., in press). The resulting occlusion test consisted of a 48 trial matrix for each right and left-handed pitcher, consisting of 3 pitch types x 2 pitch locations x 4 temporal occlusion conditions x 2 filmed versions of the pitch. The pitch types were (a) fastball: a pitch that is fast with a flat trajectory; (b) curveball: a pitch that is slower than a fastball with a downward curve; and (c) change-up: a pitch that has a flat trajectory but slower than a fastball (Muller et al., in press). Pitch locations were either inside or outside the strike zone. Temporal occlusion was applied at the point of ball release (R), 80ms after ball release (R + 2), and 200ms after ball release (R + 5). A no occlusion control condition (NOC) was also included where full ball flight and pitcher action was available to the participants (Müller et al., in press).

Participant's 2015 season baseball batting statistics judged as standard measures of batting performance by Müller and Fadde (2016) were collected from two baseball websites, www.baseballreference.com and www.MiLB.com. The six batting statistics collected were, batting average (number of safe hits per times at the batting plate), slugging percentage (how powerfully a batter hits the ball in terms of bases achieved relative to safe hits), base-on-balls (how often a batter refrains from swinging at four pitches which the umpire deems as outside the strike zone), on-base percentage (how
often a batter reaches first base successfully via a safe hit or base-on-balls), strikeouts (how often a batter accrues three strikes by either making an incorrect decision not to swing or swinging and missing) and walk-to-strikeout ratio (a batter’s ability to refrain from swinging at a bad pitch and recognise pitches that are inside the strikezone; Müller & Fadde, 2016). Participant’s plate appearances were also collected.

**Procedure**

The procedure used to obtain participants visual anticipation scores are those reported in Müller et al. (in press). The pitching footage was projected onto a video screen (1.78m x 1.38m) in a conference room. Participants were instructed to watch the footage and at the completion of each trial specify their prediction by ticking a box in an answer booklet. The six selection options were fastball strike, fastball ball, curveball strike, curveball ball, change-up strike or change-up ball. Participants had to make their prediction in the five-second break between each clip.

The website used to collect the batting statistics depended on the availability of the required statistic for each participant. Participants batting statistics were acquired by searching their name in the website’s search engine. If participants did not have batting statistics for the 2015 season due to injury or being released from the team, their 2014 season statistics were acquired. Participants averaged batting statistics for the playing season were collected.

**Data Analysis**

Visual anticipation scores for overall prediction accuracy for pitch type and location combined, overall prediction of pitch type and overall prediction of pitch location, were used. Participant’s prediction for left and right handed pitchers were combined and averaged, as baseball batters are likely to face pitchers with different
handedness within a game situation, thus increasing the representativeness of the anticipation scores (Müller et al., in press).

Assumptions of normality, linearity and homoscedasticity were checked and met as specified by Field (2013). One-sample t tests were used to identify whether prediction was above, at or below the guessing level of 16.66% for combined pitch type and location prediction, 33.33% for pitch type prediction and 50% for pitch location prediction. This test was run to determine whether participants could use the available visual information at each occlusion condition to anticipate above guessing level. Pearson’s bivariate product-moment correlation coefficient’s (r) were run between participant’s anticipation scores and the aforementioned batting statistics. No adjustments were made to the alpha level (α = .05), as corrections such as Bonferroni can be conservative (Bland & Altman, 1995).

Results

Figure 1 graphs the overall prediction accuracy for pitch type and location combined, as well as pitch type and pitch location, relative to temporal occlusion conditions. For pitch type and location correct, one-sample t tests indicated prediction of participants was significantly above the guessing level of 16.66% across R, t(104) = 9.90, p < .001; R + 2, t(104) = 11.52, p < .001; R + 5, t(104) = 19.12, p < .001; and NOC t(104) = 31.69, p < .001 conditions. One-sample t tests also indicated prediction accuracy was significantly above the guessing level of 33.33% for pitch type correct across R, t(104) = 19.78, p < .001; R + 2, t(104) = 24.90, p < .001; R + 5, t(104) = 27.98, p < .001; and NOC, t(104) = 33.00, p < .001 conditions. One-sample t tests indicated prediction was significantly above the guessing level of 50% for pitch location correct for R + 5, t(104) = 6.66, p < .001; and NOC, t(104) = 24.75, p < .001, but at guessing level for R, t(104) = -1.50, p = .137; and below guessing level for R + 2, t(104)
= -2.71, \( p = .008 \) occlusion conditions. The descriptive statistics for each of the six baseball batting statistics are presented in Table 1.

*Figure 1. Overall mean prediction accuracy for pitch type + location, pitch type and pitch location, relative to temporal occlusion condition. R = point of ball release; R + 2 = 80ms after ball release; R + 5 = 200ms after ball release; NOC = no occlusion. Error bars indicate standard error of the mean. Asterisks indicate whether anticipation was above guessing level.*
Table 1

Descriptive Statistics for Baseball Batting Statistics

<table>
<thead>
<tr>
<th>Batting Statistic</th>
<th>M</th>
<th>(SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Batting average</td>
<td>.259</td>
<td>(.032)</td>
</tr>
<tr>
<td>On-base percentage</td>
<td>.324</td>
<td>(.038)</td>
</tr>
<tr>
<td>Slugging percentage</td>
<td>.371</td>
<td>(.064)</td>
</tr>
<tr>
<td>Base-on-balls</td>
<td>.078</td>
<td>(.031)</td>
</tr>
<tr>
<td>Strikeouts</td>
<td>.193</td>
<td>(.058)</td>
</tr>
<tr>
<td>Walk-to-strikeout ratio (BB/K)</td>
<td>.446</td>
<td>(.222)</td>
</tr>
</tbody>
</table>

Note. *M* = mean; *SD* = standard deviation of the mean.

Effect sizes for Pearson’s correlations were classified as small (*r* = .10), medium (*r* = .30), or large (*r* = .50) as specified by Field (2013). Pearson correlations indicated a significant small positive relationship between pitch type and location correct at R + 2 and slugging percentage, *r*(103) = .21, *p* = .032. Furthermore, there were significant small positive correlations between pitch type correct at R + 5 and on-base percentage, *r*(103) = .23, *p* = .016 and walk-to-strikeout ratio, *r*(103) = .25, *p* = .011. Finally, there was a significant small negative correlation between pitch type correct at R + 5 and strikeouts, *r*(103) = -.28, *p* = .003. Although there was a significant small positive correlation between pitch location correct at R + 2 and slugging percentage, *r*(103) = .19, *p* = .047, participants at this occlusion condition did not predict above guessing level. There were no other significant correlations between occlusion points and batting statistics (see Table 2). Despite no significant correlations between above chance prediction of pitch location at occlusion conditions and batting statistics, there were significant small positive correlations between predictions of pitch location at NOC and
on-base percentage, \( r(103) = .24, p = .013 \), base-on-balls, \( r(103) = .21, p = .032 \), and walk-to-strikeout ratio, \( r(103) = .20, p = .044 \). Figure 2 depicts scatterplots for the significant correlations between prediction accuracy at occlusion points and batting statistics.
Table 2

Correlations for each temporal occlusion condition between baseball batting statistics for combined pitchers for pitch type and location (PT+L), pitch type (PT) and pitch location (PL)

<table>
<thead>
<tr>
<th>Batting Statistic</th>
<th>Prediction Type and Temporal Occlusion Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVG</td>
<td>PT+L, R</td>
</tr>
<tr>
<td></td>
<td>.04</td>
</tr>
<tr>
<td>OBP</td>
<td>.06</td>
</tr>
<tr>
<td>SLG</td>
<td>-.02</td>
</tr>
<tr>
<td>BB</td>
<td>.08</td>
</tr>
<tr>
<td>SO</td>
<td>.01</td>
</tr>
<tr>
<td>BB/SO</td>
<td>.09</td>
</tr>
</tbody>
</table>

Note. R = occlusion at ball release; R + 2 = occlusion 80ms after ball release; R + 5 = occlusion 200ms after ball release; AVG = batting average; OBP = on-base percentage; SLG = slugging percentage; BB = base-on-balls (walks); SO = strikeouts; BB/SO = walk-to-strikeout ratio; PT+L = pitch type + location; PT = pitch type; PL = pitch location.  
*p < .05. ** p < .01.
(a) Scatter plot showing the relationship between Prediction Accuracy and Slugging Percentage.

(b) Scatter plot showing the relationship between Prediction Accuracy and On Base Percentage.
Figure 2. Scatterplots for (a) prediction accuracy for pitch type + location at R + 2 occlusion condition and slugging percentage, (b) prediction accuracy for pitch type at R + 5 occlusion condition and on-base percentage, (c) prediction accuracy for pitch type at R + 5 occlusion condition and walk-to-strikeout ratio, (d) prediction accuracy for pitch type at R + 5 occlusion condition and strikeouts, and (e) prediction accuracy for pitch location at R + 2 occlusion condition and slugging percentage.
Discussion

The purpose of this study was to extend findings of a relationship between visual anticipation and match performance, using a newly constructed, representative video-based temporal occlusion test within the exemplar striking sport of baseball. Furthermore, this study aimed to extend the understanding of anticipation relative to a recent model of anticipation in striking sports. The results supported the hypothesis that visual anticipation scores would significantly correlate with some baseball batting statistics.

One-sample t tests indicated that participants were able to predict combined pitch type and location as well as pitch type above the guessing levels of 16.66% and 33.33% respectively, in all temporal occlusion conditions. Alternatively, participants were only able to predict pitch location above the guessing level of 50% in the R + 5 and NOC occlusion conditions. These findings reveal a highly skilled sample of participants could use advance and ball flight information provided by the representative video occlusion test for above chance anticipation. This indicates that any significant correlations at these occlusion points are meaningful as anticipation scores were not due to chance. Furthermore, the constraints included in this test (i.e., left and right-handed pitchers) that are representative of what a batter would face in a game situation when predicting pitch type and location, did not impede their ability to anticipate (Müller et al., in press). The finding that participants could not predict pitch location from before (R) and early (R + 2) ball flight conditions is expected, as the prediction of pitch location is dependent on mid to late ball flight information (Paull & Glencross, 1997). This is consistent with Paull and Glencross (1997) which show expert baseball batters prediction of a baseball's end trajectory was reliant on mid to late ball flight information and improved progressively from 80 to 240ms after the point of ball
release. Hence, as pitch location predictions were above chance at R + 5 and NOC conditions in the present study, this further supports that anticipation of pitch location is reliant on later rather than early ball flight information.

Pearson correlations revealed that correct anticipation of pitch type and location at R + 2 positively correlated with slugging percentage. This finding implies that as correct prediction of pitch type and location combined at R + 2 increases, so does slugging percentage. In the context of baseball, this finding highlights the importance of advance cues and early ball flight information to judge the power needed to hit a baseball in order to successfully reach bases. Furthermore, correct anticipation of pitch type at R + 5 negatively correlated with strikeouts, indicating that as the correct anticipation of pitch type at R + 5 increases, the amount of strikeouts decreases. This finding is important in the context of baseball, as it suggests that up-to mid ball flight information is significant in informing a batter of whether a baseball should be hit, as well as reducing the times a batter misses a baseball. Finally, correct anticipation of pitch type at R + 5 positively correlated with on-base percentage and walk-to-strikeout ratio statistics. These findings infer that as the ability to correctly anticipate pitch type at R + 5 increases so do on-base percentage and walk-to-strikeout ratio statistics.

Moreover, this suggests that up to mid ball flight information is critical for batters decisions to reach first base successfully (on-base percentage), and refraining from hitting at bad pitches, while recognising pitches that are within the strike zone (walk-to-strikeout ratio).

In comparison to Müller and Fadde (2016), there were no significant correlations between anticipation scores at R occlusion conditions and batting statistics. The correlations in the present study were also weaker compared to Müller and Fadde (2016). A possible explanation may be the representative nature of the anticipation test
used. As this test used match footage of highly skilled pitchers trying to get batters out
in a real game of baseball, it is probable that the pitchers were employing disguising
cues (i.e., certain position of the fingers on the baseball) while pitching (Müller et al., in
press). The use of disguises by opponents in tennis have been found to successfully
delay the time an opponent can start anticipating actions, as they limit the amount of
information that can be used to anticipate (Rowe, Horswill, Kronvall-Parkinson,
Poulter, & McKenna, 2009). Additionally, the inclusion of left-handed opponents in the
new anticipation test may be another explanation, as left-handers are harder to anticipate
against (Loffing et al., 2012). This left-handedness effect is most evident when
anticipatory decision are made based on early kinematic information (Loffing,
Hagemann, et al., 2015). Therefore, the weaker correlations at later occlusion points in
the present study may be due to the difficulty of the new anticipation test as it is more
representative of what a batter would encounter in a match. The significant correlations
at later occlusion points (i.e. R + 5) may also be due to the inclusion of curveballs as
one of the pitch types. Due to the late occurring curve, the trajectories of these pitches
have substantial spatial uncertainty in the early phases of ball flight. It is only in late
ball flight where the end trajectory of the pitch becomes clear (Paull & Glencross,
1997). Therefore, participants in the present study may have been waiting for later ball
flight information to guide their anticipatory decisions, which may explain the
significant correlations at later occlusion conditions.

The relationships found between anticipation scores and batting statistics
strengthens the role early information plays in expert anticipation, as outlined in Müller
and Abernethy's (2012) model. Collectively, the findings of this study suggest that as
the pitching action unfolds over time, anticipation of pitch type and location based on
kinematic and early ball flight information is related to the interceptive statistic,
slugging percentage. Additionally, the anticipation of pitch type based on later ball flight is related to the decision-making statistics, on-base percentage, strikeouts and walk-to-strikeout ratio. These findings are coherent with Müller and Abernethy's (2012) model which states that early information guides the positioning of the body for interception, and later information is used to fine-tune responses. Hence, as an interceptive statistic correlated with earlier occlusion conditions, and decision-making statistics correlated with later occlusion conditions, these findings are supported by this model.

A main limitation of the current study is the lack of significant correlations between above chance predictions of pitch location and batting statistics. A possible explanation is the time needed for batters to anticipate pitch location against skilled pitchers may be longer than the time given in the occlusion conditions. Paull and Glencross (1997) state the time for a pitch to travel from the pitcher's hand to the strike zone is approximately 500ms, while batters are required to complete cognitive operations in approximately 260ms from the moment of ball release. Therefore, as there were significant correlations between some batting statistics and pitch location at NOC conditions, it may be that an occlusion condition just after 200ms would have resulted in significant correlations. Future research should include a later occlusion point to see if this is the case. Another limitation is that correlations between anticipation and batting statistics do not ascertain cause-and-effect. However, the findings of this study coupled with the findings from Müller and Fadde (2016) strengthen the importance of anticipation for baseball batting performance. Moreover, the results further support the validity of the representative video-based anticipation test developed by Müller et al. (in press). This is due to the test including visual information that a baseball batter would view in match situations and subsequently the anticipation scores significantly
correlated with measures of batting performance. Therefore, this study further highlights the applicability of video-based anticipation tests as accessible and easily transportable instruments that may be used to test, train and recruit athletes in striking sports. Finally, this study highlights the potential for perceptual measures, such as visual anticipation, to be used to the same degree and success as sabermetrics in predicting performance in baseball.

**Conclusions**

The findings of this study confirm the potential of video-based temporal occlusion to measure visual anticipation and predict baseball batting performance, as identified by Müller and Fadde (2016). Furthermore, this study demonstrates anticipation scores on a newly constructed representative occlusion test correlated with interceptive and decision-making statistics, which are key indicators of baseball batting performance. Future research should include a later occlusion point after 200ms of ball flight, which may reveal relationships between the anticipation of pitch location and batting statistics, thus strengthening the results of this study. Taken together, this study has reinforced the relationship between perceptual measures and performance in professional baseball.
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VISUAL ANTICIPATION IN STRIKING SPORTS


Appendix A

Readers Note

The work of this thesis is part of a broader project, and a subset of data used in the present study was taken from Muller et al. (in press), which is in the process of being published. All forthcoming appendices correspond to this broader research project.
Appendix B

Ethics Approval Form

Friday, 21 February 2014

Dr Sean Muller
School of Psychology and Exercise Science
Murdoch University

Dear Sean,

Project No. 2013/216
Project Title Anticipation and Transfer in Professional Baseball Batting

Thank you for addressing the conditions placed on the above application to the Murdoch University Human Research Ethics Sub-Committee. On behalf of the Sub-Committee, I am pleased to advise the application now has:

OUTRIGHT APPROVAL

Approval is granted on the understanding that research will be conducted according to the standards of the National Statement on Ethical Conduct in Human Research (2007), the Australian Code for the Responsible Conduct of Research (2007) and Murdoch University policies at all times. You must also abide by the Human Research Ethics Committee's standard conditions of approval (see attached). All reporting forms are available on the Research Ethics website.

I wish you every success for your research.

Please quote your ethics project number in all correspondence.

Kind Regards,

[Signature]

Dr. Erich von Dietze
Manager of Research Ethics

cc: Dr Peter Fadda and Michael Horley
Human Research Ethics Committee: Standard Conditions of Approval

a) The project must be conducted in accordance with the approved application, including any conditions and amendments that have been approved. You must comply with all of the conditions imposed by the HREC, and any subsequent conditions that the HREC may require.

b) You must report immediately anything which might affect ethical acceptance of your project, including:
   - Adverse effects on participants
   - Significant unforeseen events
   - Other matters that might affect continued ethical acceptability of the project.

c) Where approval has been given pending copies of documents such as letters of support / consent from other organisations or approvals from third parties, these must be provided to the Research Ethics Office before the research may commence at each relevant location.

d) Proposed changes or amendments to the research must be applied for, using an Amendment Application form, and approved by the HREC before these may be implemented.

e) An annual Report must be provided by the due date specified each year (usually the anniversary of approval) for the project to have continuing approval.

f) A closure report must be provided at the conclusion of the project.

g) If, for any reason, the project does not proceed or is discontinued, you must advise the committee in writing, using a Closure Report form.

h) If an extension is required beyond the approved end date of the project, an extension application should be made allowing sufficient time for its consideration by the committee. Extensions cannot be granted retrospectively.

i) You must advise the HREC immediately in writing, if any complaint is made about the conduct of the project.

j) Any equipment used must meet current safety standards. Purpose built equipment must be tested and certified by independent experts for compliance with safety standards.

k) Higher degree students must have both Candidacy and Program of Study approved prior to commencing data collection.

l) You must notify the Research Ethics Office of any changes in contact details including address, phone number and email address.

m) The HREC may conduct random audits and/or require additional reports concerning the research project.

Failure to comply with the National Statement on Ethical Conduct in Human Research (2007) and with the conditions of approval may result in the suspension or withdrawal of approval for the project.

The HREC seeks to support researchers in achieving strong results and positive outcomes.

The HREC promotes a research culture in which ethics is considered and discussed at all stages of the research.

If you have any issues you wish to raise, please contact the Research Ethics Office in the first instance.
Appendix C

Ethics Annual Renewal Receipt

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Annual Project Report
Human Research Ethics Committee

It is a condition of HREC approval that Researchers provide an annual report for each project. Murdoch University includes a summary of this information in its annual report to Canberra in order to maintain national ethics accreditation.
- Projects are approved by the HREC for a period of four years from the original date of approval.
- For a project to remain open and active after the set expiry date, an application for extension, with appropriate justification, is required.
- Projects approved prior to August 2007 will not be extended and must be submitted as a new revised application. Projects which have previously received an extension (i.e. have been active for 4 or more years) will usually not receive further extension and must be submitted as a new revised application.

1. Project Details
1.1 Project Number: 2013/216
1.2 Project Title: Anticipation and Transfer in Professional Baseball Batting
1.3 Chief Investigator / Supervisor: Dr. Sean Muller

1.4 Are there any changes to the investigating team? Yes ☒ No ☐
If yes, please give details. (If there are changes to the protocol or the ethical issues a separate Amendment Form must be submitted).
(i) Chief Investigator / Supervisor:
Address:
Telephone:
Email:

(ii) Co-Investigator(s):
Address:
Telephone:
Email:

(iii) Student Researcher:
Mr. Khaya Binelli
Address:
Telephone:
Email: k.binelli@hotmail.com

2. Renewal or Extension
2.1 Indicate which of the following is being requested (choose one only):
☒ Renewal of project from years 1 to 4.
☐ Extension of project beyond the 4th year (please note a new application may be required)

2.2 Estimated end date of project (month, year):
September 2017

3. Report on Research to Date
3.1 Have you encountered any problems relating to ethical issues? Yes ☐ No ☒
If yes, what were the problems and what did you do to resolve them? (Attach additional information or reports as necessary)
3.2 Did any participant experience an unexpected or adverse consequence resulting from this research? Yes ☐ No ☒
If yes, was this reported through an Adverse Events Form? Yes ☐ No ☐
If this was not reported at the time, provide an explanation of the event(s), what was done to remedy any adverse effects on participants, and why this was not reported at the time it occurred.

3.3 Did any participant initiate any kind of complaint about the research? Yes ☐ No ☒
If yes, outline the substance of the complaint(s) and specify what was done to address this.

3.4 Did you comply with approved consent procedures and documentation? Yes ☒ No ☐
If no, please explain why you did not comply with consent procedures and documentation. (Attach additional information or reports as necessary)

3.5 Did you comply with the standard conditions? Yes ☒ No ☐
If no, please explain why you did not comply with the conditions of your permit. (Attach additional information or reports as necessary)

3.6 Did you comply with any other special conditions? N/A ☒ Yes ☐ No ☐
If no, please explain why you did not comply with the conditions of your permit. (Attach additional information or reports as necessary)

3.7 Have you published any of the research findings related to this project? Yes ☒ No ☐
If yes, please provide publication details:

4. Declaration
When completing this form, typing your name in the Signature text box will constitute an electronic signature if sent from a Murdoch email address or from one of the email addresses listed on the approved application.

4.1 Chief Investigator / Supervisor:
I continue to accept the legal and ethical responsibilities associated with this research project.

<table>
<thead>
<tr>
<th>Name:</th>
<th>Dr. Sean Muller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date:</td>
<td>5/03/2016</td>
</tr>
<tr>
<td>Signature:</td>
<td>[Signature]</td>
</tr>
</tbody>
</table>

4.2 Student Researcher:
I confirm that my role in this project will continue to be carried out ethically in the context of the currently approved project.

<table>
<thead>
<tr>
<th>Name:</th>
<th>Mr. Khaya Binelli</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date:</td>
<td>9/03/2016</td>
</tr>
<tr>
<td>Signature:</td>
<td>[Signature]</td>
</tr>
</tbody>
</table>

5. Submission:
Email an electronically signed or scanned copy of the form to human.ethics@murdoch.edu.au. Alternately, print and sign the form and mail to Research Ethics & Integrity.
Appendix D

Participant Information Letter

Anticipation and Transfer in Professional Baseball Batting

Dear Participant,

You are invited to participate in an experiment investigating anticipation and transfer skill in baseball batting being conducted through a joint association between the School Psychology and Exercise Science, Murdoch University, Southern Illinois University, USA and Tampa Bay Rays Major League Baseball organisations. Dr. Sean Müller (Murdoch University, Principal Investigator), Associate Professor Peter Fedde (Southern Illinois University, Co-Investigator) and Mr. Michael Horley (Murdoch University, Honours Student) are the researchers conducting the project. This information sheet describes the project: Please read this sheet carefully and be confident that you understand its contents before deciding whether to participate. If you have any questions about the project, please ask the principal investigator or Peter Fedde.

The purpose of this experiment is to gather information about when baseball batters pick-up visual cues from a pitcher's action to anticipate pitch type, and then, determine whether baseball batters can transfer this pitch recognition ability against different pitchers. In addition, the purpose is to understand how pitch prediction is linked to batting statistics. Participants will be asked to provide the following personal details: age, date of birth, type of batsman, years of participation in competition, current level of participation and name of association, team or club of current participation for descriptive purposes. Participants will also be asked to consent to their season batting statistics being used in this experiment. During publication of results, none of the personal information will be used to identify individuals, but will be reported to describe groups of participants.

The experiment will include two phases, with both phases completed at Tampa Bay Rays Training Facility in Port Charlotte, Florida, USA. In phase one, you will be asked to watch a series of video clips of a baseball pitcher throwing different pitches. The video clips will be stopped or blocked out at different points in the pitcher's action. After the clips are stopped you will be asked to pick the type of pitch you anticipate will be thrown in an answer booklet, that is, a fastball, curveball or changeup. You will view 48 video clips of different pitches, which will take approximately 10 minutes. After a short break, you will be asked to watch a series of video clips of two different pitcher's actions separately. Again, the video clips will be stopped or blocked out at different points in the pitchers action and after they are blocked out you will be asked to tick in an answer booklet as to which pitch type you anticipate (fastball, changeup or curveball). You will view 48 video clips of different pitches, which will take approximately 20 minutes to complete.

In phase two, some participants will be invited to perform a test in the field whilst watching a live pitcher (this will likely take place in 2015, not 2014 – date and time to be confirmed). A right arm pitcher will also be invited to participate in this field test. The pitcher will be required to throw three different pitch types like the ones in the video test. The batters will wear a pair of special glasses that will be used to block their vision out just before the pitcher releases the ball. Once the batters vision is occluded they will be required to say verbally what type of pitch was thrown. Batters will stand near home plate and behind a mesh screen to protect them from the ball. There will be approximately 24 trials in this test taking about 30 minutes to complete. This field test will be scheduled at a different time to the video test mentioned above.
The potential benefit to you as a participant in this study is that you will be involved in an internationally recognised topic to further knowledge of science in baseball batting and sports science. The potential benefit to baseball is that this research will provide information on how to coach batsmen.

This study has been approved by the Murdoch University Human Research Ethics Committee (Approval xxxx/xxx). If you have any reservation or complaint about the ethical conduct of this research, and wish to talk with an independent person, you may contact Murdoch University’s Research Ethics Office (Tel: 08 9380 6877 for overseas studies, +61 8 9380 6877) or e-mail ethics@murdoch.edu.au. Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.

If you are interested in participating or have any questions regarding this study please contact the co-investigator Associate Professor Peter Fadde on (618) 453-4019 or email: fadde@uwa.edu.

Looking forward to your involvement in progressing the knowledge of science in baseball batting and sport.

Sincerely

Dr. Sean Müller on behalf of the research team.
Appendix E

Project Consent Form

Anticipation and Transfer in Professional Baseball Batting

1. I agree voluntarily to take part in this study.

2. I have read the Information Sheet provided and been given a full explanation of the purpose of this study, of the procedures involved and of what is expected of me. The researcher has answered all my questions and has explained the possible problems that may arise as a result of my participation in this study.

3. I understand I am free to withdraw from the study at any time without needing to give any reason.

4. I understand I will not be identified in any publication arising out of this study.

5. I understand that my name and identity will be stored separately from the data, and these are accessible only to the investigators. All data provided by me will be analysed anonymously using code numbers.

6. I agree for my batting statistics to be released to the researchers.

7. I understand that all information provided by me is treated as confidential and will not be released by the researcher to a third party unless required to do so by law.

Signature of Participant: ___________________________ Date: ______/_____/______
(Name)

Signature of Investigator: ___________________________ Date: ______/_____/______
(Name)
Appendix F

Project Summary

Summary

Expertise in striking sports: The importance of visual anticipation for superior performance

Ethics Project Number: 2013/216
Researcher: Khaya Morris-Binelli
Supervisor: Dr. Sean Müller
Co-supervisors: Prof. Peter Fadde and Assoc. Prof. Corinne Reid
Research Completed: October 2016

Context and Research Aims:

Expert performers in striking sports such as baseball have a superior capability to less skilled performers to use early visual information from an opponent’s action and early ball flight information to anticipate the outcome of an action. These actions could be the type of pitch a pitcher is throwing in baseball or the type of bowl thrown by a cricket bowler. Therefore, superior visual anticipation, which is the ability to use incomplete pieces of visual information to predict the outcome of an action, is believed to be a key component of expertise in striking sports.

In striking sports such as baseball, visual anticipation is typically measured using a video-based simulation test where a pitcher’s action and ball flight is filmed and then edited (i.e., occluded) at certain points. The striking sport performer is then required to make a written or verbal prediction of a pitch’s type (e.g., a fastball in baseball). Despite extensive research showing visual anticipation is crucial for successful performance in striking sports, little is known as to whether visual anticipation scores from video-based simulation tests correlate to real-world game statistics. Recently, Müller and Fadde (2016) tested the visual anticipation skill of a sample of professional baseball batters in the United States of America. Their study found that the participant’s anticipation scores of pitch type correlated with certain baseball batting game statistics (such as a batter's batting average). The anticipation test used in this study has been advanced to include both pitch type and pitch location (e.g., inside the strike zone) predictions, which is more representative of what a baseball batter needs to do within a game to successfully perform. The aim of the current study was to take the visual anticipation scores from this new anticipation test, which had been tested on 105 professional baseball batters in the United States, and further the work of Müller and Fadde (2016), by examining whether these new anticipation scores correlate with the 105 batters common batting game statistics.

Methodology:

Participants (N = 105) visual anticipation scores on the newly constructed anticipation test were acquired from a recent study (Müller, Fadde & Harbaugh, in press). The visual display in this anticipation test had been occluded at the point of ball release (i.e. the moment the baseball left the hand of the pitcher), 80 milliseconds after ball release, and 200 milliseconds after ball release. A no occlusion condition was also included which
showed the pitchers full motion and ball flight. Participants had to make a written prediction of pitch type (i.e., fastball, curveball or change-up) and pitch location (i.e., inside or outside the batters strike zone) combined, a prediction of pitch type and a prediction of pitch location, based on the visual information that was available in either one of the occlusion or no occlusion conditions.

Six baseball batting game statistics were used in this study. These were:
1. Batting average: the number of hits a batter makes per the times they are at the batting plate.
2. Slugging percentage: how powerfully a batter hits the ball in terms of bases achieved.
3. Base-on-balls: how often a batter refrains from swinging at pitches four pitches, which are outside the strike zone.
4. On-base percentage: how often a batter reaches first base successfully via a safe hit or base-on-balls.
5. Strikeouts: how often a batter gets three strikes by either making an incorrect decision not to swing or swinging and missing.
6. Walk-to-strikeout ratio: a batters ability to recognise pitches that are inside the batters strike zone.

Two baseball websites were used to collect each participant’s baseball batting game statistics from the 2015 baseball season (www.baseballreference.com and www.MiLB.com).

Results:

There were five statistically significant correlations between participant’s anticipation scores and their batting statistics. The prediction of pitch type and location positively correlated at the occlusion point 80 milliseconds after ball release with slugging percentage. Furthermore, the prediction of pitch type 200 milliseconds after ball release positively correlated with on-base percentage and walk-to-strikeout ratio, while negatively correlating with strikeouts. Finally, the prediction of pitch location 80 milliseconds after ball release positively correlated with slugging percentage.

Implications:

Firstly, as participant’s visual anticipation scores correlated with their baseball batting game statistics, this study supports the findings of Müller & Fadde (2016). Moreover, the results further highlight the importance of visual anticipation for performance in striking sports, as highly skilled baseball batters anticipation of pitch type and pitch location related to measures of their in-game batting performance for the 2015 baseball season. The findings of this study suggest that visual anticipation tests can be used to measure batting performance within professional striking sport teams. Furthermore, the findings of this study coupled with the findings from Müller and Fadde (2016) open the possibility that visual anticipation tests could be used by professional sporting teams as a recruitment tool to measure the visual anticipation abilities and thus future performance potential of junior baseball batters.