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Howzat! Expert umpires use a gaze anchor to overcome the processing demands of leg before wicket decisions

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ABSTRACT

Cricket umpires are required to make high-pressure, match-changing decisions based on multiple complex information sources under severe temporal constraints. The aim of this study was to examine the decision-making and perceptual-cognitive differences between expert and novice cricket umpires when judging leg before wicket (LBW) decisions. Twelve expert umpires and 19 novice umpires were fitted with an eye-tracker before viewing video-based LBW appeals. Dependent variables were radial error (cm), number of fixations, average fixation duration (ms), final fixation duration (ms), and final fixation location (%). Expert umpires were significantly more accurate at adjudicating on all aspects of the LBW law, compared to the novice umpires ($p < .05$). The expert umpires' final fixation prior to ball-pad contact was directed significantly more towards the *stumps* ($p < .05$), whereas the novice umpires directed their final fixation significantly more towards a *good length* ($p < .05$). These data suggest that expert umpires utilize specialized perceptual-cognitive skills, consisting of a *gaze anchor* on the stumps in order to overcome the processing demands of the task. These data have implications for the training of current and aspiring umpires in order to enhance the accuracy of LBW decision-making across all levels of the cricketing pyramid.

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KEYWORDS
Perceptual-cognitive skill; expertise; gaze behaviours; decision making; gaze anchor

Cricket umpires make decisions regarding batter dismissals that consequently determine match outcomes (Sacheti et al., 2015). Of the modes of dismissals within cricket (see Marylebone Cricket Club, 2017), none has led to as much controversy and dispute as the leg before wicket (LBW) (Chedzoy, 1997; Sacheti et al., 2015; Southgate et al., 2008). LBW appeals occur when the ball strikes the batter on any part of their body (usually leg pads) apart from the bat and hands (Craven, 1998). For a bowler to dismiss a batter via LBW, the umpire must consider whether the delivery met a number of specific criteria (Crowe & Middeldorp, 1996). For every delivery, the umpire must initially determine whether the bowler's front foot grounds behind a line termed the crease (Adie et al., 2020).[1] Subsequently, the umpire must consider where the ball bounced (pitched), where the ball impacted the batter in relation to the stumps, and the more challenging judgement of whether the ball would have continued on its flight path to hit the stumps had the obstruction with the batter not occurred (Southgate et al., 2008). Therefore, the LBW rule appears to be one of the few regulations in sport where an official must determine what might have happened (would the ball have hit the stumps?) if other events did not occur (ball flight path being obstructed by the leg), which contributes to the dispute amongst players, media and followers of cricket (Crowe & Middeldorp, 1996). A number of contextual factors further add to the difficulty of the umpire's LBW verdict, such as the batter's stance (Southgate et al., 2008), dynamics of the delivery (spin and swing) and the ball's surface degradation (Chalkley et al., 2013). In spite of these challenges, it has been shown that professional umpires are highly accurate at making LBW decisions. Adie et al. (2020) examined 5578 decisions made in elite level cricket in Australia between 2009–2016 and found that umpires were correct 98.08% of the time. Further, when they broke down the match format, 96.20% of "out" decisions were correct in first-class cricket, 96.29% in One Day cricket and 86.15% in T20 cricket.

In 2008, the International Cricket Council (ICC) introduced the Decision Review System (DRS) into international cricket. This permits the captains of either team to refer a limited number of decisions made by the on-field umpires to the third umpire who is able to utilize an array of replays and technologies to assess the accuracy of the original decision (Borooah, 2013). Utilizing statistics from the DRS in international test cricket (July 2008 to March 2017) ESPN Cricinfo estimated that 74% of the reviews involved LBW appeals, with the overturn rate being at 22% (Davis, 2017, June, p. 1). Whilst initially this proportion seems high, it must be stressed that these officials are often placed under severe constraints when making these decisions (Chalkley et al., 2013; Southgate et al., 2008). More specifically, in certain scenarios, umpires must process information related to the ball's (7.29 cm) flight that can travel at velocities up to 95 mph over 20 m. These constraints offer umpires approximately 543 ms to process the

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[1]Since 2020 this task was no longer performed by international umpires after a number of controversial events, and therefore this decision is made by the third umpire with use of TV replays.

multitude of visual and auditory information required to make a single decision (Southgate et al., 2008). To help combat these processing demands, it has been suggested that umpires utilize specific perceptual-cognitive behaviours that contribute to the increased likelihood of correct decisions (Southgate et al., 2008).

Cricket batters face similar temporal constraints, and researchers have highlighted differing gaze behaviours to attempt to overcome these demands (Croft et al., 2010; Land & McLeod, 2000; Mann et al., 2013). Upon ball release from the bowler, expert batters generally make an anticipatory saccade to its pitching point (Croft et al., 2010). However, following the ball pitching, two distinct strategies were identified. Land and McLeod (2000) reported that batters made a saccade towards the ball about 200 ms after its bounce before attempting to pursuit track the remainder of its flight, whereas batters from Mann et al. (2013) made a saccade towards the bat at the point it contacted the ball. The variability in ball tracking techniques utilized within cricket batting was highlighted by Croft et al. (2010), who reported that whilst individual batters displayed a consistent gaze strategy, these strategies varied greatly between participants with a mixture of saccades and pursuit tracking being used at different time points before and after the ball bounced.

When tracking a projectile, such as a cricket ball, it has been suggested that use of a series of fixations or saccades limits the amount of information that can be efficiently processed (Ludwig, 2011). Therefore, in these scenarios, a single stable fixation can enable more accurate performance (Wilson et al., 2015). In a recent review, Vater et al. (2020) identified 3 unique stable gaze strategies utilized by athletes that have similar characteristics but have a functional difference: 1) foveal spot; 2) gaze anchor; and 3) visual pivot. First, the *"foveal spot"*, is a strategy that involves an individual processing information with their visual attention directed towards a central cue with the aim of accurate information processing via the fovea (Vaeyens et al., 2007). Second, the *"gaze anchor"* is a location in the centre of several critical cues in order to distribute attention to several cues using peripheral vision. Importantly, the actual fixation location may not contain any task-specific information that is being process by the fovea, but is equidistant to the pertinent cues (Vansteenkiste et al., 2014). Third, the *"visual pivot"* acts as a centre point for a series of fixations to important locations to minimize the retinal distance between critical cues. Similar to the gaze anchor, it is possible that there is no task-specific information located at the visual pivot, but it is the most efficient central position for subsequent visual scanning (Ryu et al., 2013). Given the spatial-temporal constraints that cricket umpires are under, making numerous judgements and predictions in less than 550 ms (Southgate et al., 2008), a stable fixation, such as a gaze anchor, may be the most efficient and effective strategy to process the relevant information.

Therefore, the aim of the current study was to establish whether skill-based differences exist between expert and novice cricket umpires when making judgements that are crucial for LBW decisions. Furthermore, this study aimed to elucidate whether expert umpires possess specialized visual strategies that enhance LBW decision-making. It was predicted that: 1) expert umpires will outperform novice umpires on adjudicating of all three components of LBW appeals; 2) expert umpires will utilize a specialized visual strategy consisting of fewer fixations of longer durations to more informative locations (Williams, 2009); and, p. 3) expert umpires' final fixation before the ball strikes the batter's pad will be a *gaze anchor* between a *good length* and the middle of the stumps.

Method

Participants

Participants were 12 expert umpires (M = 58 years of age, SD = 10) and 19 novice umpires (M = 42 years of age, SD = 7). The expert umpires had officiated in organized cricket at elite club (n = 9), minor counties (n = 2) and first-class cricket (n = 1). The expert umpires had a mean of 11 years (SD = 5) umpiring experience, accumulated over a mean of 100 matches (SD = 12). Additionally, the expert umpires had accumulated a mean of 279 (SD = 390) matches of playing experience in competitive club cricket. The novice participants had not umpired in any form of organized cricket. Participants gave their informed consent prior to taking part in the study and the study was approved by the Research Ethics Committee of the lead institution.

Task & Apparatus

Visual search behaviours were recorded using the TobiiGlasses2 corneal reflection eye movement system (Tobii Technology AB; Danderyd, Sweden). The test film was recorded at the Marylebone Cricket Club Cricket Academy. Video footage from an umpire's perspective was recorded using a Canon VIXIA HFR706 camera (Tokyo, Japan). The camera was positioned in line with middle stump 1.00 m away from the non-strikers popping crease. A right-handed batter who competes in the Worcestershire Premier League faced a number of deliveries delivered by a BOLA Bowling Machine (Bola Manufacturing Ltd.; Bristol, UK), from both around and over the wicket, at speeds between 65–80 mph. The batter was encouraged to play their "natural game" whilst facing these deliveries. Deliveries that struck the batter's pad were termed "appeals" and were reviewed via "Hawk Eye" (Basingstoke, UK), which reconstructed the ball flight characteristics should the obstruction not have occurred (Collins, 2010). Hawk Eye technology utilizes a theory of triangulation, which helps predict post ball-pad impact by measuring angles from the known points of the delivery's pre-impact flight (Duggal, 2014). In total, 20 appeals were used for the study with 11 being delivered from around the wicket, and 9 being delivered from over the wicket. A total of 16 appeals were deemed "out" and 4 deemed "not out" by Hawk Eye. Based on pilot testing, trials that were deemed too easy (85% and above in accuracy) were omitted from the final test film.

The footage was edited using Windows Movie Maker 2016 (Washington, USA). Each appeal formed one trial. For each trial, the trial number and position of the delivery (over or around the wicket) were each shown for 3.0 s and were followed by a 3.0s countdown. The video clip started 3.0 seconds before ball release, to represent the time for a bowler's run-up in a match scenario. The video clip continued for a further 3.0 s after ball-pad impact and was followed by a black screen, which signalled the end of the trial. The position of delivery for each trial was randomized to avoid any order effects. Additionally, five *catch trials* were randomly included in the test film, in which the batter successfully hit the ball so that participants were not always presented successive LBW appeals, and thus increased task realism.

Procedure

Participants were fitted with the TobiiGlasses2 eye tracker and were calibrated using a one-point calibration card held by the researcher 1.00 m away. The test film was projected by an Epson EB-7000 projector (Suwa; Japan) onto a large Cinefold Projection Sheet (Draper Inc; Spiceland, IN; 2.74 m × 3.66 m). Participants stood 3.20 m away from this display to ensure it subtended a visual angle of 12.8°, thereby replicating the height of the batter *in situ*. To cross-check calibration, participants viewed a still image of the pitch and were asked to direct their visual attention towards the stumps.

Initially, the researchers provided the participants with an overview of the LBW rule as per Marylebone Cricket Club guidelines, using standardized diagrams and text. To familiarize participants with the experiment protocol and response requirements, participants observed two familiarization trials, which showed LBW appeals similar to those in the test. Participants verbally predicted the three components of the LBW adjudication and then were given a handout that showed the Hawk Eye ball flight path. This familiarized participants with the scale of the Hawk Eye slides they would be adjudicating on for each trial. Following this, the testing period began. During the testing period, the participant viewed each trial and was then asked on a computer to position 3 balls (circles scaled to the Hawk Eye image) on a pitch image, once the display had gone black. Specifically, the balls were positioned on Hawk Eye slides corresponding to where they perceived the ball to: have pitched; impacted the batter's front pad; and where it would have hit/passed the stumps had its flight not been obstructed (refer Figure 1). Participants were asked to adjudicate the three variables in any order they saw fit and in a time frame similar to how they would generally make decisions in a match. Once participants had made a judgement for one of the LBW variables, they could not alter this decision. This procedure was repeated for all 20 trials. The whole collection process took approximately 40 minutes.

Measures

Response accuracy was determined by *radial error* (cm), which was defined as the Euclidean distance of the participant's judgement of ball impact with the *pitch, pad*, and *stumps* compared to the Hawk Eye data. This distance was scaled to quantify accuracy at a game scale (see Runswick et al., 2019). *Number of fixations* were measured from the onset of the trial until the offset of the trial. *Average fixation duration* (ms) was calculated by dividing the total fixation duration by the number of fixations of each trial. *Final fixation duration (ms)* was the duration of the last fixation prior to ball-pad impact until offset of the fixation or end of the trial. *Final fixation location* (%) was defined as the percentage of trials participant's final fixation was located on a specific area. Five fixation locations were coded: *good length, full length, short length, stumps, other location* (see Figure 2). The front pad of the batter occludes a large proportion of the stumps during a standard delivery. Therefore, when umpires directed their vision towards the batter's front pad, this was coded as "*stumps*" as the umpires typically maintained their gaze on the stumps after the batter had moved away, suggesting they were anchoring their gaze on the stumps as opposed to following the batter's pad.

Statistical analysis

Radial error data were analysed by a 2 (Expertise: expert, novice) x 3 (Decision: pitch, pad, stumps) mixed-factor analysis of variance (ANOVA). Number of fixations, average fixation duration (ms) and final fixation duration (ms) were analysed using separate 2 (Expertise: expert, novice) x 2 (Outcome: correct, incorrect) mixed-factor ANOVAs. Final fixation location was analysed using a 2 (Expertise: expert, novice) x 2 (Outcome: correct, incorrect) x 5 (Location: good, full, short, stumps, other) mixed-factor ANOVA. Effect sizes were calculated using partial eta squared values (ηp^2).

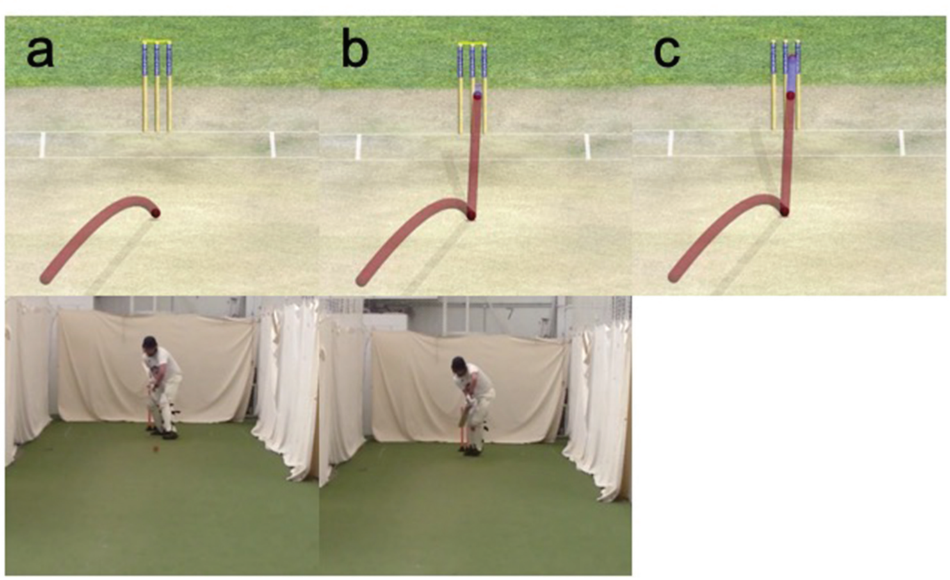

Figure 1. Frames from test film with associated Hawk Eye footage for: a) pitch, b) pad, and c) stumps.

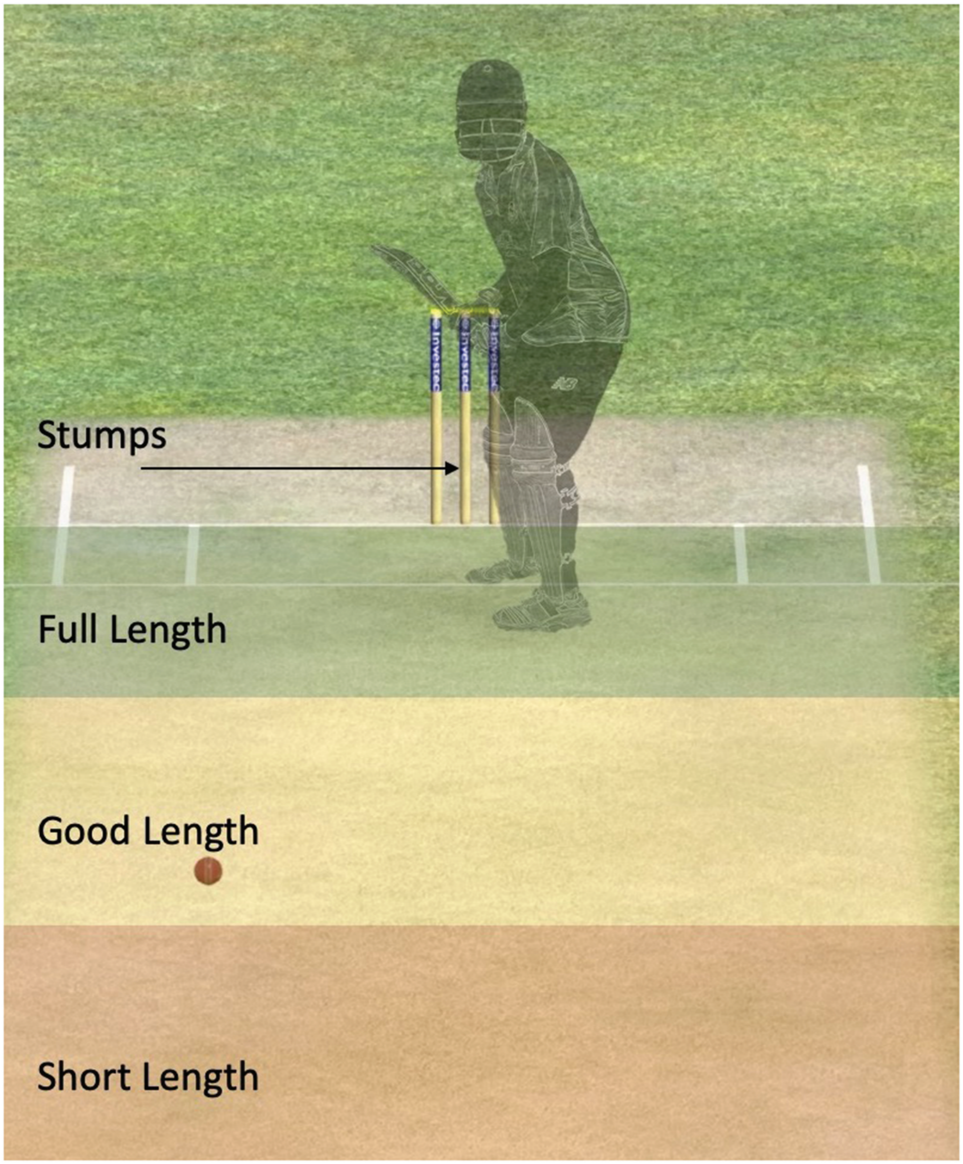

Figure 2. Final fixation locations: *good length, full length, short length, stumps.*

Greenhouse-Geisser epsilon was used to control for violations of sphericity and the alpha level for significance was set at .05 with Bonferroni adjustment to control for Type 1 errors. A priori power analysis using G*Power (Faul, Erdfelder, Lang, & Buchner, 2007) for a 3 × 2 within-between ANOVA indicated a total sample size of 28 was needed to detect a medium effect (f = 0.25) for the within-participant and interaction effects. The pool of expert umpire participants was limited so it is important to note that statistical power for tests of between-participant effects was only sufficient to detect larger effects (f > 0.42).

Results

Radial error (cm)

There was a large main effect of expertise, $F_{1,29} = 8.88$, $p = .01$, $\eta p^2 = .23$ (see Figure 3). Novice umpires had significantly higher error (M = 25.87 cm, SE = 1.31) than the expert umpires (M = 19.61 cm, SE = 1.64). The novice group were less accurate at determining the ball's impact with the *pitch* (M = 24.60 cm, SE = 2.29), *pad* (M = 22.65 cm, SE = 1.83) and *stumps* (M = 30.35 cm, SE = 2.02), compared to the expert group (pitch: M = 20.57 cm, SE = 2.88; $p < .05$; pad: M = 16.15 cm, SE = 2.30; $p < .05$; stumps: M = 22.11 cm, SE = 2.55; $p < .05$). There was also a large main effect of Decision, $F_{2,58} = 4.80$, $p = .01$, $\eta p^2 = .14$. Radial error was significantly higher for *stumps* (M = 26.23 cm, SE = 1.63) compared to *pad* (M = 19.40 cm, SE = 1.47; $p < .05$). There was no significant Group x Decision interaction $F_{2,58} = .46$, $p = .63$, $\eta p^2 = .02$.

Number of fixations

The main effects of expertise, $F_{1,27} = 1.536$, $p = .23$, $\eta p^2 = .05$, and outcome, $F_{1,27} = 2.183$, $p = .15$, $\eta p^2 = .08$, were small to moderate hence were statistically non-significant. This reflected a similar number of fixations for correct trials (M = 4.4, SE = .32) and incorrect trials (M = 4.7, SE = .33); and between expert (M = 5.0, SE = .47) and novice umpires (M = 4.2, SE = .39). The

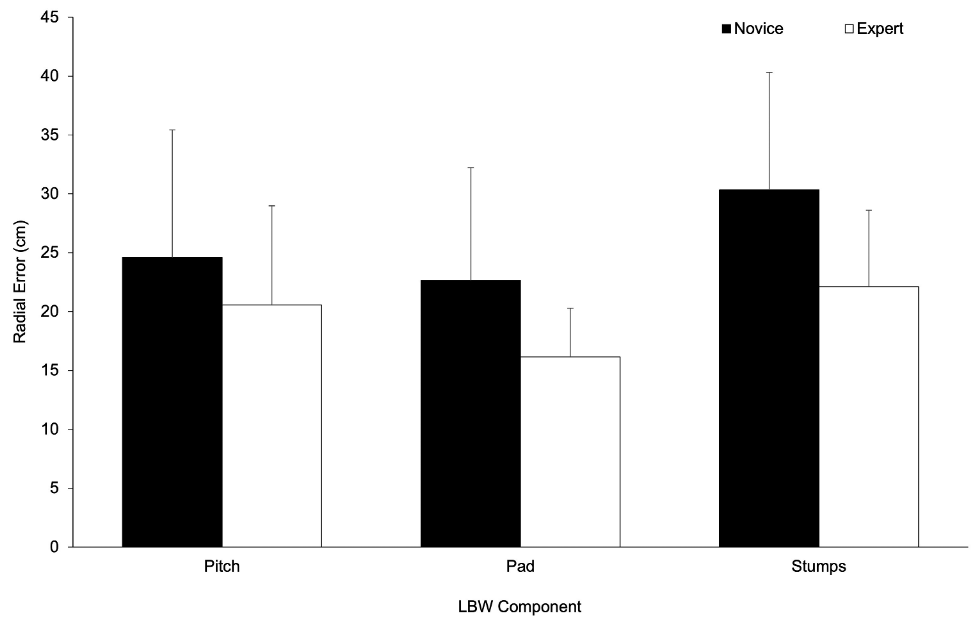

Figure 3. Radial error (cm) for expert and novice umpires, for *pitch, impact* and *stumps*.

Expertise x Outcome interaction was non-significant, $F_{1,27}$ = 1.082, p = .31, ηp^2 = .04.

Average fixation duration (ms)

There was a large effect of expertise, $F_{1,27}$ = 5.347, p = .03, ηp^2 = .17. The average fixation duration for novice umpires (*M* = 1520.42 ms, *SE* = 152.31) was significantly longer than for expert umpires (*M* = 972.91 ms, *SE* = 181.29). The main effect of outcome was small and non-significant, $F_{1,27}$ = 1.318, p = .26, ηp^2 = .05, which reflected the similar average fixation duration for correct (*M* = 1361.06 ms, *SE* = 143.85) and incorrect (*M* = 1226.67 ms, *SE* = 125.22) trials. The Expertise x Outcome interaction was non-significant, $F_{1,27}$ = .389, p = .54, ηp^2 = .01.

Final fixation duration (ms)

There was a large effect of expertise, $F_{1,27}$ = 7.787, p = .01, ηp^2 = .22. The final fixation duration was significantly longer in the novice group (*M*= 2906.14 ms, *SE* = 235.27) than the expert group (*M* = 1885.56 ms, *SE* = 280.02). There was also a moderate to large main effect of outcome, $F_{1,27}$ = 5.500, p = .03, ηp^2 = .17. Final fixation duration was significantly longer for correct (*M* = 2612.58 ms, *SD* = 1083.65) compared to incorrect trials (*M* = 2355.08 ms, *SD* = 1173.60). The Expertise x Outcome interaction was non-significant, $F_{1,27}$ = 1.743, p = .20, ηp^2 = .06.

Final fixation locations (%)

There was a very large main effect of location, $F_{2.04,\ 53.09}$ = 17.80, p < .001, ηp^2 = .41. (see Figure 4). A higher percentage of final fixations were directed towards the *stumps* (*M* = 41.95%, *SE* = 4.97) than towards a *good length* (*M* = 21.51%, *SE* = 4.01), a *full length* (*M* = 27.47%, *SE* = 3.14) (p < .05), a *short length* (*M* = 2.54%, *SE* = 1.09) and *other locations* (*M* = 7.68%, *SE* = 2.14) (all p < .01). A significantly higher percentage of fixations were directed towards a *good length* and a *full length* than towards a *short length* and *other locations* (all p < .01). There was also a large interactive effect between expertise and location, $F_{2.04,\ 53.09}$ = 7.04, p < .001, ηp^2 = .21. This reflected that the percentage of final fixations directed towards a *good length* was higher in the novice group (*M* = 35.85%, *SE* = 5.02) than the expert group (*M* = 7.17%, *SE* = 6.24; p < .05), whereas the percentage of final fixations directed towards the *stumps* was lower in the novice group (*M* = 28.89%, *SE* = 6.24; p < .05) than in the expert group (M = 55.51%, *SE* = 7.75). All other main effects and interactions were non-significant (all p > .05).

Discussion

In line with hypothesis 1, expert umpires were much more accurate on all aspects of the decision-making task, compared to the novice group. Experts demonstrated lower radial error when judging the location of the ball's pitch and impact with the batter's pad, and when predicting the location the ball would have passed the wickets had it not been obstructed. As well as providing predictive validity for the task, these data demonstrate that umpires possess domain-specific expertise in this complex decision-making task. These data corroborate previous literature that has shown that expert sports officials are able to make more accurate decisions, by developing refined perceptual-cognitive strategies through deliberate practice activities, specifically competitive match exposure (MacMahon et al., 2007). As performers become more expert they have been shown to use working memory more efficiently (Ericsson, 2008). In the current task, determination of *pitch* and *pad* primarily required the umpires to accurately track and recall the ball's spatial location, which might rely on the use of working memory (Furley & Wood, 2016). Researchers have proposed that when performing the task in which they are expert, performers are capable of

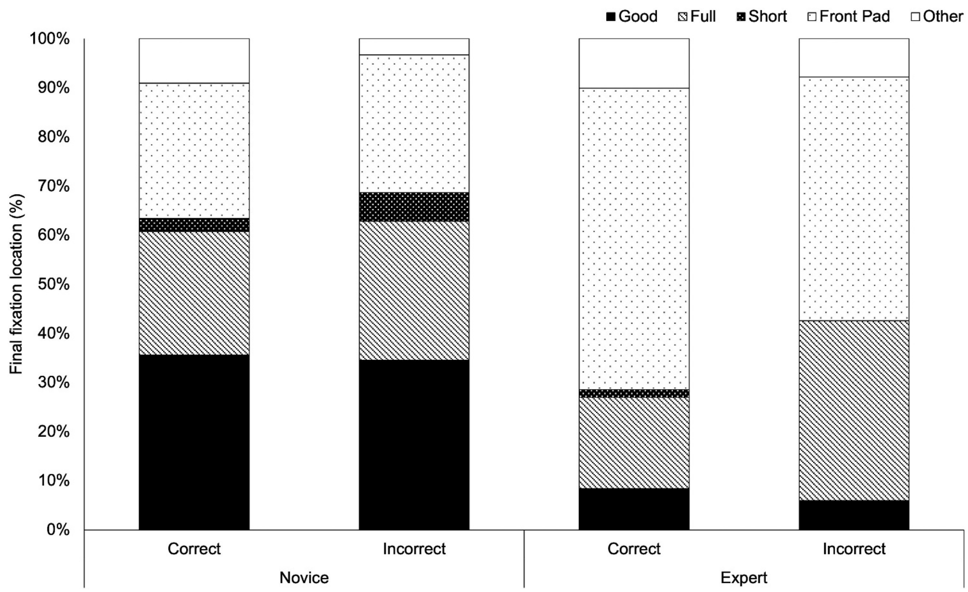

Figure 4. Final fixation locations (%) for experts and novices on correct and incorrect trials for *good, full length, short length, stumps* and *other* locations.

circumventing the limits of working memory by directly accessing domain-specific information from long-term memory through retrieval cues in short-term working memory (Ericsson & Kintsch, 1995). This may explain the more accurate decisions of the experts in the *pitch* and *pad* judgements. Such an explanation would be in line with the assumption that whilst elite officials do not have a greater working memory capacity for general tasks, they acquire strategies that enable a more efficient use of working memory in domain-specific activities (Spitz et al., 2016).

Despite their differences, both groups were less accurate when predicting *stumps* compared to *pad*. This can be explained by the fact that judging ball flight path after ball-pad contact requires a perceptual judgement based on a variety of factors such as batter stance (Southgate et al., 2008), dynamics of the delivery (spin and swing) and the ball's surface degradation (Chalkley et al., 2013). Conversely, when judging ball-pad impact, all visual information was present so the umpire did not need to consider these contextual factors.

As well as accuracy differences, previous studies of expertise in sport have consistently reported differences in the number of fixations and average fixation duration between skill levels in a variety of task (Mann et al., 2007). It is generally accepted that in a temporally constrained decision-making task, such as the current study, a more efficient strategy consists of fewer fixations of longer duration (Mann et al., 2019). This is predominantly to reduce suppression of information during saccadic eye movements in order to maximize the information that can be gathered (Ludwig, 2011). However, we found no significant difference in the number of fixations between the groups. Furthermore, the average fixation duration for the novice group was significantly *longer* than that of the expert umpires, although this was not associated with more accurate decision-making.

The finding that final fixation duration was significantly longer for the novices compared to the experts conflicts with hypothesis 2. Previous studies (Raab & Laborde, 2011) have shown that experts are better able to generate the first and best option, produce fewer overall options and are quicker to generate the first option than near-experts and novices, therefore requiring a shorter final fixation. Conversely, the novices require a much longer final fixation in order to extract the information needed to make a judgement as they have less refined perceptual-cognitive strategies (Mann et al., 2019). This is supported by reports that experts favour intuitive decision-making, compared to novices, who tend to be more deliberative (Raab & Laborde, 2011). Novices have been shown to generate more options (Raab & Laborde, 2011) and take longer to generate an initial response (Raab & Johnson, 2007). Conversely, experts have been shown to generate fewer options and pick the first option more often (Raab & Laborde, 2011), a strategy that has been shown to result in better and more consistent decisions (Johnson & Raab, 2003). This take-the-first heuristic allows the experts to make quick decisions under limitations of time, processing resources, or information. Whilst these decisions are usually accurate, they can sometimes be affected by biases (Raab & Johnson, 2007). Whilst cricket umpiring generally allows some time for deliberation, it could be argued that the speed at which critical visual information becomes available dictates that intuitive decision-making plays a key role.

In hypothesis 3, it was predicted that expert umpires would use a perceptual-cognitive strategy that consisted of a final fixation point (gaze anchor) on a location central to the critical information sites. In support of this, the more accurate decisions made by the expert group across all of the conditions could be explained by their allocation of attention to the *stumps* significantly more than their novice counterparts, who tended to allocate their final fixation towards a *good length* on the pitch. Such differences also corroborate previous research within fast-ball sports (Broadbent et al., 2015), which have shown specialized perceptual-cognitive skills utilized by expert performers enhance their ability to locate and identify salient cues, which ultimately aid decision-making success. A *gaze anchor* is located in the centre of several critical cues (pitch, pad, stumps) in order to distribute attention to several cues using peripheral vision. Use of the gaze anchor has been seen to enhance decision-making of football officials in expert and near-expert assistant football referees, who anchored their gaze on the offside line as opposed directing foveal vision on either the passer, the ball or the attacker (Schnyder et al., 2017). Notably, the actual fixation location (stumps) from the present study may not contain any task-specific information that is being processed by the fovea, but is equidistant to the pertinent cues (Vansteenkiste et al., 2014). Therefore, by anchoring their gaze towards the stumps, the expert umpires are capable of utilizing their peripheral vision to ascertain the position the ball pitched as well as the initial angle of delivery using the relative motion around the central point. Consequently, information processing via foveal vision directed towards the stumps might have enhanced their ability to perceive the height and line of impact with the pad and thus provided them with an increased accuracy when judging the trajectory of the ball towards the stumps.

Conversely, the novice umpires might not have utilized both foveal and peripheral vision to make the judgements and might have fixated on a good length due to *pitch* being the first consideration needed when applying the LBW law. Subsequently, due to the demands of processing multiple trajectories and impact points, working memory capacity of the novices may have been overwhelmed, leading to less accurate decisions on the later variables. The *information reduction hypothesis* (Haider & Frensch, 1999) postulates that when individuals practice a task, they selectively allocate attentional processes towards task-relevant information at the expense of task-redundant information which limits the load on working memory processes, and as a consequence enhances performance. In the current study, the expert's anchoring their vision on the *stumps* may have permitted them to selectively process critical information related to *pad* and stumps and thus reduce task-redundant processing. Consequently, load on the working memory will have been reduced and recall of all three components of the LBW law may have been enhanced.

Summary

Taken together, these data show that expert umpires have developed a systematic perceptual-cognitive strategy, comprising a gaze anchor, that enables them to overcome the processing demands and maximize accuracy in a complex decision-making task. These data provide an important first step towards the design of training interventions to help less-skilled umpires develop a more refined and systematic visual strategy to enhance decision-making. However, further research is required to determine the processing demands in umpires during a delivery, which includes other elements, such as the front-foot no-ball call, and other external factors influencing attentional control. For example, the use of a real-life bowler, and the front-foot no-ball decision, would increase the representativeness of both the batter's biomechanics (Pinder et al., 2009) and the overall match demands of an umpire, which may alter the umpires' visual strategy. It is possible that the limited time between the front-foot grounding and the ball-pad impact might impair the use of the gaze anchor and require umpires to implement an alternative gaze strategy. Understanding the development of these domain-specific perceptual-cognitive skills and the effect of other attentional and contextual factors will be critical in designing any future training interventions.

Disclosure statement

No potential conflict of interest was reported by the authors.

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