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A model of information use during anticipation in striking sports (MIDASS)

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Abstract

In sports such as baseball, cricket or tennis, skilled performers can strike fast moving objects with extremely high levels of accuracy. The ability to anticipate the outcome of an event, prior to the act itself, is crucial to superior performance. Published reports have identified several sources of information that skilled performers use to develop probabilistic judgements related to what might happen next. The focus has been on identifying key sources of sensory information, notionally postural cues, that may guide anticipation. However, more recently, researchers have started to explore how the context that surrounds the situation may facilitate skilled anticipation. Scientists have empirically explored how these two sources of information are integrated, prioritised, and affect anticipation and deception. Thus far, few efforts have been made to enhance the conceptual backdrop for this work or, more specifically, to identify specific hypotheses relating to performance. In this paper, we synthesise current literature and propose a model to explain how various information sources may be integrated during skilled anticipation and how this affects performance, with a particular focus on striking sports. We articulate several testable hypotheses to help focus future research.

Keywords: perceptual-cognitive-motor skill; congruence; expertise; context

Introduction

Due to the time constraints inherent in some striking sports and limits to the speed that humans can process information, skilled performers are required to anticipate what will happen next ahead of the actual event in order to provide more time to execute an appropriate response (Loffing & Cañal-Bruland, 2017; Yarrow et al., 2009). A substantive body of research now exists to show that anticipation in striking sports such as cricket and baseball is underpinned by the integration of information from at least two broad sources (Cañal-Bruland & Mann, 2015; Loffing & Cañal-Bruland, 2017; Williams & Jackson, 2019). Namely, the pick-up of sensory information from the emerging display such as an opponent's movement kinematics (Abernethy & Zawi, 2007; Müller, Abernethy, & Farrow, 2006), and the use of high-level contextual information such as the score in the game or sequencing of previous events (e.g., see Cañal-Bruland & Mann, 2015; Loffing & Cañal-Bruland, 2017; Müller & Abernethy, 2012; Murphy, Jackson, & Williams, 2019). Potentially an interaction exists, with the performer being able to rely to varying degress on the pick-up of sensory information during the task itself and contextual information that may be present or absent in the display.

Previous efforts to develop models that conceptualise the anticipation process in sport (e.g., Müller & Abernethy, 2012: Williams, 2009) have not fully accounted for the use of contextual information and how it is integrated with later emerging visual cues from an opponent (or opponents). Whilst this state of affairs is somewhat understandable, given the limited empirical work that exists focusing on the role of context in anticipation, it is increasingly apparent that models of anticipation which fail to incorporate context present an incomplete picture of the underlying mechanisms. Although several researchers have recently highlighted the importance of context in anticipation (Loffing & Cañal-Bruland, 2017; Morris-Binelli & Müller, 2017; Williams & Jackson, 2019), nobody has yet synthesised these findings with previous work in an effort to outline a conceptual model that may advance knowledge and understanding of the phenomenon and produce explicit testable hypotheses. In this paper, we present the *M*odel of *I*nformation use *D*uring *A*nticipation in *S*triking *S*ports (MIDASS) and articulate testable hypotheses that researchers in the field can examine emprically in an effort to refine conceptual understanding. We begin by providing a brief overview of the current literature. We do not present an exhaustive account of the literature in this field (for such reviews, see Loffing & Cañal-Bruland, 2017; Morris-Binelli & Müller, 2017; Williams & Jackson, 2019), but rather briefly highlight the key information sources that underpin anticipation and explain how these may be integrated during performance.

Visual Information

The perception and pick-up of visual information is most often seen in the ability to recognise advanced postural cues from an opponent (Müller et al., 2006; Smeeton, Hüttermann, & Williams, 2019) or to detect familiarity in patterns within a display (e.g., North, Hope, & Williams, 2017; North, Williams, Hodges, Ward, & Ericsson, 2009). Moreover, a large body of evidence exists demonstrating that skilled athletes display different visual search behaviours compared to less-skilled athletes (e.g., Mann, Williams, Ward, & Janelle, 2007; Mann, Causer, Nakamoto, & Runswick, 2019; McRobert, Ward, Eccles, & Williams, 2011; Williams, Janelle, & Davids, 2004). Since information processing is suppressed when visual fixation changes location through saccadic eye movements (Campbell & Wurtz, 1978), periods of fixation are associated with the pick-up of information from both foveal (Mann et al., 2007) and peripheral vision (Ryu, Abernethy, Mann, & Poolton, 2015; Ryu, Mann, Abernethy, & Poolton, 2016). Skilled performers typically demonstrate search patterns that lead to fixations on, and the retrieval of, information most pertinent to performance in any given situation (Mann et al., 2019). This work has helped to identify the most relevant sources of visual information that lead to enhanced anticipation.

The use of advance postural cues from an opponent is one of the most widely investigated sources of visual information underpinning skilled anticipation (Smeeton et al., 2019). Williams and Davids (1998) showed that skilled players in soccer can process advance cues to better anticipate the movements of an opponent. Similarly, Savelsbergh, Williams, van der Kamp, and Ward (2002) reported that skilled soccer goalkeepers used fewer fixations of longer duration to different locations on the opponent's body than less-skilled counterparts when predicting the direction of a penalty kick, suggesting enhanced pick-up of pertinent visual information. Initially, it was believed that skilled performers extracted information from isolated postural cues, however, contemporary research suggests that postural cue usage could be a form of pattern recognition (Smeeton, Hüttermann, & Williams, 2019; Smeeton & Huys, 2011). In striking sports, performers may recognise patterns that emerge from the relationships between body parts and can differentiate different skill types such as a slice, flat, or kick serve in tennis (i.e., intra-individual patterns; Huys et al., 2009). Whereas in interactive team sports, performers recognise patterns of movement between separate players (i.e., inter-individual patterns; North et al., 2009).

Pattern recognition is the ability to perceive familiarity in patterns of play early in their evolution in an effort to facilitate anticipation (North & Williams, 2019). It is considered particularly important in team games such as soccer, basketball, and field hockey (Williams & Ford, 2008). Skilled performers are better at recognising and recalling complex patterns of play in comparison with less-skilled players (Allard, Graham, & Paarsalu, 1980; Williams, Hodges, North, & Barton, 2006) and appear to do so by encoding relational and structural information rather than relying on isolated pieces of surface level information. For example, using a screen-based paradigm, North et al. (2009) showed that skilled soccer players were more accurate in anticipating pass outcome and displayed an increased sensitivity in their recognition judgments when viewing patterns of play in the absence of context or postural cues.

In striking sports, following information pick-up from patterns or postural cues, further pertinent information can become available from the motion of an object and can be used if time allows. For example, in a penalty kick in soccer, using ball-flight information to anticipate a shot direction may not leave enough time for a response. However, in cricket (depending on the speed of a bowler) some of the most pertinent visual information can be gained from the very early phases of ball flight (Müller et al., 2006; Runswick et al., 2018b; Runswick, Green, & North, 2020).

Non-visual Sensory Information

Scientists have also examined the importance of non-visual information during anticipation. Building on the early findings of Takeuchi (1993) that showed the importance of auditory information, Cañal-Bruland, Müller, Lach, and Spence (2018) used a series of video clips from a major tennis tournament and manipulated the volume of racket ball contact while players predicted the landing point of shots. When presented with louder racket-ball contact, tennis players consistently anticipated deeper groundstrokes. Similarly, Müller, Jauernig, and Cañal-Bruland (2019) showed that the intensity of a grunt when hitting the ball in tennis systematically influenced judgement of ball trajectory. While traditionally researchers have primarily focused on identifying the visual sources of information that underpin skilled anticipation, this recent work highlights the multi-sensory nature of anticipation.

Contextual Information

Sensory input is not the only source of information that can underpin the ability to assess situations and judge the probability of specific actions occurring. Abernethy, Gill, Parks, and Packer (2001) coined the term 'situational probabilities' to describe the use of information that was separate from the movement observed. Although earlier work set a platform for others to follow (Alain & Girardin, 1978; Alain & Proteau, 1980), the influence of what is now often termed 'context' on the ability to develop probabilities based on the information surrounding a situation and enhance anticipation has received limited attention. Consequently, researchers have often neglected key sources of information in understanding anticipation in sport (Cañal-Bruland & Mann, 2015).

The term context refers to sources of information that facilitate understanding of a situation and could relate to both the current stiuation and prior experiences of a performer. For example, a baseball batter could develop expectations of a pitcher's actions based on the current game situation, events that have occured previously in the current match, and every other match historically played against the same pitcher. It is possible that context could inform anticipation through processes in short-term memory, retrieval of information from long-term memory, and by updating retrieval structures 'on the fly' through interaction between information in working memory and long term memory (long-term working memory, cf. Ericsson & Kintsch, 1995; Murphy et al., 2016). Context is an embedded and tiered hierarchy of information that can be obtained prior to, or during, play. This information can sometimes be visual in nature (e.g. looking at the scoreboard) and at other times independent of visual input (e.g. a conversation with a coach about an opponent's tendencies). Therefore, it is necessary for researchers to clearly define the different sources of context that can be controlled experimentally in order to avoid the confusion of such an all encompassing term.

Several researchers have identified pertinent sources of contextual information in striking sports (see Table 1). For example, knowledge of game score (Farrow & Reid, 2012), the sequence in which information is displayed (McRobert et al., 2011), knowledge of opponent position (Loffing & Hagemann, 2014), action preferences (Mann, Schaefers, & Cañal-Bruland, 2014), and information concerning the positioning of both opposing players (Runswick et al., 2018a) are all different sources of contextual information which have been shown to influence anticipation. In the MIDASS presented in this paper, we focus our efforts on identifying information that is available prior to the execution of the skill by the opponent and which remains stable throughout the process of making a response; such as action preferences, action capabilities, score in a game, sequencing and field settings. While the score, sequencing, and field placing can change across a game, in most striking sports they remain stable for each occasion at which a skill is executed (e.g., a point in tennis, delivery in cricket, or pitch in baseball).

Skilled performers are better at utilising early available contextual information to assign probabilities to possible events that may occur given their experience and sophisticated supporting knowledge structures (Ward & Williams, 2003). For example, the type of delivery likely to be bowled based on previous deliveries in cricket or where a certain player might place a penalty kick in soccer. The superior ability of skilled performers to use context to anticipate actions has been displayed empirically in a variety of sports, with a particular focus on time constrained striking sports such as cricket (McRobert et al., 2011; Müller, Brenton, & Mansingh, 2020, Runswick et al., 2018a) and tennis (Murphy et al., 2016).

Table 1. Some examples of contextual and sensory information sources identified as playing a role in anticipation.

Contextual	**Examples**	**Example Citation**
Event Sequences	Shot sequence in tennis points	Murphy et al. (2018)
	Attack sequence in karate	Milazzo et al. (2015)
Opponent action tendencies/preferences	Attacking tendencies in soccer	Gredin et al. (2018)
	Shooting direction preference in handball	Mann et al. (2014)
Game related information	Score and time in cricket	Runswick et al. (2018a, 2018b)
Prior player positioning	Court position in tennis	Loffing and Hagemann (2014)
	Fielder position in cricket	Runswick et al. (2018a, 2018b)

Current Sensory	Examples	Example Citation
Relative motion	Motion of basketball players	Allard et al. (1980)
	Motion of attacking players in soccer	North et al. (2009)
Advanced Cues	Postural cues in squash	Abernethy (1990)
	Postural cues in soccer penalties	Savelsbergh et al. (2002)
Object motion	Ball flight in cricket	Müller et al. (2006)
	Ball trajectory in baseball	Gray & Cañal-Bruland, (2018)
Sound	Racquet-ball contact in tennis	Cañal-Bruland et al. (2018)

Information Integration

An important question relates to how these various sources of information are integrated to facilitate superior anticipation. Gredin et al., (2020) have suggested that the researchers could look to adopt a Bayesian integration model of probabilistic influence to explain this process. Very few researchers have examined this issue directly, with two recent exceptions. Gray and Cañal-Bruland (2018) showed that baseball batters can integrate probabilistic information with visual information from postural cues and ball flight depending on the reliability of each source and the time that it is available. Runswick, Roca, Williams, McRobert, and North (2018b) showed that perceptual judgements were initially formed based on context (field placing, score and time in the game) prior to the appearance of useful sensory information, with re-prioritisation between these different sources occurring later in the process. This latter conclusion has been supported in more fundamental investigations of the interaction between expectations and perceptions where expectations (probabilistic judgements based on context) are relied upon strongly when stimuli (e.g., visual cues from an opponent or ball-flight) are unclear (de Lange, Heilbron & Kok, 2018). However, when sources of information are misleading (such as a deceptive field setting in cricket) this can have a negative effect on the athlete's (batter's) ability to predict location of the ball in the optimum amount of time (Runswick, Roca, Williams, McRobert, & North, 2019).

Deception

The challenge of picking-up key information sources to guide anticipation does not always have a positive effect on performance (Jackson & Cañal-Bruland, 2019). For example, deception can be inherently part of movement execution in sport (covert deception). Alternatively, deliberately employing deceptive actions can lead opponents to make incorrect anticipatory judgements (overt deception); a topic that has recently received significant attention in the literature investigating skills such as sidesteps in rugby and head fakes in basketball (e.g. Cañal-Bruland, & Schmidt, 2009; Güldenpenning, Kunde, & Weigelt, 2017; Jackson, Warren, & Abernethy, 2006). Equally, in addition to deceiving or disguising through postural cues, it is possible to deceive by providing incorrect or misleading context (Cañal-Bruland, Filius, & Oudejans, 2015; Runswick et al., 2019). For example, in baseball if the batter is aware the pitcher has the capability to deliver a fastball this can negatively affect the batter's ability to anticipate a slower pitch. In general, this research has shown that performance outcomes in response to deceptive actions are dependent on the prioritisation of information sources and whether the information that is prioritised, be it contextual or sensory, is congruent with the event outcome (Murphy et al., 2019). These findings are aligned with athletes employing Bayesian reliability-based strategies (Gredin et al., 2020). When skilled performers prioritise visual information, they have been shown to be better able to adapt to deceptive visual information, albeit they are likely to be more significantly negatively affected when prioritising context (Runswick et al., 2019). Past attempts to conceptualise anticipation in sport have not made specific predictions about how using different sources of information will affect performance and, in such models, scientists have not considered the negative impact that may arise when deceptive information is presented.

Current Models

A conceptual model that fully incorporates contextual information and makes specific predictions about performance outcomes does not currently exist. A few previous models have been produced showing various approaches to conceptualising anticipation (e.g., Müller & Abernethy, 2012; Williams et al., 2009) or the use of visual information in sport (Laby & Kirschen, 2018). However, these models have not presented specific predictions about the influence of different information sources on performance, how information sources are integrated, or could be deceptive in nature. In this section, we extend on the work of Müller and Abernethy (2012) who proposed a two-stage model that centred on outlining the visual processes involved during skilled anticipation in striking sports. The model focused on the use of advanced visual information, such as kinematic cues for early movement of the lower body, and the use of ball-flight information to build on these probabilities and execute an interceptive action. The model uses the term 'situational probabilities', but, while acknowledging the limited literature available at the time, fails to account fully for the broader use of contextual information throughout the anticipation process. An updated version of this model proposed by Morris-Binelli and Müller (2017) acknowledges the wider role of situational-probabilities and poses further questions about the prioritisation of information, but does not make explicit testable predictions relating to the positive or negative effects that various combinations of information could have on performance. Furthermore, while the model did suggest that expertise is characterised by broader information use, the linear nature in which information is used in the model does not allow for the dynamic interaction and differing prioritisation of information sources over time that has been displayed in more recent work around deception and information integration (see Gredin et al., 2020).

A more recent attempt to produce a sport-specific model in striking sports was proposed by Vernon, Farrow, and Reid (2018). Using data from eight interviews with tennis players who had been in the top 250 in the world, the authors highlighted themes including the use of both contextual and kinematic information sources during anticipation over the period from 24 hours prior to anticipating a serve in tennis to after ball contact during the return. However, the nature of this approach is limited by the use of qualitative data from a limited sample and, while insightful, athletes will only report explicit rather than implicit processes, which may limit the impact of the work and its application to anticipation in striking sports as a whole. A model that conceptualises common aspects across striking sports and produces hypotheses that are testable in a broad range of tasks can guide future empirical work. This shift towards more empirically-driven work will ultimately enhance the generalizability of findings and increase the translational impact of this work to applied domains.

Model of Information use During Anticipation in Striking Sports (MIDASS)

The body of evidence for the use of contextual information to aid anticipation continues to grow, along with our understanding for how the relative importance of postural cues and context vary and interact over time. Therefore, researchers aiming to investigate anticipation in striking sports would benefit from a model that accounts for task-specific differences in information usage and for the complex relationships that exist between the many different sources of sensory and contextual information that impact on anticipation. A model of the continuous processing of contextual and sensory information, accounting for both positive and negative effects on performance, is required to fully understand anticipation in sport and to guide future research in this field. The Model of Information use During Anticipation in Striking Sports (MIDASS; Figure 1) was developed using current empirical research and inspiration from other models of perceptual-motor-control (e.g., Nieuwenhuys & Oudejans,

2012) in order to enhance understanding of the processes and mechanisms underpinning anticipation and to provide researchers with specific testable hypotheses.

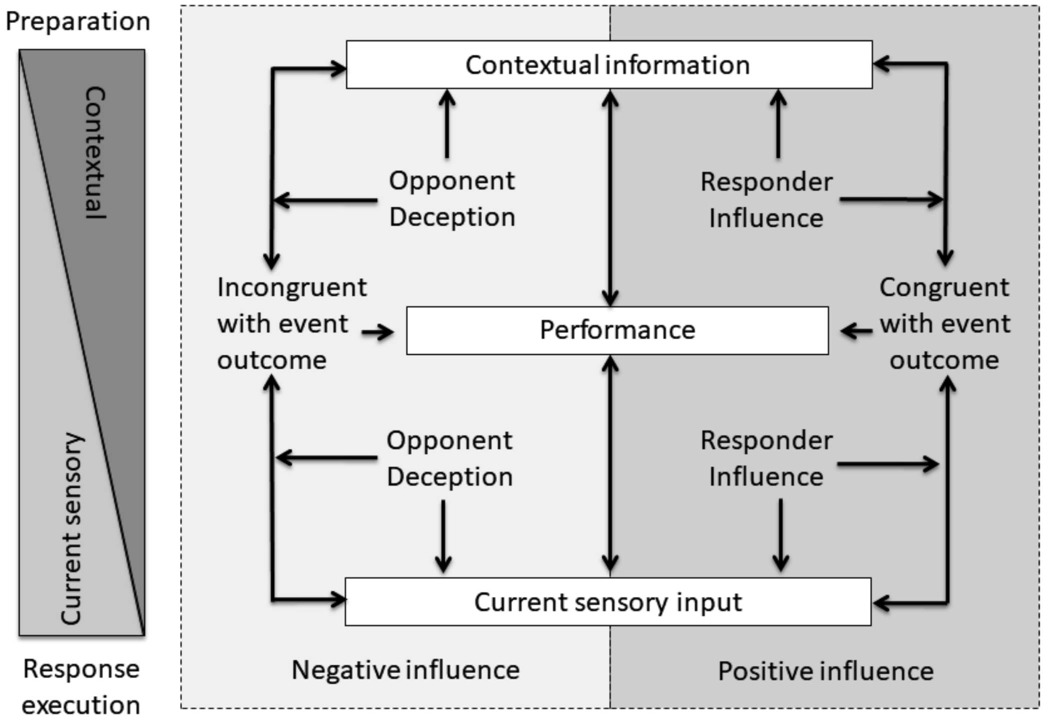

Figure 1. The Model of Information use During Anticipation in Striking Sports (MIDASS). The left-hand section shows the information that becomes available over time. The right-hand section shows how these sources of information interact to affect performance.

Scope and Aim of MIDASS

We categorise the different sources of information used during anticipation in Figure 1. Contextual information includes early available sources of information that facilitate understanding of a situation, such as an opponent's action preference(s), action capabilities, prior performances, game score, time left in the game, the conditions of the pitch, opponent positioning or formation, and the sequence of preceding events. While contextual sources of information can be visual or auditory in nature, we refer to sensory information as sources of current novel information available to a performer during the anticipation process, such as information from kinematic cues, pattern recognition, and other task specific sources including ball flight. While it is likely that contextual and sensory information will have a dynamic relationship, for producing a model that can make specific predictions about the relationship between contextual and sensory information and performance, it is necessary to categorise these sources.

Many performance measures in the literature have focused on the accuracy of anticipation (e.g., Müller et al., 2020; Murphy et al., 2016; Runswick et al., 2018a). However, there is clearly a significant temporal element to anticipation, particularly in fast-paced striking sports (e.g., baseball, cricket, or tennis). The MIDASS centres on performance, referring to the speed and accuracy of an anticipation judgement. Müller and Abernethy's (2012) model suggests that the use of ball flight information combined with postural cues would enable the responder's striking action to evolve 'just in time'. We propose that the speed of a decision, however, does not mean at the last possible moment or that a faster decision is better. Decisions need to either be made at the optimum time for the specific task or with the highest possible level of accuracy in the limited time available. A negative effect on anticipation performance incorporates either a less accurate judgement or a judgement made at a less opportune time for a specific task. The MIDASS offers predictions as to how different sources of information contribute to anticipation in the form of the production of accurate decisions at the most appropriate time to make those judgements. These predictions are based on the congruence between information (from any source) and the actual event outcome (i.e., available information does or does not match the outcome of a future event). While this relationship may exist on a continuum of certainty (Gray & Cañal-Bruland, 2018), for the purposes of producing clear and easily testable hypotheses from this model, we refer to this in a dichotomous fashion with information either falling on the congruent and incongruent side of the continuum.

Our model suggests that contextual information will be the predominant source early in the anticipation process and that current sensory information will be become more influential close to the interception point (Müller & Abernethy, 2012) . However, in the current model, the relative contribution of each source of information is likely to vary over time and the time at which certain sources of information emerge, and are used, is likely to be task- and situation-specific (e.g., Gredin et al., 2018; Runswick et al., 2018b; Vernon et al., 2018). While we offer broad suggestions on the use of information over time, the model allows for varying levels of influence from information sources across time depending on the specific skill being investigated. Furthermore, this model does not suggest that only one source of contextual and sensory information is working at once. In fact, multiple sources of information interact dynamically and constantly to inform action until a response is executed, and the nature of anticipation performance is dependent on the relationship between these information sources and the event outcome.

Hypotheses and Empirical Support

Hypothesis 1.

Both contextual and current sensory information can influence anticipation performance directly, but this effect is neutral (chance level) until knowledge of the relationships between information sources and event outcomes is developed by a performer.

The arrows in Figure 1 represent relationships between information sources and performance and what, if anything, mediates this relationship. The location of these arrows shows whether this relationship is negative (left) or positive (right). The central arrows from the information categories to performance represent the direct influence that both contextual and sensory information have on anticipation. Previously, researchers have shown that context can influence anticipation in the absence of other novel sensory information (Murphy et al., 2016; Runswick et al., 2018b) and that sensory information can influence anticipation in the absence of context (Müller et al., 2009). However, these sources of information are meaningless until performers develop knowledge structures to link information to probabilities of potential event outcomes (Christensen et al., 2016). For example, a novice tennis player will know the score of the game and sequence of serves that have occurred, but may not have sufficient knowledge to link this information to a future event outcome, thereby rendering this information meaningless. When anticipation predictions move above or below chance, a source of information is being utilised and linked to a future event outcome either correctly or incorrectly.

Hypothesis 1 is based on literature that has demonstrated skill level differences in the use of both contextual and sensory information (e.g., Müller et al., 2009; Runswick et al., 2018b). However, research that can show novice performers recognising contextual and sensory information but anticipating at chance level, being exposed to either explicit instruction on the relationship between information and event outcome for a period practice, then improving above chance, would further support this prediction. This relationship between anticipation performance, information source, and event outcome is a key to the model.

Hypothesis 2.

Contextual information is available before current sensory information. Earlier judgements are therefore based predominantly on context. Information available later (e.g. postural cues or ball-flight) will be used to confirm, update, or override original judgements.

In their earlier two-stage model, Müller and Abernethy (2012), while touching on ‘situational probabilities’, focused on the use of advanced visual information, such as kinematic cues for early movement and the use of ball-flight information to build on these probabilities and execute an interceptive action. Morris-Binelli and Müller, (2017) extended this model, by acknowledging the influence of early available contextual information, and posed questions on how it may be integrated with visual information. Vernon, Farrow, and Reid (2018) have since identified information that was used by elite tennis players for a period from 24 hours prior to a match. We acknowledge the prediction that contextual information can be available significantly earlier than kinematic information and be used to narrow probabilities of possible outcomes, potentially long before any movement response is initiated. However, following the appearance of kinematic and ball flight information, athletes will not use this information to produce judgements independent of context, but will integrate emerging sensory information with early available context to confirm, update, or override original judgements depending on congruence and reliability (Gredin et al., 2020; Runswick et al., 2018b). Hypothesis 5 discusses how information can be prioritised if different sources suggest contrasting outcomes.

Hypothesis 2 is made based on research paradigms that have systematically occluded the availability of either contextual or visual information and measured anticipation performance (e.g., Müller et al., 2020; Runswick et al., 2018b). In future, researchers could further test this prediction by including more direct measures of information processing (e.g., EEG, Simonet et al., 2019) or testing this in-situ using methods such as occlusion goggles.

Hypothesis 3.

When information is congruent with the event outcome, this will enhance anticipation performance and the greatest positive impact on performance will occur when all sources of contextual and sensory information are congruent with the event outcome.

A congruent relationship exists when an information source indicates an outcome that matches the actual event outcome that occurs. As discussed earlier, the majority of researchers have focused on identifying the key sources of congruent visual information that facilitate skilled anticipation performance (Smeeton et al., 2019). More recent work has shown that skilled performers use contextual information to facilitate anticipation (Murphy et al., 2016; Runswick et al., 2018a). On the basis of these previously published reports, MIDASS predicts that when either sensory *or* contextual information is present and congruent with actual event outcome then there will be a positive effect on anticipation performance. However, we recognise that sensory information and contextual information do not operate in isolation, but rather more often will interact and work in parallel. In this regard, MIDASS predicts that when concurrent sensory information and contextual information are both congruent with the actual event outcome, while they might carry different weight, then their effects will be additive and more facilitative to anticipation than either in isolation.

Hypothesis 4.

When information is incongruent with the event outcome, this will negatively affect anticipation. The greatest negative impact will occur when all sources of sensory and contextual information are incongruent with the outcome.

An incongruent relationship exists when an information source indicates an outcome that is different from the event that actually occurs. This relationship is displayed on the left side of the model. Although researchers have shown that when congruence exists between the available information and actual outcome then anticipation improves, it has also been demonstrated that when performers are presented with deceptive or misleading information (i.e., the available information is not congruent with the actual outcome) then anticipation is negatively affected (see Güldenpenning, Kunde, & Weigelt, 2017; Jackson & Cañal-Bruland, 2019). While Hypothesis 2 outlines the positive effects of context on anticipation, Runswick et al. (2019) used cricket batting to show that a negative effect on anticipation can occur when contextual information is incongruent with the actual event outcome. Therefore, MIDASS predicts that if all sources of information (current sensory information *and* contextual information) indicate an outcome which is different to that which occurs, then anticipation performance will negatively be affected to the greatest possible extent. The negative effects will be additive and more pronounced than if either just sensory information *or* contextual information were incongruent with the actual outcome.

Hypotheses 3 and 4 can both be tested in parallel by researchers systematically manipulating the relationship between contextual information, sensory information, and the event outcome to test the additive effects of multiple congruent information sources or indeed the negative effects of consistently incongruent information. This testing could occur in the laboratory using controlled video or virtual stimuli or in-situ where researchers can use hypothetical scenarios to simulate performance environments.

Hypothesis 5.

Congruent and incongruent information can act simultaneously; the overall anticipation performance will depend on how the anticipator prioritises information and the reliability of information sources and the point of time in the anticipation process.

As highlighted, current sensory information and contextual information do not present themselves in isolation, but rather will frequently be available simultaneously. It is, of course, possible for one of these sources of information to be congruent with event outcome and the other to be incongruent. For example, in cricket, a fielding team may place fielders in such a way to increase the possibility of a certain type of delivery, but the visual cues from the biological motion of the bowler may increase the probability of a different type of delivery. In such instances, the effect on anticipation is dependent on how these information sources are prioritised, which itself is not fixed and may fluctuate over time. Runswick et al. (2018b) occluded video footage at various points in the bowling sequence in cricket and demonstrated that contextual information was prioritised earlier (when it became available) and remained influential throughout, with visual sensory information having a greater influence when it became available later. In a follow-up study using the same task, Runswick et al. (2019) showed that when context was incongruent with the event outcome, but current sensory (visual in this case) information was congruent, the negative impact on performance could be mediated by the differential prioritisation of information sources. Similarly, baseball batters can integrate probabilistic information related to pitch type with visual information by prioritising information use based on the reliability of each source and the time that it is available (Gray & Cañal-Bruland, 2018). Prioritisation of what are deemed to be the most reliable information sources can lead to a significant performance benefit if a congruent source is prioritised or performance deficit if information that is incongruent with the eventual event outcome is prioritised.

In a similar fashion to hypothesis 3, hypothesis 5 could be tested by employing more direct measures of information processing where the use of current sensory input can be objectively differentiated from the use of information from memory stores that are a result of context that was available earlier. This process, combined with manipulation of information reliability and measures of performance, could tease apart how context and sensory input are prioritised based on reliability. The investigation of this hypothesis could also benefit from the application of the Bayesian model of probabilistic inference proposed by Gredin et al. (2020). While this a broader theoretical approach than the MIDASS it could offer a useful bridge with which to incorporate understanding of information integration from other domains with our understanding of striking sports.

Hypothesis 6.

The opponent can deliberately manipulate information sources to his/her advantage to decrease anticipation accuracy. This effect occurs by deliberately developing incongruent relationships between contextual information, sensory information, and event outcome.

A large body of literature has shown that opponents can use kinematic cues to deceive or disguise action intentions and impair anticipation performance (see Güldenpenning et al., 2017; Jackson et al., 2006). As detailed in Hypothesis 4, Runswick et al. (2019) showed that contextual information can negatively affect anticipation when it is incongruent with actual event outcome, opening up the possibility that performers could deliberately manipulate such contextual information to similarly deceive anticipation responses. MIDASS shows that deception from an opponent's use of either sensory (e.g., postural cues) or contextual information can affect performance by altering the congruence of the relationship between information sources and the event outcome. For example, an opponent can deliberately execute a skill that is unlikely in a certain situation. This action would mean that context is incongruent with the postural-cues and then with the event outcome and anticipation performance decreases. Likewise, an opponent could execute a skill that is highly likely in the given context, but simultaneously aim to disguise sensory cues, such as covering up finger position on a baseball, thereby rendering kinematic information incongruent with the event outcome and decreasing anticipation performance. An opponent can negate a performer's ability to make an accurate anticipatory judgement by employing a manipulation that causes incongruence between sensory information, contextual information or both and the actual event outcome. As predicted in Hypothesis 5, this can be countered by the responder prioritising the most reliable, congruent sources of information or be most detrimental when all sources of information are incongruent (Hypothesis 4).

Hypothesis 7.

The responder can deliberately manipulate situations to his/her advantage and increase anticipation accuracy.

An area that has lacked investigation in the literature is the influence of the performer who is anticipating and executing a response in the process- in this MIDASS, referred to as 'responder influence'. To counter opponent deception, the responder could influence the opponent to create favourable situations in which sources of information are congruent with the outcome. For example, in cricket, the responder can manipulate the contextual information that develops, such as sequences of event (McRobert et al., 2011). Cricket batters often play a series of shots moving closer to the bowler to induce a short ball delivery later on. In tennis, a returner may position his/her body in a way that encourages the opponent to direct the serve in a specific direction, thereby increasing the probability of that event outcome occurring. A defender in football will often position his/her body in a certain way to force the opponent in a certain direction to greatly increase the probability of that outcome occurring. To understand what happens in anticipation in striking sports tasks, it is necessary to investigate the part responders play in the anticipation process. This MIDASS makes predictions to guide this investigation going forward. The responder can also manipulate current sensory and contextual information, increasing the probability of an opponent executing a certain action and therefore create congruence between information sources and the event outcome.

In future, those testing hypotheses 6 and 7 could facilitate a significant step forward in understanding by treating anticipation and deception as dynamic and interactive processes. Paradigms may need to be developed where both parties (i.e., actor and perceiver) are able to execute skills freely, presenting the need to measure how to manipulate contextual and sensory information. Performance analysis could have a significant role to play in sports such as cricket where the positions of fielders are carefully manipulated by the bowling team and actions of bowlers and outcome of deliveries are regularly recorded.

While the proposed model accounts for a number of areas that have been missing from previous attempts to model anticipation, not least the detailed inclusion of contextual information alongside sensory information and the presentation of specific and testable hypotheses, there is still much work to be done. We hope the MIDASS can provide a focal point for directly testing hypotheses in order to continue to enhance and refine our understanding of the processes underpinning anticipation. In future, further work could allow for other factors that affect anticipation such as anxiety and fatigue to be considered and how such factors impact on information pick-up. Furthermore, researchers should move beyond simply investigating the anticipator in sporting situations and focus on investigating the dynamic relationship between the opponent and responder in understanding anticipation.

By directly testing the hypotheses proposed in this model, and furthering understanding of the prioritisation and integration of information sources in skilled performers, researchers can begin to unpack the dynamic relationship between responder and opponent in striking sports. Such hypothesis-driven testing can lead to continued improvement in interventions to not only develop skilled anticipators but athletes who are skilled in using sensory and contextual information to hide their intentions, manipulate competitive situations, and create probabilities in their favour.

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