That's out! How expert umpires make leg-before-wicket judgements in cricket

Joshua M. Adie, Ian Renshaw, Scott Russell, Remco Polman & David L. Mann

View supplementary material ⧉

Published online: 17 Apr 2024.

Submit your article to this journal ⧉

Article views: 1136

View related articles ⧉

View Crossmark data ⧉

Citing articles: 1 View citing articles ⧉

Routledge
Taylor & Francis Group

SPORT AND EXERCISE PSYCHOLOGY

🔓 OPEN ACCESS | Check for updates

That's out! How expert umpires make leg-before-wicket judgements in cricket

Joshua M. Adie [ID][a], Ian Renshaw[b], Scott Russell[b], Remco Polman[c] and David L. Mann[d]

[a]School of Psychology & Wellbeing, University of Southern Queensland, Ipswich, Australia; [b]School of Exercise & Nutrition Sciences, Queensland University of Technology, Kelvin Grove, Australia; [c]Institute of Health and Wellbeing, Federation University, Berwick, Australia; [d]Department of Human Movement Sciences, Vrije Universiteit Amsterdam, Amsterdam, Netherlands

ABSTRACT

Despite evidence that elite-level cricket umpires are highly accurate in making leg-before-wicket (LBW) judgements, there is limited understanding as to how they make these judgements. In this study, we explored the explicit LBW decision-making expertise of elite-level cricket umpires ($N = 10$) via 10 individual semi-structured interviews. Using thematic analysis, we aimed to identify the sources of information that umpires incorporate into their decision-making process. Results indicated that umpires engage in intentional pre-delivery information-gathering to guide their expectations, and to set context-specific parameters as to what would constitute an LBW dismissal. Not only do umpires use information about the ball trajectory, but they also use additional information about the condition of the pitch, the action-capabilities and susceptibilities of players, and the unique requirements of different match formats. Umpires reported employing a gaze-anchor strategy when gathering information for each delivery and described the process of this information as initially intuitive, before engaging in deeper post-hoc reasoning. Findings highlight the importance of including contextual information when exploring officials' decisions and may inform future training interventions for cricket umpires.

Sports officials' decisions can largely be classified as a perceptual categorisation task in which the referee, umpire, or judge must categorise various informational cues into discrete classes (Plessner et al., 2009). This multiple-cue account of how officials process decisions stems from Brunswik's (1955) concept of probabilistic functionalism. According to Brunswik, because people usually do not have direct access to the "true state of the world", they must infer it from the visible features of the environment. These features, or cues, are not deterministic in nature, but instead represent probabilistic information as to the true state of the world. The concept of probabilistic functionalism has been predominantly illustrated in lens model of decision making (see Goldstein, 2004). In turn, expertise lies in a performers' increasing ability to attune to specifying information that more reliably allows correct categorisation of an incident or event (Doherty & Kurz, 1996).

According to Plessner et al. (2009), officials' decision-making can be described primarily as an intuitive process where officials simultaneously process multiple sources of information to make a decision. For example, when making a foul judgement in football, a referee would need to consider perceptual information from multiple players' movements, the ball, and information relating to the laws/rules of the game. However, research has suggested that sometimes officials utilise sources of information that are less reliable to allow officials to "fill in the gaps" in perception when unable to pick-up specifying information (MacMahon & Mildenhall, 2012). MacMahon and Mildenhall argue that this approach to decision making by officials is necessary to cope

with extreme time pressure, and incomplete perceptual information. For example, a football assistant referee judging an offside situation may utilise pre-event knowledge of a player's running abilities to determine whether it is plausible that the player was able to be onside (MacMahon & Mildenhall, 2012).

The majority of sports officiating tasks that have been investigated in the literature above have generally focussed on decisions where the official makes only a reactive judgement based on their immediate perceptual experience. For example, football referees generally focus on whether a tackle they have just witnessed was a foul or not (i.e., there is no prediction element). In some cases, football referees might also engage in prediction to determine whether a tackle was a professional foul (e.g., preventing a genuine goal-scoring opportunity) in order to enact the correct level of punishment (i.e., red card). However, this is a prediction about the likelihood of an outcome (e.g., the likelihood of maintaining control), rather than an explicit prediction of the trajectory that the ball would have travelled. In contrast, the Leg-Before-Wicket (LBW) law requires cricket umpires to first make *reactive* spatial judgements based on visual information (e.g., where did the ball bounce and hit the batsman, and did it hit their bat before hitting them?), and then uniquely also make a *predictive spatial judgement* as to where the ball would have travelled had it not hit the batter. In these cases, the batter can be adjudicated as "out" on appeal from the opposing team.

Due to the controversial nature of LBW decisions, most studies in officiating in cricket have focussed on the accuracy and bias of cricket umpires when making those decisions. For

instance, Sacheti et al. (2015) explored whether LBW decisions were more favourable for home (as opposed to away) batters and found that umpires from the home country favoured the home team. They also found that this bias to favour the home team decreased with the introduction of neutral umpires. Adie et al. (2020) showed that cricket umpires are remarkably accurate (98% correct), but are also conservatively biased decision-makers who favour "not out" calls for LBW decisions. This finding is not surprising given that the lore of the game has suggested that batters should always be given the benefit of the doubt. They also showed that in the shortest format of the game, T20 cricket, umpires are less accurate, and even more conservative than in the other game formats (i.e., four-day and one-day cricket). These findings suggest that changes in cricket umpires' decision-making behaviour are associated with contextual factors.

Given that umpires appear to have biases in their decision making, previous studies have begun to explore the specifying information that umpires use when making LBW decisions. Using a temporal occlusion paradigm, where ball flight was stopped either at bounce or two frames post-bounce, Chalkley et al. (2013) showed that club-level intermediate and expert umpires were able to more accurately predict the flight path of a cricket ball than a novice control group. Given that the expert umpires did not perform better than the intermediate umpires, it is possible that the lack of representativeness of the experimental task failed to sample the true nature of the expertise of those umpires. More specifically, the use of isolated video clips in their study removed almost all contextual information (e.g., previous deliveries, pitch conditions, etc.) that may differentiate expert and intermediate umpires' decision-making ability in the real world. This task was also relatively simple, as it provided the participants with only one cue to focus upon (ball trajectory), rather than including multiple cues (e.g., information from the movements of the bowler and batter) that are potentially critical when making actual decisions (Plessner et al., 2009). As such, the true expertise of the higher-level umpires may not have been revealed due to the issues with (insufficient) representative design of the decision-making test (Pinder et al., 2011).

Given the extreme temporal challenge involved when making LBW decisions (the ball can hit the batter less than 0.6 seconds after leaving the bowler's hand), interest has turned to where umpires might look when making their decisions. Recently, Ramachandran et al. (2021) showed isolated video clips to expert cricket umpires of single deliveries projected by a bowling machine towards a batter. These clips did not include contextual information nor information from a bowler. Ramachandran found that the umpires used a gaze anchor by fixating on a location in the centre of the multiple cues (e.g., batter's pads, gloves, bat, or the stumps) that might be used when making a decision to overcome the visual processing demands required to track a fast-moving cricket ball. Effectively, the umpires appeared to be using their peripheral vision to monitor those cues. In that study, participants were required to explicitly indicate where the ball had bounced, where it impacted the batter, and where it would have passed the stumps. While these judgements are vital when

making an LBW decision, the authors assumed that umpires must go through an explicit "checklist" of decisions when making an LBW judgement.

Broader research in expert categorisation tasks provides reason to believe that umpires might not be altogether systematic in their decision making. Expert categorisation research shows that experts are commonly able to accurately discriminate between categories based on *stylistic* information (i.e., low level features that are shared across a category), rather than individual features (Searston et al., 2019). For example, fingerprint examiners can identify matching prints at a glance even when images are degraded, and without identifying specifying features of the fingerprint (Thompson et al., 2014). Similarly, it is possible that rather than going through an explicit checklist (e.g., each point of the LBW law), cricket umpires could instead follow a more intuitive process when making LBW decisions where they make a stylistic judgement (i.e., a judgement of "outness"). As such, their gaze behaviour may differ in actual games from what was found in this study. While we this study provided an important first step in understanding the gaze behaviour of umpires, future studies should aim to incorporate features that are representative of the demands of the performance environment (e.g., bowler's foot, batter movement etc.) to further understand umpires' gaze strategies.

These previous studies have focused on *what* cricket umpires do when making LBW decisions, yet no study to date has explored *how* cricket umpires make those decisions. In particular, it remains unclear which sources of information umpires prioritise to judge an LBW appeal as either "out", or "not out". Further, no study to date has explored LBW decision-making from the umpire's perspective. The aim of this study was to uncover the key sources of information that cricket umpires utilise when making an LBW judgement. To do so, we first sought to understand the sources of information umpires use when making an LBW decision, and then investigated how umpires integrate those sources of information in their decision-making process. We explored the explicit LBW decision-making expertise of elite-level cricket umpires via semi-structured interviews. Our work does not aim to verify information sources or generate a list of every piece of information that the umpire uses during competitive cricket matches. Rather, our work seeks to better understand how umpire priorities shape decision-making processes and choices when adjudicating LBW appeals (Russell et al., 2020).

Method

We used reflexive thematic analysis to generate an understanding of the LBW decision making of cricket umpires (Braun & Clarke, 2006, 2019). We assumed a critical realist ontology, which acknowledges that social phenomena (i.e., in this case, expert LBW decisions) exist as a social construction that cannot be directly measured. Using semi-structured interviews, we investigated the beliefs of elite cricket umpires (as categorised by Kittel et al., 2019) in relation to the sources of information they rely on when making LBW decisions, to gain insight into their decision-making process.

Participants

Prior to undertaking interviews with the umpires, ethical approval was granted from the local university's ethics committee. Participants were purposefully recruited via Cricket Australia as part of an ongoing research collaboration with the lead author. This meant that only Australian umpires who were officiating at the elite-level were invited to participate. All umpires provided written consent to participate in the study. Participant anonymity was preserved at all levels of the interview process. Ten umpires agreed to participate, with an average of 14.7 years umpiring experience (SD = 5.62). The participants were all male and had a mean age of 49.2 years (SD = 7.2). At the time of interviewing, one umpire (Umpire H) was a member of the International Cricket Council (ICC) Elite Panel of Umpires, six umpires (Umpires A, D, E, F, I, & J) were members of the Cricket Australia National Umpire Panel (NUP), while the final three umpires (Umpires B, C, and G) were members of the Cricket Australia Supplementary Umpire Panel (SUP). The ICC umpire officiated predominantly international matches, the NUP umpires officiated predominantly national-level men's matches, and SUP umpires officiated predominately national-level female matches, however were also appointed to some national-level men's matches. One interview was conducted in person, and nine interviews were conducted online via zoom over a two-month period.

Interview procedure

Semi- structured interviews were conducted lasting between 30 and 60 minutes (M = 36.9, SD = 11.08) by the lead author who is also an experienced cricket umpire. This experience assisted in establishing rapport with the interviewees, and in interpretation of the results (e.g., interpreting domain-specific jargon). Two specific lines of questioning were followed: (i) what sources of information do cricket umpires use when making LBW decisions, and (ii) how do umpires incorporate this information in their decision-making process? Interviews adopted a funnel strategy, starting broadly with initial rapport-building questions, before moving to questions that sought to hear the participants' views on LBW decisions more generally. To facilitate this, questions asked interviewees to consider topics such as: what makes a good/bad cricket umpire decision-maker and what makes a good LBW decision? As the interview progressed, more purposeful questions were asked such as: what sources of information do you use to make an LBW decision? And how would you describe your decision-making process? While these questions were designed to answer our specific research questions, they also acted as *points of departure* to allow the umpires to introduce topics of conversation that they thought were important, which the research team may not have considered. For example, umpires introduced the concept of using the ball movement after it hit the batter as a decision-making heuristic. Interviews were conducted until the richness and complexity of the data was sufficient to answer our stated research questions (Braun & Clarke, 2021).

Data analysis

All interviews were transcribed verbatim by a professional transcription company. The lead author then edited the transcriptions to ensure their accuracy, and before analysing the data using reflexive thematic approach (Braun & Clarke, 2020). This process involved initial familiarisation with the data and note taking. The next phase involved the systematic coding of the interviews conducted concurrently by two authors (JMA and SR) using Nvivo (JMA) and manual methods (SR). Codes were generated via both deductive and inductive approaches, where existing literature was compared to the data. Initially, we analysed the data inductively to ground our results in the ideas of the participants. As codes became stronger and more focussed, themes were deductively compared with existing decision-making theories (e.g., theories of perceptual cognition and probabilistic functionalism/lens models) to develop theory that builds on existing conceptual knowledge (Weed, 2017).

The next phase of the analysis involved generating initial themes from the coded data. These initial themes were developed collaboratively by authors JMA, SR, and IR by printing out the codes and comparing each other's perspectives. To enhance rigour, these early themes were discussed as often as needed with members of the research team to "encourage reflection upon, and exploration of, multiple and alternative explanations" (Smith & McGannon, 2018, 113). This process was particularly important given the lead author is an experienced cricket umpire. By utilising the research team's varied theoretical backgrounds (e.g., cognitive psychology, vision science, ecological dynamics, and constraints led approaches) as well as degree of involvement in sports officiating, the lead author was able to reflect and consider how his background as a cricket umpire "inevitably impacted upon the meaning and context of the experience under investigation" (Horsburgh, 2003, 308).

The next phase of the analysis involved developing and reviewing the themes, as a process of refining, defining, and naming the generated themes. This final stage was carried out collaboratively by all listed authors and resulted in a conceptual modelling of key processes that guide LBW decision-making judgements.

The findings presented in the following section do not necessarily represent specific categories that umpires voiced during the interviews. Instead, they serve as a theoretical abstraction of the collective umpire's views about LBW decision-making (Russell et al., 2019).

Results

The reflexive thematic analysis led to the development of an overarching conceptual model of LBW decisions (See Figure 1) which could be conceptually organised into two main phases: *information gathering* before and during a delivery, and the actual *decision-making* after the delivery. We identified that the overarching goals of *information gathering* were to aid in *anticipation* and to generate context-specific *a priori parameters* of what would constitute an LBW dismissal. Further, the decision-making phase incorporated two key sub-phases: *intentions* and *reasoning*. These goals and sub-phases are
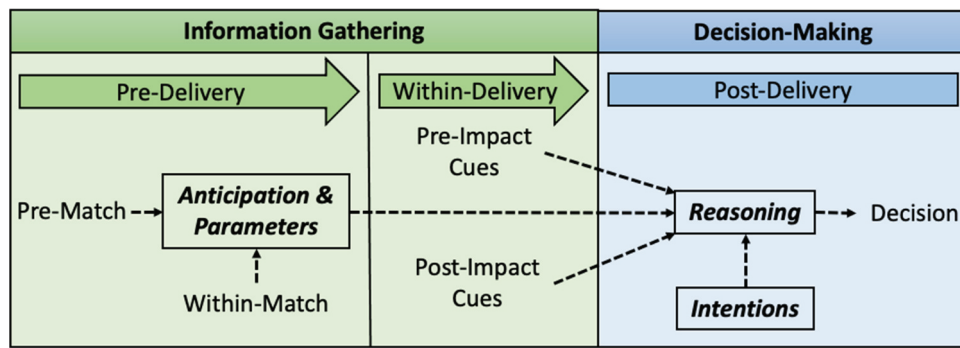
Figure 1. A conceptual model of elite cricket umpires' LBW decisions.

higher-level conceptualisations and are therefore evidenced within the relevant phases, rather than separately (see Figure 1). In the following section, each phase of the LBW decision process will be conceptually defined and evidenced with extracts from the interviews to assist with transparency (Russell et al., 2019).

Information gathering

"Information Gathering" refers to the process reported by the umpires whereby they gather information from various sources to inform their LBW decisions. Umpires reported using in their decisions, information from sources available both pre-delivery and within-delivery. Umpires reported implementing specific within-delivery gaze strategies to aid in this information gathering process. In the following section, we outline how Information Gathering plays an important role in guiding expectations of what might happen to ensure that the umpires focus on the most important sources of information in that scenario. Furthermore, we highlight how this information helps umpires to develop an *a priori*, context-specific framework for determining what will constitute an LBW dismissal. To conclude this section, we outline heuristics that umpires say they use to overcome the limits of perception.

Pre-delivery

The main sources of information that umpires draw on during the pre-delivery period include the pitch, players, and game format. These sources of information are useful for guiding umpires' expectations of what might occur in order to ensure they are attending to the cues which have the highest utility.

The pitch

Prior to a match, umpires source information about the pitch during a pre-match pitch inspection, and via discussions with curators, to develop an understanding of how the ball might interact with the pitch (i.e., the playing surface) during the upcoming match (e.g., the amount that the ball would be expected to spin and bounce). Umpires were interested in the preparation of the pitch, and how environmental constraints may have influenced its' characteristics. These conversations played an important role in allowing umpires to refine how they interpret key information that is available during the game. For example,

the ball may land in one position and yet lead to different LBW outcomes depending on the condition of pitch:

> The preparation of the the, the pitch, the conditions, um, you know some pitches are known to be um, they're low and slow, is it a wearing pitch? What part of the season is it? Early on they've had the Winter sports played on it, so it's a bit of a, a rough, rough sort of surface, so uh, the ball's going to keep low, do a few things untoward. This is probably the best pitch, this is probably the best wicket in, in Sydney. So, you know, we expect genuine bounce and carry, and, you know, that'll be factored into how and what decisions we make. (Umpire B)

Similarly, the historical reputation of individual grounds influences how different LBW outcomes can be reached:

> Some are bouncier than others. If you're at The Gabba [*a ground in Brisbane*] or Perth, it could hit you under the knee-roll and still go over. But places like Sydney, or even the MCG [*Melbourne Cricket Ground*], it can hit you on the knee-roll and and not go over. (Umpire D)

The characteristics of a pitch may not only impact the parameters that umpires set (i.e., in terms of what needs to happen for a batter to be out LBW) but may also influence the likelihood that an LBW appeal will occur. This likelihood can then impact the umpire's information gathering intentions. For example, if the likelihood of an LBW is lower, umpires can choose to focus on sources of information that might be more useful for other decisions more likely to occur than LBW:

> Flat decks [*pitches*] is a great example. If it's a flat deck there won't be much bowling at the stumps. They're gonna utilize the short-pitch bowling a lot more. So, that's usually their main tactic, so you have to adjust to that as well, 'cause then you're starting to think, actually, you know, what it's gonna be. I've got to be looking at the gloves. I've got to be looking for a little touch down the leg side, then up in the hip. Your, focal points change a little bit in those sorts of scenarios. (Umpire J)

Importantly, the parameters relating to how the pitch will behave are dynamic. Due to the fact that cricket is often played over multiple days, umpires update their expectations relating to pitch behaviour as the condition of the pitch changes given that an older pitch would be expected to bounce less. Umpires also utilise information that they gather while at square leg (side on to the pitch) to monitor how high the ball is bouncing to refine their LBW parameters:

> On day four, there's lower bounce. So again, you're looking when you're at square leg, you're just, okay. On day one, they were clearly going, you know, stump high or just over, now they're below the knee roll. (Umpire I)

In summary, umpires gain information about the pitch both before and during a match to estimate the likelihood of an LBW dismissal and to develop parameters for what would constitute an LBW. These parameters and expectations are context-dependent and are updated as the umpires gain more information about the pitch.

The players

Umpires also consider the intentions, capabilities, and susceptibilities of players when making LBW decisions. Umpires reported viewing video footage of the bowlers they would be adjudicating in their next match to identify what the bowler might do (e.g., the strategies they might implement to dismiss the batter, or the types of deliveries they tend to bowl). This is exemplified by the following quote:

> . . . if I'm coming into a game with guys I've not umpired before or who I've not seen before I'll have a bit of a look at them on AMS [*a video replay database*] just to see whereabouts on the crease they deliver the ball, um what their action's like, what, you know, what the ball does when they bowl. (Umpire A)

Umpire J elaborates on this idea and says that by identifying a bowler's action capabilities, an umpire can be alert for potential outcomes (*anticipation*). Thus, better umpires utilise pre-event information to recognise situations that require them to be prepared for an appeal:

> He's got a really massive late in-swinger, particularly with a pink ball. Now, if he's keeping it outside off stump, you're almost telling yourself . . . you're just reminding yourself, just stay focused. You know what he can do. (Umpire J)

Another way that umpires utilise information about the players is to identify batters who, due to their technique or playing style, have a history of being prone to LBW dismissals:

> You've just got to go in with the increased awareness that their style or their way of playing, they're, they're susceptible to it. And, if um, if the op-, if it does come up, then you're not, sort of, as either surprised, or taken back by what's happening. (Umpire B)

Several umpires noted that while it is important for umpires to be alert to potential outcomes, they must not *pre-empt* giving a batter out (intentions):

> I really don't want to pre-empt it, 'cause it's, it's dangerous to do so . . . if you're looking for something to happen, you'll make it happen. So, when the ball hits the pad and you're thinking "he's gonna get him, he's gonna get him", your finger will go up before you realize, "well hey, hang on, that was too high". So, whilst having an appreciation of the, the shapes that he's bowling, I don't like to pre-empt what's he try- what- what's going to occur. (Umpire H)

In summary, umpires seek to understand both the bowler's action capabilities, and the batter's susceptibilities, in order to ensure they are attuned to relevant sources of information if an LBW appeal eventuates. Importantly, however, umpires clarified that an expectation that an appeal is *likely* to occur should not be extended to an expectation that the batter *will* be out.

Game format

Umpires also identified that their information gathering priorities change depending on the format of the game. In this quote, Umpire B identifies that in the shorter form of the game (T20), umpires' intentions are shaped by the need to focus on fielding restrictions, and other more likely outcomes:

> . . . LBWs, caught behinds, catches to the slips region, are more pre-prevalent in the longer format game. So, you are really focusing on, on those, and really making sure you're switched on for that. When you get to the shorter formats, again, first couple of overs the ball's swinging around a little bit, you might have that for the first 10 overs, but then after that, your focus is really shifting to potential run outs, stumpings, you've got restrictions but they're not, not dismissals, whereas, the, the types of dismissals are sort of weighted differently in the terms of the different formats. (Umpire B)

Umpire B goes on to elaborate that this is at least in part due to players' behaviours in different match formats. In this respect, rather than attempting to focus on all information in the performance environment for all possible outcomes, umpires instead calibrate their attention to specific information that will be relevant to potential modes of dismissal whose probabilities differ based on competition format. Umpire B explains:

> . . . the players in shorter formats are trying to minimise runs compared to take the wickets . . . . In the longer format you've got to bowl them out twice, to win the game . . . So, the focus is always on taking the wickets. (Umpire B)

A key way umpires achieve this focus is by using within-match contextual information to guide anticipation. Umpires themselves describe this skill as *knowing the game*, which involves identifying what players are trying to achieve. *For* example, Umpire G explains how understanding a bowler's intentions can allow the umpire to start to understand whether a combination of cues will come together appropriately to lead to an LBW:

> You know when a bowler's trying to set a batsman up. What they're trying to achieve. You get to know players and what they're gonna do. (Umpire G)

In summary, umpires develop *a priori*, context-specific pre-delivery information parameters related to individual (e.g., the players action capabilities and intentions), environmental (e.g., pitch conditions) and task (e.g., game format) constraints that provide a framework to interpret within-event cues. This information can also shape umpires' expectancies, and subsequently their information gathering priorities. Caution though is required to ensure that the expectancies developed through this information gathering do not lead to the umpire pre-empting the outcome and biasing their decisions. These decision parameters and information gathering priorities are dynamic, and are updated as the game progresses, the pitch deteriorates, and as perceived player intentions and capabilities change.

Within-delivery

In this section, we highlight the sources of information that umpires rely on *within-delivery* and how they gather this

information (e.g., gaze strategies). We conceptualised "within-delivery information" as information that umpires gather from the moment the bowler begins to run in to bowl, until after the delivery has concluded, allowing the umpire to use all the available information to make their decision. We also identified the heuristics that umpires use to "fill in the gaps" when information is not available or is ambiguous.

The players

Umpires begin to gather within-delivery information as the bowler runs in before they release the ball. For example, umpires identify where the batter is standing in relation to the stumps (e.g., alignment, and distance from the stumps) to set decision parameters about what would need to occur for an LBW to occur:

> Obviously, a batter who is taking guard on off stump is more likely to get outside the line if the ball is hitting the pads, and if he's playing a stroke, that negates an LBW decision ... the second thing is in relation to the striker, is how far/where they're standing in relation to their depth from the wickets. So are they standing, most batsmen stand with their back foot on or around the popping crease. Some stand a little bit behind, some stand in front. So obviously, the further forward you are, the less likely the chance, or the more doubt there is. (Umpire C)

Umpires also take into consideration the batter's movement when playing the ball to consider how their actions impact the likelihood of the ball hitting the stumps:

> I see a guy hit just on top of the knee roll from a spinner for example, the wickets not bouncing that much, and I look at it and I say, look, if, if he's on the crease there, that's out. But if he's a foot forward of the crease, that's probably going over the top. (Umpire H)

Umpires also consider the position of the bowler at the point of release in relation to the batter's position to again consider the parameters of what would need to happen for a batter to be given out LBW. Umpire F identified the importance of this factor here:

> You've actually got to be able to have an idea of what angle, where does this need to hit the batter to be going on and hitting the stumps? And if the bowler is quite wide, bowling wide, like just say he's bowling round the wicket [*right arm bowler from the right side of the pitch to a left-hand batter*] and he's bowling wide of the crease, then really the only way it can be hitting the stumps is if it hits him in front of, you know, in front of off stump or, or at best middle and off. And that's a ball that's going straight. So, one of the things I do in that circumstance, if I see the bowler is about to go around the wicket I might go and stand where he's bowling, and just to have a quick look at the other end and see if the batter is batting on middle stump what's the line the ball's going to go. So generally you find that in that situation, it's really got to hit him in line with off stump for it to be hitting leg stump. (Umpire F)

Heuristics

Cricket umpires consider the limits of perception when making LBW decisions, and acknowledge that they may be presented with incomplete or unreliable information. For example, several umpires mentioned that they often have to rely on what they see rather than what they hear (especially in front of crowds). To overcome these difficulties, the umpires have developed several heuristics ("mental shortcuts") to assist in how they process perceptual information. For example, the umpires identified that it is often difficult to hear if the ball has hit the bat (in which case the batter cannot be out LBW). However, how the ball moves after impact with the batter can be a visual cue to what has happened:

> If the ball goes, bang, straight down, generally, there's, there could be some bat involved, 'cause it just drops it dead, straight down. Generally, there's an inside edge onto the pad and then that goes straight down. (Umpire G)

Similarly, the umpires have identified that post-impact ball movement can also be used as a heuristic to estimate the flight of the ball, had it not been intercepted. For example:

> ... if the ball comes in and then really balloons or pops up in the air after it's made contact, it suggests that the ball trajectory is on the rise. It's going up. So, if that's occurring, how far forward are they? And then obviously, still how far it's got to go to the stumps. There's a good chance that that ball may be going over the top. (Umpire B)

Similarly, Umpire H stated:

> ... the one that's going that bounces off and shoots down leg-side which is a warning sign, that's a danger, that's thinking, whoa, it's probably missing leg. (Umpire H)

Further, the movement of the wicket-keeper in response to the delivery can be informative as to the ball's trajectory. For example, one umpire identified:

> With the better keepers, that's a good gauge too if they're starting to fly down leg then perhaps the ball's gone quite a distance. (Umpire E)

Another source of information that umpires use is the strength of the appeal from the fielding side. Specifically, the umpires identified that if the appeal from the fielding side is weak or stifled, it is likely that there is something amiss. That is, a stifled appeal can be a useful heuristic to identify that the umpire may have missed a key piece of evidence that could rule out an LBW dismissal, or that the fielding team doesn't think that it is out:

> You might have two of the three slip fielders arms up, appealing like you wouldn't believe. And then you've got one at first slip just shaking his head, like, yeah, that can't be out, it's off the bat. That can kind of give it away that, have we missed an inside edge? Or no, clearly that's too high. (Umpire G)

Finally, umpires identified that one of the most common issues in LBW decisions is the judgement of height. More specifically, the umpires identified that they have a tendency to underestimate the height of the ball at the point of impact with the batter. To overcome this, some umpires incorporated the fact that the ball is often higher than their vision would suggest:

> Inevitably when you watch it on replay the ball is always one to two balls, uh, higher than what you actually see. Okay, so it's really important to recognize that you might have seen it at a certain height, but inevitably there will be a margin of error there. (Umpire E)

In summary, umpires have identified several within-delivery cues that can be utilised as heuristics to account for gaps in perception, or to identify moments where they need to further consider the information they have at hand.

Gaze strategies

During a given delivery, umpires report using intentional pre-planned perceptual strategies that help them to gather information. Nine of the umpires, rather than trying to "track" the ball with their eyes, reported implementing what can be understood as a gaze-anchor strategy where they direct their gaze towards particular position(s) in space (see Ramachandran et al., 2021). Umpires reported different gaze-anchor points as the delivery unfolds, such as looking at the top or the base of the stumps, the batter's feet, the batter's pad, and the area in front of the batter. For example, Umpire J reported focussing on the batter's feet as the bowler is running in, before looking at where the bowler's foot lands, and finally returning the gaze to the batter's feet:

> I'm down around the shoes or the bat, base of the stumps, but I'm in that area, and that'll be a hard focus. Quickly flick down to the, the popping crease, I'll see where the ball's being delivered from, flick back. And when I flick back, obviously we're waiting for that ball to enter into a zone. (Umpire J)

Two umpires also reported adjusting their gaze-anchor in response to changes in the condition of the pitch. For example:

> "My eyes will be focused on the top of the off-bail at the start of the match. But as the pitch deteriorates and the ball starts to keep low, I will move that point down a bit to make sure I'm looking where the ball might go". (Umpire H)

Only one umpire reported attempting to follow the ball with their eyes to gather information about the trajectory of the ball (anticipation):

> . . . my eyes pick up the flow of the ball. And then I then try and work out which is the shiny side, because in a normal delivery, the ball will swing away from the shiny side. So, if the shiny side is towards the batter, it's more likely to go away from him, unless it's reversing. (Umpire C).

Decision-making

In this section, we describe how umpires' decision-making *intentions* shape how they make LBW decisions. Further, we conceptualise umpires' LBW decision-making as a process of *reasoning*, where umpires combine *intuitive* judgements with explicit *post-hoc interrogation* of within-delivery information to determine whether a batter is out, based on what they judge would need to constitute an LBW dismissal in that particular context.

Intentions

One umpire acknowledged that "the planets really have to align for the ball to actually hit the stumps, after it's impacted the pad" (Umpire H). This understanding of how difficult it is to achieve an LBW dismissal can shape an umpire's intentions, and is manifested in a general tendency to judge a batter as "not out" in the presence of doubt. Similarly, umpires suggest that the game expects officials to err on the side of responding not out:

> I'd rather let a guilty man go than put an innocent man away. A batsman only gets once chance and to guess them out, that's not the way the game is supposed to be played. So, when I do talk myself out of it, it's usually an out decision being talked into a not out, rather than the other way around. (Umpire H)

The within-match context of a decision can also shape umpires' intentions. For example, decisions made early in a long format of the game are "setting the tone" (Umpire E) for what will constitute an LBW dismissal throughout the game:

> Early on in the match you don't want to be giving ones that are dubious in terms of height, because then you put yourself in a precarious position for the rest of the match. (Umpire E)

Similarly in the shorter formats, the timing of a decision can further impact the umpire's intention of giving the batter the benefit of the doubt:

> Say it's a tight LBW decision, you go, "Okay, well if I just say, "not out", 'cause it's 50/50 at this stage, they've got two balls left to go, it's not really going to be a big talking point, or they're not really going to focus in on it", but if it's early on and you say not out, and then the batter goes on to score another 60, 70 runs, there's different impacts on the game. (Umpire B)

Reasoning

After the information-gathering phase, umpires must determine whether the batter is out or not based on the available sources of information. The umpires identified elements of this process that can be categorised into two distinct sub-phases: *intuition* and *post-hoc interrogation*. At the moment of an LBW appeal, the umpires describe an initial "gut-feeling" of whether the batter is out or not. For example, one umpire stated that an LBW needs "to rip my throat out if I'm going to give it out" (Umpire E). Similarly, umpires will experience LBW decisions where they "know if it's not out very quickly" (Umpire E). Conversely, in some cases the umpire will feel general uncertainty or doubt, which then requires further interrogation:

> A lot of it for me is gut instinct. Often when I'm making an LBW decision, I'll just go, there's something wrong with that, it's not out. And I don't really know why. And most often that gut decision, your gut feeling was correct. You know, he had got an edge, I hadn't really heard it. (Umpire H)

In some cases, however, umpires report that the intuitive feeling of an "out" or "not-out" call may not be reliable. For example, in situations where the umpire is on high-alert for an LBW appeal due to pre-delivery information (e.g., batter susceptibility), they may *expect* that the batter will be out LBW. To avoid this, umpires will interrogate the available within-delivery information to search for a reason to override their initial gut feeling:

> Bang, it's LBW, the gut tells me that that's crashing into the stumps and it's just taking that extra breath, I suppose, while I was processing. Hang on, there's more information there. There's more information. There's a noise. What's the noise? It's obviously quickly, but you know, straight away it's in it, he's hit it. He's hit it. That's not out. Don't give it out!. (Umpire I)

In summary, cricket umpires process information from multiple sources first intuitively, before engaging in deeper post-hoc interrogation and contemplation. During this interrogation process, umpires determine whether the within-delivery information has met the context-specific parameters they have set as to what would constitute an LBW dismissal in a given

moment (e.g., where the ball would need to bounce and hit the batter). During this process, umpires' intentions to give the batter the benefit of the doubt means that they are generally searching for a reason to give the batter not out. Issues arise when pre-delivery expectancies are weighted too heavily at the cost of within-delivery information that could legitimately negate an LBW appeal.

Discussion

This study used a reflexive-thematic analysis approach to investigate the beliefs and perceptions of elite-level cricket umpires to understand key information and processes they adopt when making LBW decisions on-field. To do so, we undertook interviews to interrogate: (i) the sources of information that cricket umpires use when making LBW decisions, and (ii), how umpires incorporate this information into their decision-making process. Following interviews with elite-level umpires we proposed two main phases in the process of making LBW judgements: an *information gathering* phase and an actual *decision-making* phase.

During the information gathering phase, umpires incorporated multiple sources of information into their decision process (Plessner et al., 2009) to identify pre-delivery information. This pre-delivery information worked to help specify a priori contextually specific parameters related to the individual players (e.g., their action capabilities and intentions), the environmental (e.g., pitch conditions), and the task (e.g., game format), interacting to provide a framework for the umpire to interpret information within the delivery itself. That is, umpires develop contextually dependent parameters or expectations for what would need to occur for a batter to be dismissed LBW (e.g., where the ball should land and hit the batter based on those constraints). We also found that pre-delivery information can shape umpires' expectancies, and subsequently the way that they gather information (e.g., focus of attention, gaze strategies) and use heuristics to "fill in the gaps" in perception (MacMahon & Mildenhall, 2012). Their decision parameters and information gathering priorities are dynamic, and are updated as the game progresses, as the pitch deteriorates, and as player intentions and capabilities are perceived to shift.

During the *decision-making* phase, umpires report first making an intuitive judgement before engaging in a deeper post-hoc interrogation and contemplation of their intuitive judgement. During this interrogation process, umpires determine whether the information available within the delivery has met the contextually specific parameters they set prior to the delivery as to what would constitute an LBW dismissal (e.g., did the ball impact the pad too high to be hitting the stumps on this pitch). In line with their intentions to judge the batter "not out" in the presence of any doubt, this deliberative process is often aimed at searching for a reason to give the batter not out (Adie et al., 2020). Of significance, this is a continuous iterative process throughout that match. That is, specific combinations of information that potentially indicate an LBW decision early in the game, may later in the game no longer characterise an LBW decision.

We also found that umpires decision-making priorities/intentions were shaped by the format of the game. Adie et al.

(2020) found that umpires' LBW decisions are less accurate and more likely to be judged as "not out" in T20 matches. One possible explanation was that the added pressure of the larger crowds in T20 matches could lead umpires to give the batter the benefit of the doubt more often. The findings of the present study provide further explanation for this behaviour. Umpires reported that player intentions in T20 matches (e.g., prioritising stopping runs rather than taking wickets) may result in a reduction of the likelihood of an LBW appeal. As a result, umpires focus their attention on information that is more likely to be useful (e.g., fielding restrictions). Subsequently, umpires may encounter more uncertainty when making LBW decisions in T20 matches, and be more likely to give the batter the benefit of the doubt.

The model of umpire decision-making presented in this study could have broader implications for understanding officiating in other sports. Officials in other sports such as soccer and rugby union are likely to also engage in information gathering behaviour prior to an event itself and to employ similar decision-making strategies. As such, future research could apply the model presented here to different domains. For example, football referees may gather information about players' action capabilities and susceptibilities in order to "stay ahead of the game", similar to assertions by MacMahon and Mildenhall (2012) that referees may use knowledge about a player's speed when making offside judgements. In fact, Jones et al. (2002) showed that association football referees were more likely to award red and yellow cards (but not more fouls) if a team had an aggressive reputation, suggesting that referees intentions could shape how they manage infractions. In rugby, referees may review scrum footage to identify common areas that might cause infractions and direct their attention to these areas. For example, Moore et al. (2019) found that rugby officials tend to direct their gaze to the centre of the pack (i.e., front rows & bind locations) rather than the outer areas, and suggested that this may be related to the fact that a high proportion of scrum infractions occur in this area. This could be particularly important for decisions where referees must make a predictive judgement as to what may have occurred (e.g., judging a genuine goal scoring opportunity or when looking for the cause when a scrum collapses).

Our work also outlined key methods and processes that umpires use to undertake LBW decisions. For example, almost all umpires reported employing an intentional gaze-anchor strategy to pick-up vital information for making LBW judgements. Similar findings have been reported by Ramachandran et al. (2021), though our findings highlight important caveats. First, Ramachandran et al. (2021) required participants to report the specific location that the ball bounced, hit the batter, and would have passed the stumps had it not hit the batter. This approach assumes that umpires explicitly process these details when making an LBW decision. The findings of our study suggest that umpires' LBW decisions are instead, at least initially, an intuitive judgement of the "outness" of the appeal. Therefore, requiring umpires to explicitly recall these elements may not be representative of what they actually do

in the real world. That is, requiring umpires to recall the location of the ball (at the bounce, impact with the pad, and the stumps) may have led them to focus their attention in a way that is not representative of the performance environment i.e., the instructions might have altered umpires' gaze behaviour. Further, our study found that the context in which a decision occurs shapes both the umpires' expectancies, and their information-gathering priorities (focus of attention). Moreover, the absence of any contextual information (i.e., expectations and priorities) may have also altered the behaviour of the umpires in the Ramachandran et al. study. Given recent advances in portable eye-tracking technology, these issues could be overcome by recording umpires' gaze behaviour in the performance environment (e.g., in a match context). These findings highlight the importance of considering contextual information when exploring expertise in sports officiating more generally, rather than focussing on a single decision or cue in isolation (e.g., the flight of the ball in this context). Particularly as the importance of cues is contextually situated over the course of the match, and conditional on the relationship between factors at any given moment. Further, these findings could influence how cricket umpires are trained. For example, umpires could be presented with training that highlights the multiple sources of information that can assist in LBW decisions (e.g., pitch condition, batter position), and engage in practical activities designed to draw attention to these factors. Further, future research could test the efficacy of umpire accreditation programs that include the information presented here (e.g., multiple sources, gaze anchoring).

Research implications from this work include insight from umpires about potentially often *underestimating* the height at which the ball impacts the pads. Previous research in fast-ball sports has shown that experts compensate for delays in visual processing by extrapolating the location of the ball in advance of its motion (e.g., Nakamoto et al., 2015). That is, memory of the final position of a moving object is distorted further along its path of motion (i.e., representational momentum). In the context of LBW decisions, the ball will generally hit the batter on the pads, after the ball has bounced, while the ball is still rising. As such, previous work in representational momentum would predict that rather than underestimating the height of the ball as reported in this study, the umpires would rather recall the point of impact as being further along the trajectory of the ball and subsequently *overestimate* the height of the ball when it hit the batter. This discrepancy warrants further quantitative investigation.

The main limitation of this study is that it relied on retrospective recall during interviews. It is possible that umpires do not remember events accurately (Whitehead et al., 2015), and that they do not have conscious access to the information that they use or the gaze strategies they employ (Koedijker & Mann, 2014), or that they may add meaning to their decision process after the event. To overcome this, future research could employ "Think Aloud" protocols to investigate umpires' decisions closer to the actual event (see Whitehead et al., 2015).

Conclusion

This study examines the manner in which sport officials integrate prior and real-time information to make predictive judgements when officiating. More specifically, it presents the first overview of the LBW decision-making process from the perspective of elite cricket umpires. Umpires report using a series of pre-delivery information-gathering strategies to set parameters and guide their expectations about how they will make their LBW judgements within upcoming scenarios. Further, we showed that umpires' decisions are shaped by intentions (e.g., giving the benefit of the doubt) and involve both intuitive judgements and post-hoc reasoning. Finally, umpires engage in explicit gaze-anchoring strategies when gathering within-delivery information. These findings highlight the importance of incorporating relevant contextual information into future studies of expertise in sport officiating. Studies that lack contextual information may fail to tap into the true nature of expertise in sports officiating. The model presented here is likely to add relevance for officiating in other sports and may lead to the development of training interventions to enhance the information-gathering and decision-making capabilities of sports officials.

Disclosure statement

Funding

ORCID

Joshua M. Adie http://orcid.org/0000-0002-9377-1159

References

Adie, J. M., Renshaw, I., Polman, R., Thompson, M. B., & Mann, D. L. (2020). When in doubt, it's not out: Match format is associated with differences in elite-level cricket umpires' leg-before-wicket decisions. *Psychology of Sport and Exercise*, 51, 101760. https://doi.org/10.1016/j.psychsport. 2020.101760

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77–101. https://doi.org/10. 1191/1478088706qp063oa

Braun, V., & Clarke, V. (2019). Reflecting on reflexive thematic analysis. *Qualitative Research in Sport Exercise and Health*, 11(4), 589–597. https://doi.org/10.1080/2159676X.2019.1628806

Braun, V., & Clarke, V. (2020). One size fits all? What counts as quality practice in (reflexive) thematic analysis? *Qualitative Research in Psychology*, 18(3), 1–25. https://doi.org/10.1080/14780887.2020.1769238

Braun, V., & Clarke, V. (2021). To saturate or not to saturate? Questioning data saturation as a useful concept for thematic analysis and sample-size rationales. *Qualitative Research in Sport Exercise and Health*, 13(2), 201–216. https://doi.org/10.1080/2159676X.2019.1704846

Brunswik, E. (1955). Representative design and probabilistic theory in a functional psychology. *Psychological Review*, *62*(3), 193–217. https://doi.org/10.1037/h0047470

Chalkley, D., MacMahon, C., & Ball, K. (2013). Predicting ball flight in cricket from an umpire's perspective. *International Journal of Sports Science & Coaching*, *8*(3), 445–454. https://doi.org/10.1260/1747-9541.8.3.445

Doherty, M. E., & Kurz, E. M. (1996). Social judgement theory. *Thinking & Reasoning*, *2*(2–3), 109–140. https://doi.org/10.1080/135467896394474

Goldstein, W. M. (2004). Social judgment theory: Applying and extending Brunswik`s probabilistic functionalism. In D. Koehler & N. Harvey (Eds.), *Blackwell handbook of judgment and decision making* (pp. 37–61). Blackwell Publishing.

Horsburgh, D. (2003). Evaluation of qualitative research. *Journal of Clinical Nursing*, *12*(2), 307–312. https://doi.org/10.1046/j.1365-2702.2003.00683.x

Jones, M. V., Paull, G. C., & Erskine, J. (2002). The impact of a team's aggressive reputation on the decisions of association football referees. *Journal of Sports Sciences*, *20*(12), 991–1000. https://doi.org/10.1080/026404102321011751

Kittel, A., Larkin, P., Elsworthy, N., & Spittle, M. (2019). Video-based testing in sporting officials: A systematic review. *Psychology of Sport and Exercise*, *43*, 261–270. https://doi.org/10.1016/j.psychsport.2019.03.013

Koedijker, J., & Mann, D. L. (2014). Consciousness and choking in visually-guided actions. *Phenomenology and the Cognitive Sciences*, *14*(2), 333–348. https://doi.org/10.1007/s11097-014-9398-3

MacMahon, C., & Mildenhall, B. (2012). A practical perspective on decision making influences in sports officiating. *International Journal of Sports Science & Coaching*, *7*(1), 153–165. https://doi.org/10.1260/1747-9541.7.1.153

Moore, L. J., Harris, D. J., Sharpe, B. T., Vine, S. J., & Wilson, M. R. (2019). Perceptual-cognitive expertise when refereeing the scrum in rugby union. *Journal of Sports Sciences*, *37*(15), 1778–1786. https://doi.org/10.1080/02640414.2019.1594568

Nakamoto, H., Mori, S., Ikudome, S., Unenaka, S., & Imanaka, K. (2015). Effects of sport expertise on representational momentum during timing control. Attention*Perception, & Psychophysics*, *77*(3), 961–971. https://doi.org/10.3758/s13414-014-0818-9

Pinder, R. A., Davids, K., Renshaw, I., & Araújo, D. (2011). Representative learning design and functionality of research and practice in sport. *Journal of Sport & Exercise Psychology*, *33*(1), 146–155. https://doi.org/10.1123/jsep.33.1.146

Plessner, H., Schweizer, G., Brand, R., & O'Hare, D. (2009). A multiple-cue learning approach as the basis for understanding and improving soccer referees' decision making. *Progress in Brain Research*, *174*, 151–158. https://doi.org/10.1016/S0079-6123(09)01313-2

Ramachandran, P., Watts, M., Jackson, R. C., Hayes, S. J., & Causer, J. (2021). Howzat! Expert umpires use a gaze anchor to overcome the processing demands of leg before wicket decisions. *Journal of Sports Sciences*, *39*(17), 1–8. https://doi.org/10.1080/02640414.2021.1908734

Russell, S., Renshaw, I., & Davids, K. (2019). How interacting constraints shape emergent decision-making of national-level football referees. *Qualitative Research in Sport, Exercise and Health*, *11*(4), 573–588. https://doi.org/10.1080/2159676X.2018.1493525

Russell, S., Renshaw, I., & Davids, K. (2020). Sport arbitration as an emergent process in a complex system: Decision-making variability is a marker of expertise in national-level football referees. *Journal of Applied Sport Psychology*, *34*(3), 1–25. https://doi.org/10.1080/10413200.2020.1831651

Sacheti, A., Gregory-Smith, I., & Paton, D. (2015). Home bias in officiating: Evidence from international cricket. *Journal of the Royal Statistical Society: Series A (Statistics in Society)*, *178*(3), 741–755. https://doi.org/10.1111/rssa.12086

Searston, R. A., Thompson, M. B., Vokey, J. R., French, L. A., & Tangen, J. M. (2019). How low can you go? Detecting style in extremely low resolution images. *Journal of Experimental Psychology: Human Perception and Performance*, *45*(5), 573. https://doi.org/10.1037/xhp0000628

Smith, B., & McGannon, K. R. (2018). Developing rigor in qualitative research: Problems and opportunities within sport and exercise psychology. *International Review of Sport & Exercise Psychology*, *11*(1), 101–121. https://doi.org/10.1080/1750984X.2017.1317357

Thompson, M. B., Tangen, J. M., & Allen, P. (2014). The nature of expertise in fingerprint matching: Experts can do a lot with a little. *Public Library of Science One*, *9*(12), e114759. https://doi.org/10.1371/journal.pone.0114759

Weed, M. (2017). Capturing the essence of grounded theory: The importance of understanding commonalities and variants. *Qualitative Research in Sport Exercise and Health*, *9*(1), 149–156. https://doi.org/10.1080/2159676X.2016.1251701

Whitehead, A. E., Taylor, J. A., & Polman, R. C. (2015). Examination of the suitability of collecting in event cognitive processes using think aloud protocol in golf. *Frontiers in Psychology*, *6*, 1083. https://doi.org/10.3389/fpsyg.2015.01083