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Running Head: TRADITIONAL AND IMMERSIVE VIDEO ANTICIPATION

Effects of Traditional and Immersive Video on Anticipation in Cricket: A Temporal Occlusion Study

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Introduction

Due to the extreme time constraints of interceptive sports such as cricket, athletes are required to process information and make decisions in a manner that frequently pushes the limits of human performance (Cotterill & Discombe, 2016; Runswick et al., 2020). For example, it has been reported that when ball velocities reach extremely fast speeds (e.g., exceeding 140 km/h or 38.8m/s), the transit time from bowler to batsman is ~500ms (Regan, 1997). Conversely, a batter's total preparatory time, including simple reaction time and the time to complete essential foot and bat movements, is at least 900ms (Müller & Abernethy, 2012). Hence, batters are required to anticipate the outcome of the delivery and initiate advance movements in a predictive fashion. Successful performance can be directly attributed to the effectiveness of an athlete's anticipation and decision-making abilities (Williams & Jackson, 2019).

To overcome such temporal challenges, athletes develop numerous perceptual-cognitive skills, including the ability to recognise patterns in play (North et al., 2017), use contextual information (Müller et al., 2020; Murphy et al., 2016), and recognise advance postural cues (Causer et al., 2017). Recent theoretical frameworks such as the Bayesian Integration Framework (Gredin et al., 2020), Active Inference (Harris et al., 2021), and the Model of Information use During Anticipation in Striking Sports (MIDASS; Runswick et al., 2020) have outlined how multiple sources of information are integrated with prior knowledge, according to their reliability, to generate probabilistic judgements about likely outcomes and enable effective anticipation.

Occlusion research indicates that there is a strong relationship between cricketers' skill level and their ability to anticipate successfully (Brenton et al., 2016; Müller et al., 2006). When presented with video footage showing only the pre-release movements of medium-paced bowlers, elite (i.e., first class) cricketers demonstrated superior ability when compared to intermediate (i.e., club), and lesser skilled (i.e., university students) batters, by consistently predicting pitch location (i.e., where the ball will bounce; Müller et al., 2006). Similarly, highly skilled (i.e., club) adult batters demonstrated superior anticipation compared to youth players (Brenton et al., 2016). This finding has been reported across a wide range of bowling styles, including left/right armed fast-paced bowlers (McRobert & Tayler, 2005) and spin bowlers (Renshaw & Fairweather, 2000).

Elite athletes appear to pick-up cues at an earlier stage in the action and use more proximal kinematic information than amateur athletes, who typically rely on the flight of the ball, to predict the outcome of an event (i.e., amateurs predict differently or less than elites; Causer et al., 2017; Farrow & Abernethy, 2015; Mann et al., 2013; Müller et al., 2010). Given these findings, it is plausible that perceptual cognitive skills can be trained and transferred into a competitive environment (Müller & Abernethy, 2012), and therefore it is important to understand how to best train these abilities during practice.

A principled theoretical account for designing such training interventions is the Modified Perceptual Training Framework (MPTF; Hadlow et al., 2018), which outlines the factors that predict the success and transfer of visual and perceptual training approaches. The MPTF consists of three axes containing fundamental components for visual and perceptual training tasks. *Targeted perceptual function* refers to the perceptual skill that is to be trained. The researchers suggested that perceptual training is likely to be more effective for high-order perceptual skills (e.g., sport specific anticipation) when compared to low-order generalised visual skills (e.g., acuity). *Stimulus correspondence* concerns the similarity between the stimuli presented during perceptual training and that which is experienced during competition. Creating training tasks which accurately represent the real-world environment is crucial for maximising the effectiveness of the training intervention. Finally, *response correspondence* refers to the extent to which the responses required during perceptual training mirror those of the real-world activity. Realistic movement patterns, as opposed to verbal or written responses, can sustain perception-action links and enhance the accuracy of perceptual-cognitive performance (Hadlow et al., 2018).

Two of the most common training tools employed to practice batting in cricket are bowling machines and the use of throwdowns (i.e., throwing the ball to the batter). Unfortunately, both bear little resemblance to the performance environment from a perceptual and cognitive perspective (i.e., low stimulus correspondence; Hadlow et al., 2018). Researchers have suggested that there are many differences between batting against a bowling machine and facing a human bowler (Bartlett, 2003). For example, bowling machines do not provide pre-delivery postural cues. This is an important departure from a competitive cricket environment, given that skilled batters typically rely on information from the bowling arm to effectively anticipate the outcome of events (Müller et al., 2006; Tayler & McRobert, 2004). The removal of pre-delivery information when using a bowling machine can also alter batters' movement, timing, and coordination (Pinder et al., 2011; Weissensteiner et al., 2011). Therefore, coaches and players should be cautious that practicing with bowling machines can potentially lead to inappropriate information–movement couplings, thereby inhibiting batters' anticipation and decision-making capabilities (Renshaw et al., 2007).

Based on theories of anticipation which emphasise integration of multiple information sources (Gredin et al., 2020; Harris et al., 2021; Runswick et al., 2020), an over-reliance on bowling machines will likely result in attunement to early ball flight information, as opposed to a balanced integration of all advanced visual cues. This is a strategy typically employed by amateur athletes (Causer et al., 2017; Müller et al., 2010).

To overcome the paucity of pre-delivery cues associated with bowling machines and throwdowns, scholars have suggested using video-based occlusion training programmes to test and enhance anticipation (Brenton et al., 2016; Müller et al., 2015; Runswick, Roca, Williams, McRobert, et al., 2018). Video footage of a bowler executing different deliveries is typically filmed from the batter's point-of-view. Thereafter, the footage is occluded at crucial stages in the bowler's kinematics (e.g., just before, at, or just after the ball release), to allow the batter to predict the outcome of the delivery. Feedback can be provided to the batter by showing them the video in full (i.e., without occlusion; Brenton et al., 2019). Pragmatically, this approach allows batters to train in the absence of human bowlers, who are particularly susceptible to injury (Orchard et al., 2006).

Video-based temporal occlusion training interventions have been associated with improvements in prediction accuracy across a range of sports, such as tennis (Smeeton et al., 2005), hockey (Müller et al., 2017), and cricket (Brenton, Müller, & Dempsey, 2019; Smeeton et al., 2013). Researchers have also advocated the collection of confidence ratings, alongside prediction accuracy, to assess athlete's awareness of the information they use to anticipate (Murphy et al., 2018). The Higher-Order Thought Theory (Rosenthal, 2000) holds that if an individual has a higher-order thought concerning their current mental state, then that state can be considered conscious. Researchers have suggested that in judgement tasks, high degrees of accuracy and confidence (i.e., the higher order thought) indicate awareness of information being used to make correct judgements (Murphy et al., 2018). Conversely, high levels of accuracy coupled with low confidence suggest a lack of awareness. Therefore, assessments of confidence can help ascertain the task relevance of presented stimuli (Jackson & Mogan, 2007; Murphy et al., 2018).

The majority of video-based temporal occlusion training interventions are predicated on traditional videos displayed via television screens or projectors (see e.g., Brenton et al., 2016). Nonetheless, there are notable limitations associated with traditional videos. For example, such video footage is not fully egocentric, as it does not update in accordance with the viewer's head movements. This compromises the environment/viewer relationship that is present during sporting encounters (Craig, 2013), thereby reducing stimulus correspondence (Hadlow et al., 2018; Panchuk et al., 2018). The advancement of modern technology has afforded alternative modes of delivery that have the potential to enhance the effectiveness of this form of anticipation training.

Access to virtual reality (VR) head-mounted displays has grown significantly in recent years and has been identified as a potential approach for perceptual-cognitive training in sport (Bird, 2020; Gray, 2019; Wood et al., 2020). VR head-mounted displays are considered more immersive than traditional displays, as they occlude the physical reality from the individual, accommodate a range of senses, offer panoramic environments, and incorporate high-resolution displays (Bailey & Bailenson, 2017; Slater & Wilbur, 1997). A correlate of immersion is *presence,* which refers to the perceptual illusion of being inside the virtual environment, despite the knowledge that it is not real (Harris, Bird, et al., 2020). This increased immersion could improve performance outcomes when compared to traditional displays, owing to greater stimulus correspondence (Hadlow et al., 2018). Moreover, the use of VR head-mounted displays, where elements of stimulus and response correspondence can be easily manipulated, could also serve to generate novel theoretical insights pertaining to optimal training of perceptual-cognitive skill (e.g., by testing the predictions of the MPTF; Hadlow et al., 2018).

Discussions relating to the application of VR in sport have focused on distinct approaches to content creation. For example, researchers have worked in collaboration with software developers to create simulated content for VR head-mounted displays (Craig, 2013). It has been suggested that such content has the ability to assist in the development of decision-making and anticipation (Vignais et al., 2015). An advantage of using simulated content is that practitioners can attach tracking sensors to physical objects (e.g., a cricket bat) so that when an action is performed in the physical world, it is replicated virtually (Bird, 2020), thereby enhancing response correspondence (Hadlow et al., 2018). However, the programming expertise associated with developing simulations with high stimulus and response correspondence is typically beyond the scope of many sporting organisations (Panchuk et al., 2018).

Alternatively, video content can be recorded from a first-person perspective in 360-degrees (herein referred to as *immersive videos*) and viewed through a VR head-mounted display (Craig, 2013; Panchuk et al., 2018). Immersive videos do not fully maintain perception-action coupling and therefore lack the same opportunities for response correspondence when compared to simulated content. Nonetheless, a strength of immersive videos, which depict live-action footage, is the potential to subject an athlete to an experience that closely resembles a competitive environment (i.e., high stimulus correspondence; Hadlow et al., 2018).

Relatively few attempts have been made to examine the effects of immersive videos on anticipation and decision-making in sport. Consequently, it is unclear whether immersive videos provide better stimulus correspondence than traditional video training. Panchuk et al. (2018) administered immersive video training sessions to youth basketball players over a three-week period. The researchers did not observe any differences between pre- and post-decision-making performance, but noted several improvements in overall performance during small-sided games. The researchers refrained from comparing the effects of immersive videos to traditional videos but emphasised this as a fruitful direction for future research.

Kittel et al. (2019, 2020) reported that Australian football officials performed better in decision-making accuracy when viewing immersive videos when compared to traditional match broadcasts. Moreover, immersive videos were rated more highly than traditional videos for psychological fidelity, enjoyment, and relevance (Kittel et al., 2020). The early findings supporting the efficacy of immersive videos are encouraging. Nonetheless, there is a dearth of research comparing traditional and immersive videos in relation to anticipation performance in cricket.

The primary aim of the present investigation was to compare batters' ability to accurately predict the landing location (i.e., the line and length) of deliveries, and assess their confidence in such predictions, when using traditional and immersive videos. A secondary aim was to examine the degree to which batters could accurately and confidently predict landing location when facing footage depicting a bowling machine, throwdowns, spin, and pace bowling.

It was hypothesised that batters would predict the landing location of the ball with greater accuracy when viewing immersive videos compared to traditional videos (H_1). Additionally, that batters' prediction confidence would be higher upon viewing immersive videos compared to traditional videos (H_2). It was also hypothesised that batters would predict landing locations with greater accuracy when viewing spin and pace bowling when compared to a bowling machine or throwdowns (H_3). Finally, that batters' prediction confidence would be higher in the spin and pace bowling conditions when compared to a bowling machine or throwdowns (H_4).

The hypothesised effects are derived from the theoretical predictions of the MPTF (Hadlow et al., 2018). In the case of H_1 and H_2, immersive videos were considered to entail a greater degree of stimulus correspondence when compared to traditional videos, given that VR head-mounted displays are responsive to head movements (Pagé et al., 2019). Regarding H_3 and H_4, spin and pace deliveries were thought to comprise higher stimulus correspondence when compared to a bowling machine or throwdowns. This is because bowling machines and throwdowns are not encountered during competitive cricket (Hadlow et al., 2018).

Furthermore, spin and pace deliveries were thought to contain the most task-relevant information (Jackson & Mogan, 2007; Murphy et al., 2018).

Methods

Participants

Sample size was determined by a resource constraints approach (i.e., access to amateur cricket players fitting the criteria). A sensitivity analysis was conducted to determine the minimal statistically detectable effect, in accordance with recent recommendations for power analyses (Lakens, 2021). Given $N = 18$, $\alpha = .05$, and $1\text{-}\beta = .80$, a critical effect size of $\eta_p^2 = .17$ was identified. Ethical approval was granted by the Health, Exercise, and Sport Ethics Committee at __________. Following written informed consent, a purposive sample of 18 amateur cricketers were recruited (4 women and 14 men; $M_{\text{age}} = 22.0$ years; $SD = 4.0$ years). Recruitment was conducted at local clubs and University cricket teams. Participants met three inclusion criteria, they: (1) trained at least once per week for the past month; (2) played in at least one competitive match in the past month; and (3) were not considered elite (Swann et al., 2015), having not played first class/professional cricket. These criteria ensured that participants had not recently sustained lengthy absences from cricket and that the sample was relatively homogenous.

Video Content

Immersive video footage was recorded in an indoor net environment with a view to replicating the perspective of a batter (Figure 1a). It is important to note that although indoor net scenarios do not provide contextual priors (e.g., match status, opponent positioning; Gredin et al., 2020), the environment is a familiar one for competitive cricketers. A monoscopic 360-degree video camera (Garmin VIRB; Olathe, KS, USA) was positioned at a height of 5ft 10 inches on the popping crease (i.e., the location where a batter would typically stand) using a tripod and an extended arm, which held the camera firmly in position. The camera recorded deliveries in 4K resolution under each of the following delivery styles: (1) bowling machine, (2) throwdowns, (3) spin bowler, and (4) pace bowler. The speed of the bowling machine was set at 70mph with no swing imparted on the ball. This speed was considered medium pace for men and fast pace for women, given that ball release speeds are significantly slower in women's cricket (Munro & Christie, 2018). A total of 80 deliveries (i.e., 20 per style) were initially recorded.

The researchers reviewed each of the deliveries and selection criteria stipulated that the ball be located centrally in one of the 10 squares depicted by a 2 × 5 landing location grid (see Figure 1a). Hence, deliveries that entailed ambiguous landing locations (e.g., between B1 and C1, or C1 and C2; see Figure 1b) were excluded. Video footage obtained from an additional camera (Panasonic HC-V100; Kadoma, Osaka, Japan), positioned towards the landing location grid, served to enhance the validity of this process. A total of 47 deliveries met the inclusion criteria. Thereafter, random number generators were used to select 10 deliveries per style, yielding a total of 40 deliveries for use in the experimental trials. Ten deliveries that did not meet the inclusion criteria were used for the purpose of habituation (see Procedure; Belling et al., 2015).

Video editing software (Adobe Premier Pro; San Jose, CA, USA) was used to create traditional versions of the immersive video footage, which inhibited the function to navigate the scene in 360-degrees. Moreover, the software was used to temporally occlude all footage (i.e., immersive and traditional). The footage presented to participants included the first 120ms of the balls flight, after which time the ball and the bowler/bowling machine were occluded. Subsequently, the co-ordinates for a 2 × 5 landing location grid were presented to participants for 7 s, with letters and numbers corresponding to the length and line of the ball, respectively (Figure 1b). Pilot testing ($n = 4$) revealed that 7 s was an appropriate period of time in which participants could verbally respond to the task and similar epochs have been employed in previous anticipation-related investigations (see e.g., Murphy et al., 2018). The order in which the 40 deliveries were presented was randomised for each viewing condition but identical for all participants (Pagé et al., 2019). Adobe Premier Pro was used to collate the deliveries. Thereafter, the final videos (i.e., immersive and traditional) were exported as .mp4 files and each had a duration of 7 min 13 s.

***** Insert Figure 1 about here *****

Apparatus and Measures

The traditional videos were projected onto a screen (95cm × 53cm) placed 1.5 m away from each participant during experimental trials. Moreover, a VR head-mounted display (Oculus Rift; Menlo Park, CA, USA) was used to deliver the immersive video. Participants were required to stand in their regular batting stance in full cricket kit, which consisted of batting pads, gloves, thigh guards and their own cricket bat. Cricket helmets were not employed during experimental trials to allow the VR head-mounted display to be fitted comfortably.

To assess each participant's ability to anticipate the landing location of the delivery during the experimental trials, a scoring system was devised in relation to the aforementioned 2 × 5 landing location grid (Figure 1b): (a) correct landing locations = 10, (b) cells adjacent to the correct landing location = 5, and (c) all other cells = 0. Moreover, confidence was measured following each participant's prediction using a 10-point scale anchored by 1 (*not confident at all*) to 10 (*extremely confident*).

Procedure

Participants were required to meet with the research team on one occasion. A repeated-measures crossover design was employed, and participants were randomly assigned to one of two groups: (1) traditional video followed by immersive video, or (2) immersive video followed by traditional video.

Participants were shown a habituation video before taking part in each of the experimental conditions. This video contained 10 occluded deliveries (all delivery styles were represented) and had a duration of 1 min 48 s. The purpose of the habituation video was to ensure that participants were entirely comfortable with the experimental setup and appropriate response requirements (Murphy et al., 2018). Each participant was informed that they should perform a shadow shot following the cessation of each video clip, as though they were intercepting the delivery, to enhance response correspondence (Hadlow et al., 2018). Thereafter, participants were instructed to provide two verbal responses: (1) the coordinates associated with the cell in which they predicted the ball to land, and (2) their prediction-related confidence.

Following a 10 min period of seated rest, each participant proceeded to take part in the first experimental condition (i.e., traditional or immersive video). Participants were required to view 40 deliveries in a randomised order (i.e., 10 deliveries depicting a pace bowler, spin bowler, bowling machine, and throwdowns). Furthermore, participants provided verbal responses pertaining to landing location prediction and confidence following the conclusion of each video clip. Participants were instructed to rest for a period of 20 min upon completion of the first experimental condition to reduce the likelihood of boredom and fatigue effects (Murphy et al., 2018). Thereafter, they repeated the process (i.e., habituation followed by experimental trials) under the second viewing condition. The entire testing protocol lasted ~60 min.

Data Analysis

Data were screened for univariate outliers by means of standardised *z*-scores ($z > \pm 3.29$) and multivariate outliers using the Mahalanobis distance test ($p < .001$; Tabachnick & Fidell, 2019). Furthermore, data were examined for the parametric assumptions that underlie MANOVA (e.g., normality, absence of multicollinearity; Tabachnick & Fidell, 2019).

Dependent variables (prediction accuracy and confidence) were analysed using a 2 (Viewing Condition) × 4 (Delivery) MANOVA. Greenhouse–Geisser adjustments were made to *F* tests when the sphericity assumption was violated. Bonferroni-adjusted pairwise comparisons and checks of 95% CIs were employed to identify differences when the *F* ratio was significant.

Results

Prior to the main analysis, no univariate or multivariate outliers were identified (Tabachnick & Fidell, 2019). Moreover, tests of the distributional properties of the data in each cell of the analysis did not reveal any violations of normality. Descriptive statistics are presented in Figure 2 and Figure 3.

***** Insert Figure 2 and Figure 3 about here *****

The omnibus analysis revealed that the Viewing Condition × Delivery interaction was non-significant ($p = .682$, $\eta_p^2 = .04$; see Table 1), indicating no overall interaction effect on the dependent variables.

***** Insert Table 1 about here *****

There was a main effect of viewing condition that applied only to prediction accuracy ($p = .037$, $\eta_p^2 = .23$) and was associated with a large effect size. Pairwise comparisons showed that the immersive video condition prompted significantly greater prediction accuracy scores when compared to the traditional video condition ($p = .037$, 95% CI [0.25, 6.98]; see Figure 4).

***** Insert Figure 4 about here *****

There was a main effect of delivery for confidence only ($p < .001$, $\eta_p^2 = .35$) that was associated with a large effect size. Pairwise comparisons revealed that, compared to the bowling machine condition, confidence scores were significantly higher in the throwdown ($p = .031$, 95% CI [0.33, 9.06]), spin ($p = .011$, 95% CI [1.14, 10.70]), and pace ($p = .018$, 95% CI [0.66, 8.84]) conditions (see Figure 5).

***** Insert Figure 5 about here *****

Discussion

The primary aim of the study was to compare batters' ability to accurately predict the landing location of deliveries and assess their confidence in such predictions, when using traditional and immersive video footage. Furthermore, we sought to investigate the degree to which batters could accurately and confidently predict landing location when facing footage depicting a range of delivery styles.

The hypothesis that batters would predict the landing location of the ball with greater accuracy when viewing immersive videos compared to traditional videos (H_1) was accepted. In accordance with the MPTF (Hadlow et al., 2018), the targeted perceptual function (i.e., cricket specific anticipation) and response correspondence (i.e., shadow shot) were identical across viewing conditions. Conversely, the stimulus correspondence did change, suggesting that this was the reason for the improved prediction accuracy. Immersive videos delivered via VR head-mounted displays can more closely replicate the competitive environment when compared to traditional videos (Pagé et al., 2019) and this might help explain the greater distribution of predictions on the scoring grid in the immersive video condition (see Figure 3). It is also plausible that the immersive videos prompted superior perceptions of presence, increased attention and engagement with the task when compared to traditional videos (Gray, 2019). These findings support a growing corpus of research indicating the potentially positive application of immersive videos for training anticipation and decision-making in sport (Kittel et al., 2019, 2020; Panchuk et al., 2018).

We hypothesised that batters would be more confident in their predictions when viewing immersive videos compared to traditional videos (H_2). The non-significant main effect of viewing condition for confidence precluded the acceptance of H_2, albeit that this was associated with a large effect size ($\eta_p^2 = .16$; see Table 1). The non-acceptance of H_2 was a somewhat surprising finding given that participants predicted the landing location of deliveries with greater accuracy when viewing immersive videos compared to traditional videos. It has been suggested that mastery experiences are a key source of confidence in sporting contexts and the degree of success an individual has in performing similar tasks influences their self-efficacy (Beaumont et al., 2015; Musculus et al., 2018). Many of the participants in the present study had not used a VR head-mounted display prior to the investigation but would have had extensive experience engaging with traditional videos (e.g., via smartphone technology). It is plausible that participants' confidence might have been weakened in the immersive video condition and strengthened in the traditional video condition, owing to mastery experiences. This would account for the converging confidence scores between viewing conditions following the discrepancy in task performance (i.e., prediction scores).

The hypothesis that batters would predict landing location with greater accuracy when viewing spin and pace bowling when compared to a bowling machine or throwdowns (H_3), was not supported. This was particularly surprising given that spin and pace bowling conditions were associated with the greatest stimulus correspondence (Hadlow et al., 2018). Researchers have consistently reported that elite athletes are superior to amateurs at using visual information prior to object flight as a means of predicting the future location of that object for interception (Müller et al., 2006; Runswick, Roca, Williams, McRobert, et al., 2018). Conversely, amateur athletes are less able to act upon such early information, reducing the likelihood of performing a successful interception (Müller & Abernethy, 2012). Hence, it appears that the amateur participants in the present study were unable to use the pre-delivery visual cues effectively when making their associated predictions in the spin and pace conditions.

It is noteworthy that contextual priors (e.g., match status, opponent positioning; Gredin et al., 2020) were absent from the videos employed in the current investigation. Contextual information has been shown to be important for successful anticipation in cricket (Runswick, Roca, Williams, Bezodis, et al., 2018; Runswick, Roca, Williams, McRobert, et al., 2018). Researchers have suggested that context informs anticipation through a series of processes pertaining to short- and long-term memory (Runswick et al., 2020). Accordingly, it is possible that contextual information might have bolstered prediction accuracy for the deliveries that comprised the highest stimulus correspondence (i.e., spin and pace bowling).

We hypothesised that batters' confidence in their predictions would be greater in the spin and pace bowling conditions when compared to a bowling machine or throwdowns (H_4). Spin and pace conditions prompted significantly greater confidence scores when compared to the bowling machine. However, the differences between throwdowns and spin/pace conditions were negligible and precluded the full acceptance of H_4. Batting against a bowling machine is considerably different to facing a bowler, particularly pre-ball release (Bartlett, 2003). Bowling machines prevent advance information that is available to batters in competitive environments and can be considered to comprise low stimulus correspondence (Hadlow et al., 2018).

The present findings indicate that batters' prediction confidence was greatest when advance information was presented to them (i.e., when facing spin, pace, and throwdowns). While we predicted that the throwdowns would lead to lower anticipation and confidence scores compared to spin and pace bowling, it appears that the advance cues from the thrower increased confidence in participants' predictions. The improvement in confidence scores when advance delivery cues were available adds weight to the argument that current methods of training (e.g., bowling machines) may not benefit the batter and could potentially harm their development (Pinder et al., 2011). Therefore, coaches might limit the use of bowling machines and players should be aware that practising with such machinery can potentially inhibit their anticipation capabilities.

Theoretical and Practical Implications

Using the MPTF (Hadlow et al., 2018) as a lodestar, we sought to enhance stimulus correspondence in the occlusion paradigm by employing immersive videos, coupled with a VR head-mounted display, that automatically updated the viewer's perspective according to their head movements. This mode of delivery allowed for a closer replication of the performance environment when compared to traditional videos and yielded statistically greater anticipation accuracy. It is plausible that a longitudinal training intervention predicated on VR head-mounted displays could elicit enhanced transfer of learning when compared to traditional videos (Hadlow et al., 2018; Panchuk et al., 2018). However, additional research is required to examine this empirically in cricket.

In accordance with the Higher-Order Thought Theory (Rosenthal, 2000), researchers have suggested that high levels of anticipation accuracy coupled with high confidence indicates awareness of information being used to make correct judgements. On the other hand, high levels of accuracy and low confidence suggest an absence of awareness (Murphy et al., 2018). The present findings support the notion that cricketers were consciously aware of the information derived from the bowler's approach during the anticipation task, albeit that such awareness did not translate to an improvement in anticipation accuracy when compared to the bowling machine.

From a practical perspective, batters would ideally train against human bowlers to develop their perception and anticipatory skills. However, bowlers, particularly fast bowlers, have the highest rate of injury in cricket (Orchard et al., 2006). Consequently, it is not always possible for batters to train against human bowlers. Hence, alternative methods are required to train anticipation. Simulated content holds significant promise for training anticipation and decision making for interceptive sports (Gray, 2017, 2019), but might be out of scope for many sporting organisations (Panchuk et al., 2018). The present investigation provides initial support for the application of immersive videos presented via a VR head-mounted display for the assessment of anticipation in cricket. This approach maintains some of the advantages associated with simulated VR content, without the associated demand on resources (Panchuk et al., 2018).

Limitations and Future Research

A limitation of the study concerns the delivery velocities. The speed of the bowling machine was set at 70mph with no swing imparted on the ball and it was estimated that the pace deliveries reached an equivalent velocity. This speed can be considered medium-paced for men's cricket, but fast for women's cricket. Accordingly, the female volunteers might not have accumulated as much exposure to this bowling velocity when compared to their male counterparts. Researchers might incorporate a range of delivery speeds to gain a fuller understanding of female and male batters' anticipation abilities. Fast bowlers are conventional within amateur and professional cricket. Hence, their absence from the perception and vision-related research in cricket is surprising.

It is possible to further enhance the stimulus correspondence and physical fidelity of the video intervention used in the present investigation (Hadlow et al., 2018; Harris, Bird, et al., 2020). For example, video footage depicting female bowlers could be employed when investigating female cricketer's anticipation. Furthermore, researchers are encouraged to gather video footage from cricket pitches, as opposed to indoor nets. A realistic match environment that is consistent with participants' level of performance could be created with the inclusion of fielders and umpires, as well as incorporating audio that is routinely heard during a typical match (e.g., from spectators). The inclusion of such contextual priors is particularly apposite given their role in anticipation performance (Gredin et al., 2020; Harris et al., 2021; Runswick et al., 2020).

A logical extension to the present investigation would entail a decision-making task (e.g., deciding whether to play a delivery or leave it; Runswick, Roca, Mark Williams, et al., 2018). This would allow for an assessment of *motor confidence* (i.e., an estimation of one's own ability to execute the generated option; Musculus et al., 2018), which can help illuminate the relationship between cricketer's cognitive decision-making processes and motor skills. Measures of presence and cognitive load (e.g., SIM-TLX; Harris, Wilson, et al., 2020) might be included in future work. Finally, researchers are encouraged to investigate the extent to which immersive interventions enable successful transfer of learning (Harris, Bird, et al., 2020; Kittel et al., 2021).

Conclusions

The findings indicated that cricket batters were able to predict the landing location of the ball with greater accuracy when viewing immersive videos when compared to traditional videos. This was likely due to an increase in stimulus correspondence, in accordance with the MPTF (Hadlow et al., 2018). The findings also support the notion that cricket batters are more confident in their anticipation capabilities when facing a human compared to a machine. These results suggest potentially fruitful applications of immersive video and VR for perceptual-cognitive training. VR head-mounted displays have the capacity to deliver engaging experiences that replicate the real environment more closely than traditional videos. Given the increasing rate at which VR is becoming accessible, such technology should be considered by sport psychologists as an effective means of assessing anticipation in cricket.

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Table 1

Inferential Statistics for Dependent Variables

	Pillai's Trace	*F*	*df*	*p*	η_p^2
Viewing Condition × Delivery	.075	0.66	6, 102	.682	.04
Prediction Accuracy	–	0.13	3, 51	.943	.01
Confidence	–	1.11	2, 36	.343	.06
Viewing Condition	.313	3.65	2, 16	.049	.31
Prediction Accuracy	–	5.13	1, 17	.037	.23
Confidence	–	3.21	1, 17	.091	.16
Delivery	.436	4.75	6, 102	< .001	.22
Prediction Accuracy	–	1.82	3, 51	.155	.10
Confidence	–	9.12	2, 34	< .001	.35

Figure 1

Video Footage Prior to Occlusion (a) and Post-Occlusion (b)

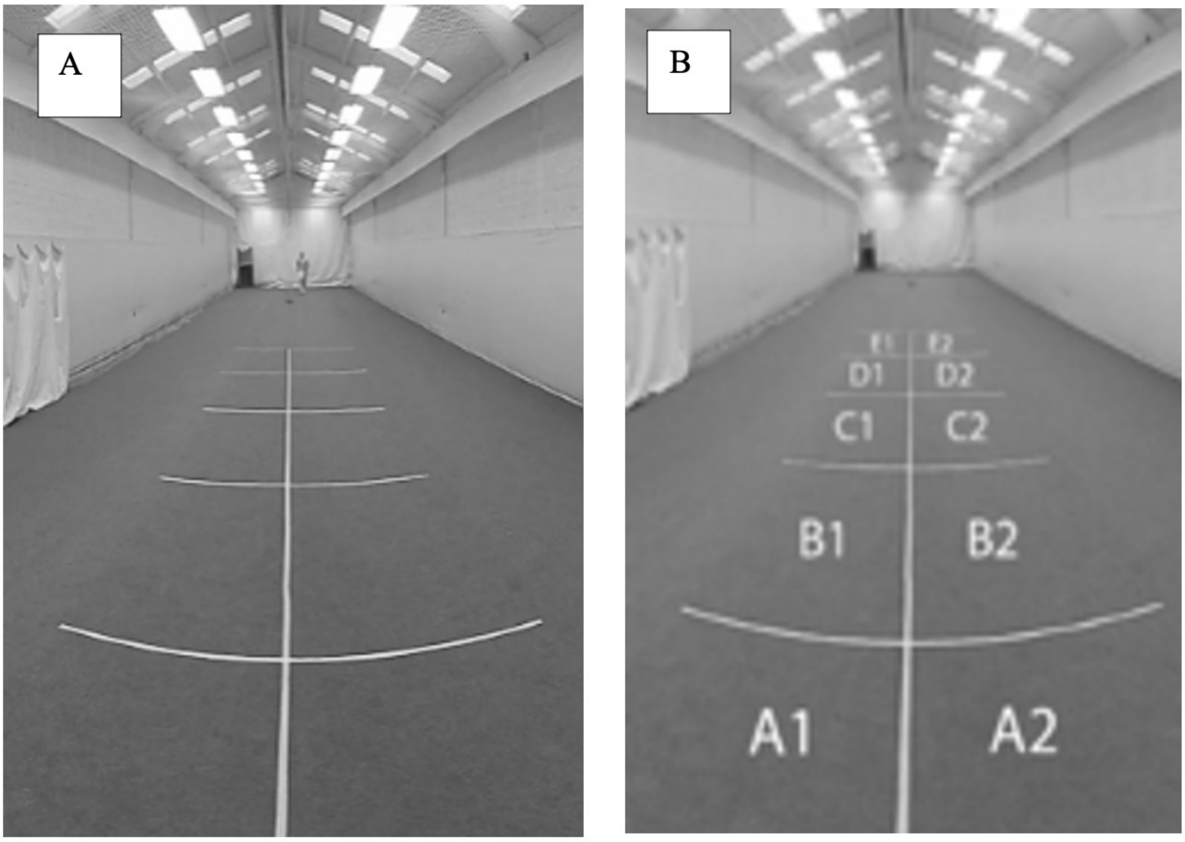
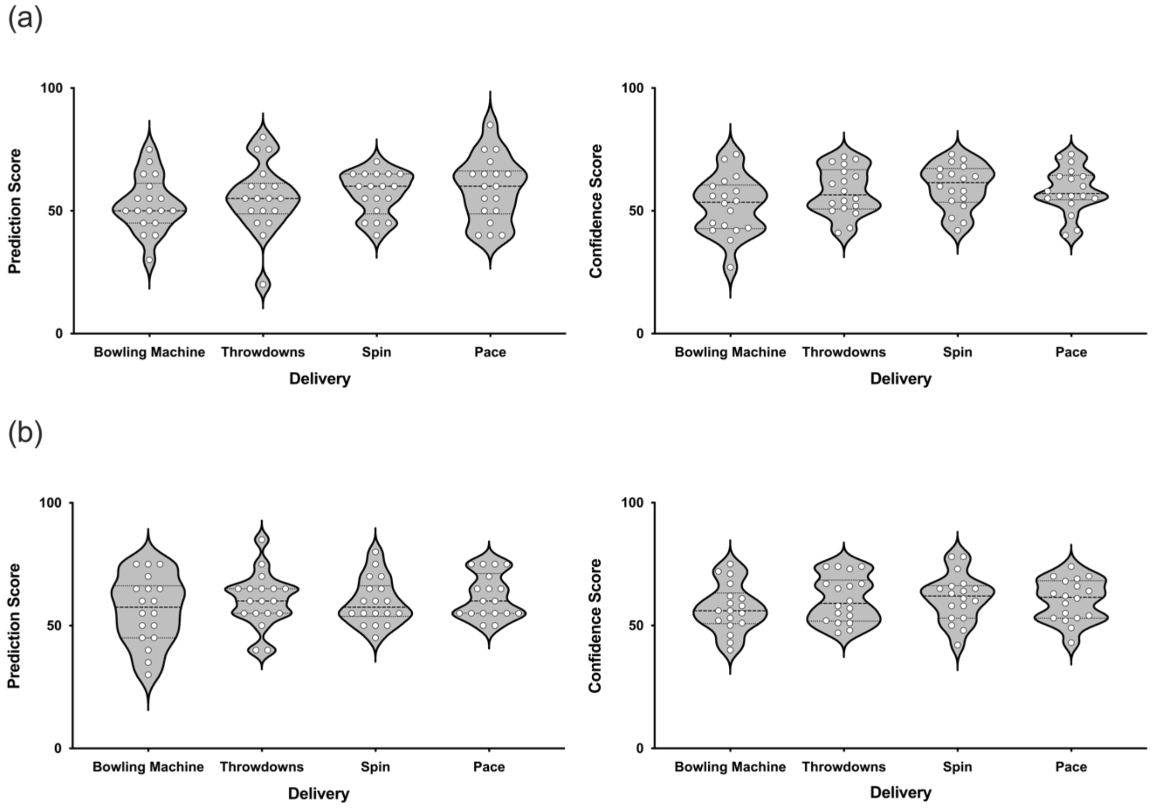


Figure 2

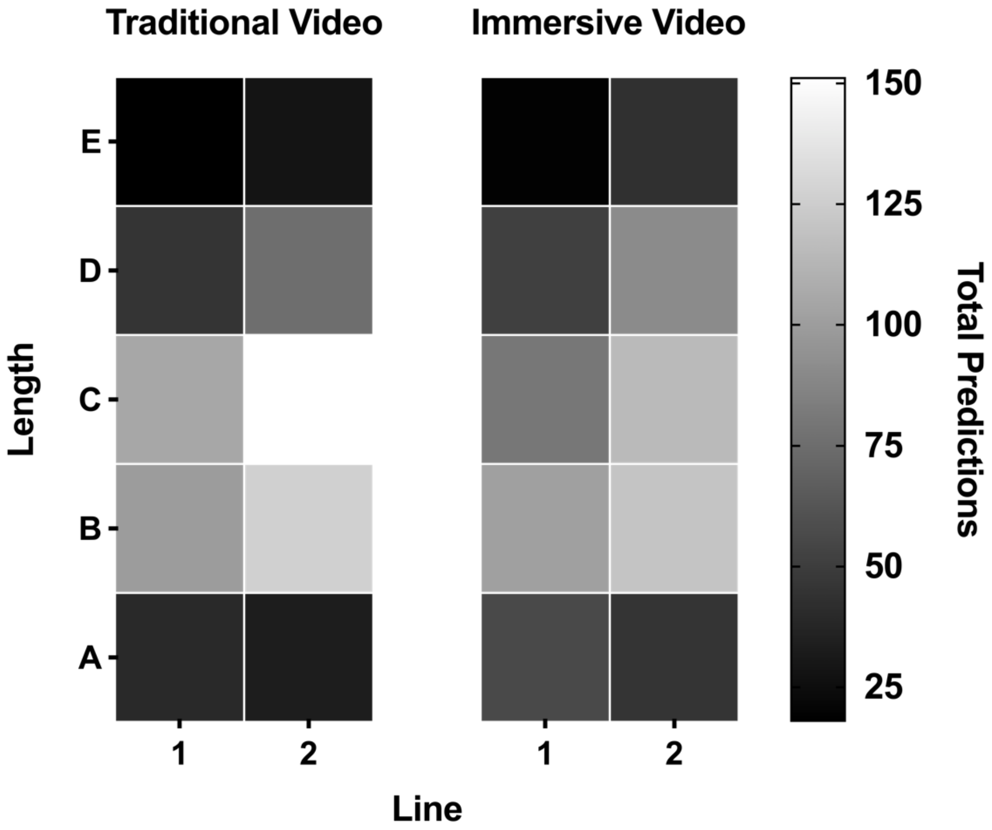
Prediction Scores (left) and Confidence Scores (right) for Traditional Video (a) and Immersive Video (b)



Note. Each plot displays a five-number summary: The sample median, the first and third quartiles, and the minimum and maximum.

Figure 3

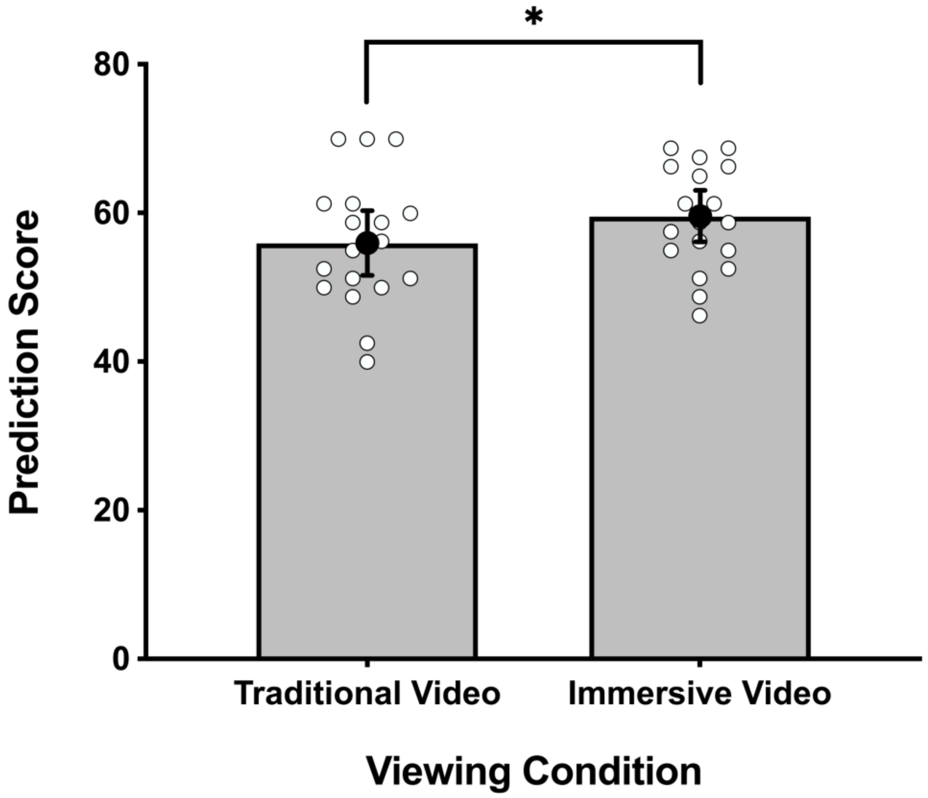
Total Number of Predictions for Traditional Video (left) and Immersive Video (right)



Note. 1 = Pitching leg side, 2 = Pitching off side.

Figure 4

Prediction Scores (M and 95% CI) Between Viewing Conditions

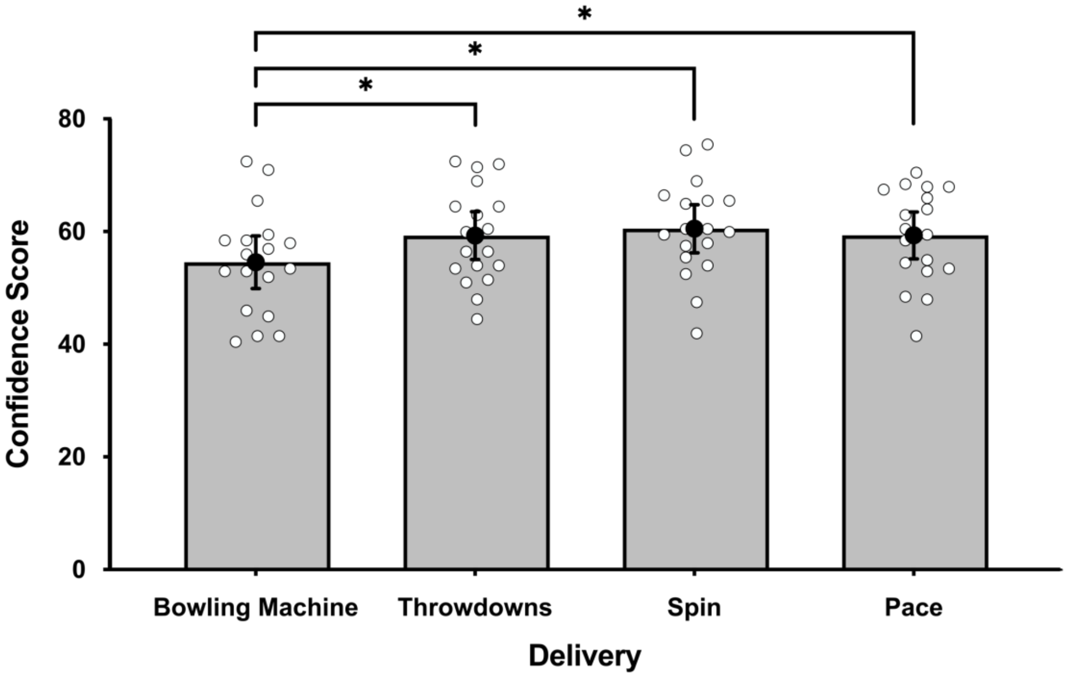


*Note. M*s and 95% CIs are predicated on estimated marginal means.

* $p < .05$.

Figure 5

Confidence Scores (M and 95% CI) Among Delivery Conditions



*Note. M*s and 95% CIs are predicated on estimated marginal means.

* *p* < .05.