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Player Perceptions of Face Validity and Fidelity in 360-Video and Virtual Reality Cricket

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Virtual reality (VR) and 360° video can provide new opportunities for testing and training in sport. Both options offer different benefits in terms of efficacy for training, ease of use, and cost. This creates questions about the implementation of immersive technologies, and research is required to further understand their use. We aimed to gain initial evidence of athletes' perceptions of face validity and fidelity in VR and 360-video. Thirty-nine international pathway cricketers experienced five overs in VR cricket and in a 360-video recording. After trying each technology, players completed questionnaires to measure perceptions of presence and task workload. Participants reported immersive experience in both methods, but higher levels of realism, possibility to act, physical effort, temporal constraints, and task control in VR. 360-video offers a better possibility to visually examine the environment, while VR offers enhanced realism and physical elements, but 360-video may still offer affordable solutions for visual tasks.

Keywords: immersive, presence, sport, task load

Virtual reality (VR; Gray, 2019; Harris et al., 2022) and 360° videos (Discombe et al., 2022; Kittel et al., 2019) can provide sports organizations with new opportunities for testing and training (Neumann et al., 2018). These two methods are often discussed interchangeably, but they offer fundamentally different options in terms of utility, cost, ease of implementation, and the integration of perception and action. VR refers to a computer-simulated environment that aims to induce a sense of being present in another place and allows individuals to interact with the environment (Neumann et al., 2018). The downside is that this approach can involve high cost and need for programming skills (Panchuk et al., 2018). The alternative option is to produce video content. It is now possible to produce immersive footage using a 360° camera that can be displayed in the same head-mounted display used for VR (Craig, 2013; Panchuk et al., 2018). 360-video does not allow interaction with the environment but is an immersive view of the real world that is relatively cheap and simple to implement.

A key issue for the use of simulation technologies is the potential activation of different visual systems. Milner and Goodale (1995, 2008) proposed a ventral stream for visual perception and a separate dorsal stream for the visual control of action. Striking sports involve both visual perception and the constant integration and updating of information to control actions (see Harris et al., 2022; Runswick et al., 2018, 2020). This means that tasks that include only the visual stimuli and no movement responses, such as 360-video, may not replicate the same processes used in a performance environment. In turn, this can produce differences in visual search behavior and the kinematics of movement responses (Dicks et al., 2010; Van Der Kamp et al., 2008). 360-video offers realistic stimuli for visual perception but does not allow for interaction with the virtual environment. VR does allow for participants to use visual information to control action through interaction with the environment (Bird, 2020; Hadlow et al., 2018) but does not offer completely realistic stimuli (Harris et al., 2019). This suggests that

players using 360-video may perceive high levels of visual realism but reductions in the possibility to act compared with VR. There is; therefore, a need to understand the use of VR and 360-video in terms of theoretical accounts of the visual control of action to then support informed implementation of the technologies.

Work has already begun to investigate the use of VR (Kelly et al., 2022) and 360-video (Discombe et al., 2022) in a variety of sports. This research has shown validity of both immersive simulation methods for capturing performance (Discombe et al., 2022; Wood et al., 2021) and replicating the psychological aspects of competition (Kelly et al., 2022). However, there has also been recent evidence that, even in the relatively simple movement of golf putting, VR may not fully represent real-world kinematics (Brook et al., 2023). In general, the levels of validity that the simulations have shown have been promising. However, this is often driven by the immersion that the specific environment offers (i.e., the objective output of the technology being used; Nilsson et al., 2016). Previous work has not directly compared simulation methods with different levels of possibility to interact with the environment and has often failed to capture how players subjectively perceive such simulations. A factor known as “presence” (Grassini & Laumann, 2020).

Harris et al. (2020) outlined a framework for testing and validating simulated environments designed for testing and training. This includes examination of elements of the two visual systems, face validity that is related to visual perception (i.e., does the simulation look and feel realistic), physical fidelity that is related to the visual control of action (is there a high degree of realism in the physical elements), and psychological fidelity (does the simulation accurately represent the perceptual and cognitive features of the task). These elements can be captured with existing measures of presence (e.g., presence questionnaires; Witmer et al., 2005) and task load (e.g., simulation task load index [SIM-TLX]; Harris et al., 2020). Data can provide information on how the two simulations, which are likely to employ different visual systems, are perceived by the players themselves, and can help inform sports organizations on the implementation of the technologies.

International pathway cricketers took part in performance testing using a VR cricket training platform and 360-video anticipation test. For the SIM-TLX, we hypothesized that 360-video would produce lower levels of task control, physical effort, and situational stress than VR but higher levels of frustration due to lack of ability to interact. For the presence questionnaire, we hypothesized that 360-video would produce higher levels than VR on realism due to its visually real stimuli that support ventral processing. However, 360-video would incur lower levels of possibility to act on and examine the environment and self-evaluate performance due to the lack of integration of the dorsal stream for the visual control of action.

Methods

Participants

We took the expected effect size approach (Lakens, 2022) to calculate an a priori sample size for the difference between two matched pairs in G*Power (Faul et al., 2007). The main effect of viewing condition from Discombe et al. (2022; $d_z = 0.52$) alongside a one-tailed α of .05 and power ($1 - \beta$) of 0.95 resulted in a total required sample size of 42. A power of 0.95 was selected due to the historically low power in the sport sciences literature (Abt et al., 2020) coupled with benefits of lower error rates and the relative ease of recruiting players on a performance testing day (Lakens, 2022). We were able to recruit 39 male cricketers who were currently part of the England and Wales Cricket Board player development pathway (mean age = 15.9 years; mean competitive experience = 9.1 years); this is around one-third of the entire population and needs to be considered based on availability of highly skilled players (Campitelli, 2019; Lakens, 2022). The study was approved by the local university research ethics committee, and participants and parents or guardians gave informed consent prior to participating.

Materials

360-Video

A 360° temporal occlusion cricket anticipation test was created at a first-class ground (Figure 1A). A Go-Pro 360 max (30FPS at 5.6k, Go-Pro Inc.) camera was placed at eye height (1.70 m) in the batter's position, and bowlers delivered balls at the camera in a set of T20 scenarios that incorporated field settings (using a full set of fielders) and game scenarios presented on the large electronic scoreboard. Five overs were created, and all scenarios were agreed by a panel of coaches. Footage was occluded after 120 ms (four frames) of ball flight (Discombe et al., 2022), and after each response, batters were able to review the full delivery for feedback.

VR Cricket Training

Cover Drive Cricket is a commercially available cricket batting simulation that is aimed at testing and training cricket players (Figure 1B). This application allowed for control of bowler and ball types and field settings so we could produce five overs of stimuli to match the 360-video as closely as possible. Participants hold a real cricket bat with the controller attached to the shoulder of the bat. The controller trigger is pressed when the player is ready to face a delivery, but no other buttons are required to play. The bat is used to strike the ball as in a real-world game situation. The simulation offers auditory and visual feedback for every shot. Depending on the quality and direction of the strike, and locations of fielders, players receive runs for each shot but are not required to run between the wickets themselves.

Presence Questionnaire

The presence questionnaire was used to capture face validity and physical fidelity through measuring perceptions of active

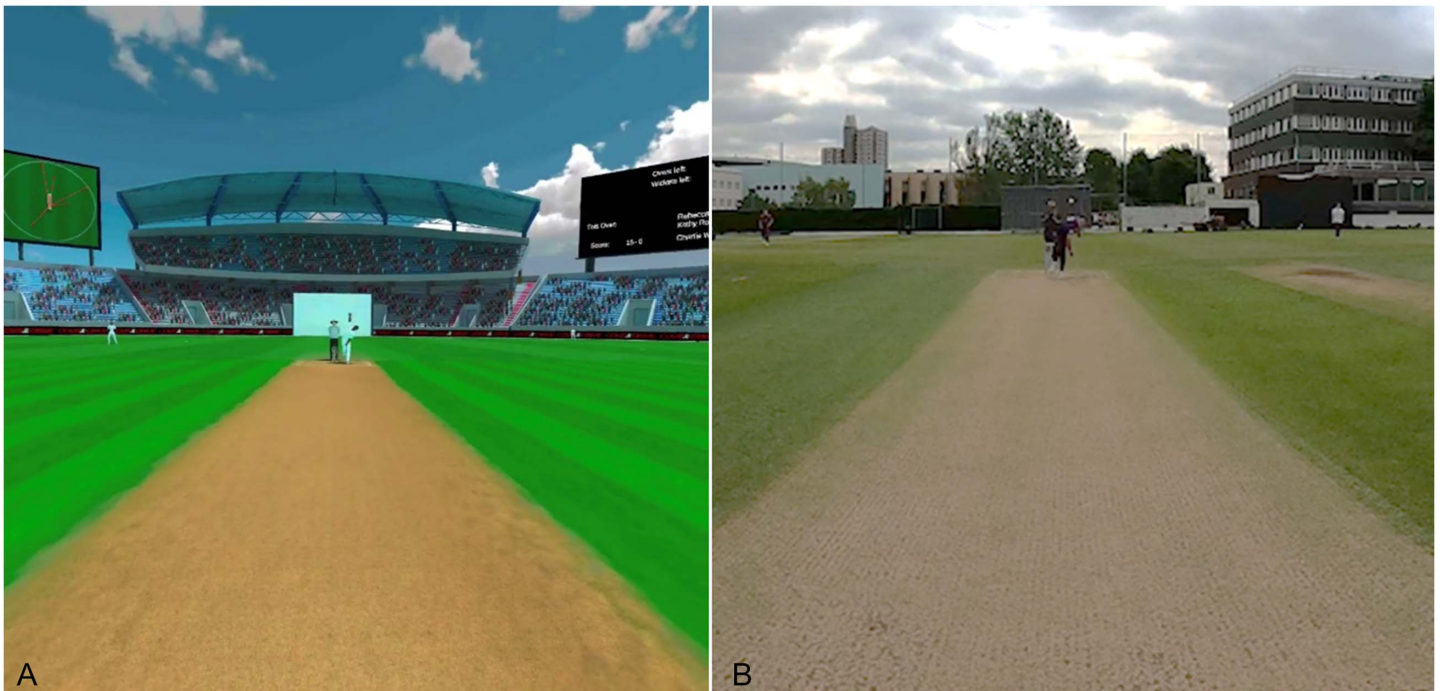


Figure 1 — A section of the player's view in virtual reality (A) and 360-video (B).

involvement and immersion in the virtual environment (Witmer et al., 2005). It is related to task performance (Grassini & Laumann, 2020), can be completed outside of the virtual environment after use without results differing from inside the headset, and is the most widely used measure of presence in simulated environments (Schwind et al., 2019). The questionnaire includes 22 items (excluding touch), are answered on a 7-point scale, and scored to create six factors of possibility to act, possibility to examine, realism, quality of interface, sounds, and self-evaluation of performance (Cronbach's alpha = .84).

SIM-TLX

The SIM-TLX was used to capture psychological fidelity through measures of perceived workload (Harris, Wilson, & Vine, 2020). It is an extension of the National Aeronautics and Space Administration of Task Load Index (Hart & Staveland, 1988), the most used validated tool for measuring mental workload that is strongly related to task performance (see Hernandez et al., 2021). The SIM-TLX is designed to maintain the same structure as the National Aeronautics and Space Administration of Task Load Index but is specific to measuring workload in virtual environments. It has shown both convergent and divergent validity (Harris et al., 2020) and includes nine 21-point rating scales of mental, physical, and temporal demands, frustration, task complexity, situational stress, distraction, perceptual strain, and task control.

Procedure

Players were briefed on the study and use of VR to test game understanding. Players then put on a Meta Quest 2 headset, picked up a cricket bat to which the Quest controller was attached, and were asked to navigate from the menu to their first testing mode to allow them time to familiarize wearing the headset. They then experienced five overs (30 deliveries) in VR and 360-video (counterbalanced). In both simulations, players were required to play shots in response, and in VR, they were able to play the ball into the appropriate areas for the game scenarios. In the 360-video, they were required to anticipate ball location rather than strike the ball (which is not possible in 360-video). Participants completed the questionnaires immediately after each of the simulated environments (see Schwind et al., 2019). Participants were asked to report any simulation sickness and whether they would be interested in using VR and 360-video for cricket in future. We did not record scores to ensure participants were aware research was not being used for selection. Due to the time pressures of such performance settings, all players were able to complete the presence questionnaire in both conditions but only 21 completed both SIM-TLX.

Data Analysis

Factor scores were calculated following guidance from the questionnaires. Data were analyzed using JASP (version 0.17.1, JASP Team, 2023). Data were checked for normality using Shapiro-Wilk tests. Within-subject comparisons between conditions were made for each factor via Student's paired *t* test for factors presenting normal distribution or Wilcoxon signed-rank tests where variables deviated significantly from normal. All comparisons made were preplanned; therefore, alpha value was kept at $p = .05$ and effect sizes (Cohen's *d*) and 95% confidence intervals were reported (Althouse, 2016).

Results

No players reported motion sickness, and all reported they would be interested in using both methods in training and testing.

Presence

Presence data are displayed in Figure 2. Participants reported higher levels of realism in VR ($M \pm SD = 5.250 \pm 0.678$) compared with 360-video (4.757 ± 0.631 ; $t[38] = 4.990$; $p < .001$; $d = 0.799$ [0.434, 1.156]), and higher levels of possibility to act in VR (5.158 ± 0.621) compared with 360-video (4.726 ± 1.206 ; $t[38] = 2.260$; $p = .039$; $d = 0.362$ [0.035, 0.684]). However, 360-video was rated to have a higher quality interface (reverse scale) compared with VR (360-video = 2.462 ± 1.112 ; VR = 2.981 ± 1.113 ; $t[38] = 3.022$; $p = .004$; $d = 0.484$ [0.149, 0.813]), and higher possibility to examine the environment (360-video = 5.364 ± 1.010 ; VR = 5.037 ± 1.113 ; $W = 491.500$; $p = .035$; $d = 0.398$ [0.052, 0.659]). No differences were reported for ability to evaluate one's own performance on the task (360-video = 5.432 ± 0.725 ; VR = 5.221 ± 0.711 ; $W = 364.500$; $p = .060$; $d = 0.381$ [0.004, 0.663]) or on the quality of sounds (360-video = 4.642 ± 1.099 ; VR = 4.845 ± 0.802 ; $W = 314.000$; $p = .291$; $d = 0.195$ [-0.506, 0.161]).

Task Load

Task load data are displayed in Figures 3A and 3B. Participants reported higher levels of physical effort in VR ($M \pm SD = 6.667 \pm 5.902$) compared with 360-video (2.495 ± 1.617 ; $W = 5.000$; $p = .001$; $d = 0.926$ [0.792, 0.975]), higher levels of temporal demand in VR (8.000 ± 5.727) compared with 360-video (5.857 ± 3.953 ; $t[20] = 2.366$; $p = .030$; $d = 0.568$ [0.132, 0.820]), and higher levels of task control in VR (8.333 ± 5.053) compared with 360-video (5.048 ± 4.165 ; $W = 9.500$; $p < .001$; $d = 0.889$ [0.712, 0.960]). No differences were reported for mental effort (360-video = 7.952 ± 5.315 ; VR = 6.810 ± 5.722 ; $t[20] = 1.194$; $p = .246$; $d = 0.327$ [-0.199, 0.707]), frustration (360-video = 4.333 ± 3.864 ; VR = 4.667 ± 4.575 ; $W = 69.000$; $p = .738$, $d = -0.098$ [-0.565, 0.416]), task complexity (360-video = 6.190 ± 4.686 ; VR = 7.714 ± 5.763 ; $t[20] = 1.490$; $p = .152$; $d = -0.325$ [-0.731, 0.095]), situational stress (360-video = 3.429 ± 3.558 ; VR = 4.619 ± 4.727 ; $W = 25.000$; $p = .281$; $d = -0.333$ [-0.736, 0.243]), distraction (360-video = 3.429 ± 2.749 ; VR = 3.619 ± 3.074 ; $W = 63.000$; $p = .811$; $d = -0.074$ [-0.559, 0.449]), or perceptual strain (360-video = 4.952 ± 5.162 ; VR = 4.286 ± 3.875 ; $W = 75.000$; $p = .394$; $d = 0.250$ [-0.309, 0.681]).

Discussion

We aimed to gain an initial understanding of how 360-video and VR simulations, which are likely to employ different visual systems (Milner & Goodale, 1995, 2008), are perceived by athletes. Findings can help inform the cost-effective implementation of simulation technologies in sports. The international pathway cricketers who took part reported high levels of face validity in both technologies. However, VR offered enhanced physical fidelity compared to 360-video, including possibility to act and physical effort. The 360-video offered better visual aspects as reported by a higher possibility to examine (visual element) and a higher quality interface. Interestingly, realism was rated as higher in the VR, despite 360-videos being visually real.

The perception of higher levels of realism in the animated VR environment, compared with the video-based 360-video, suggests

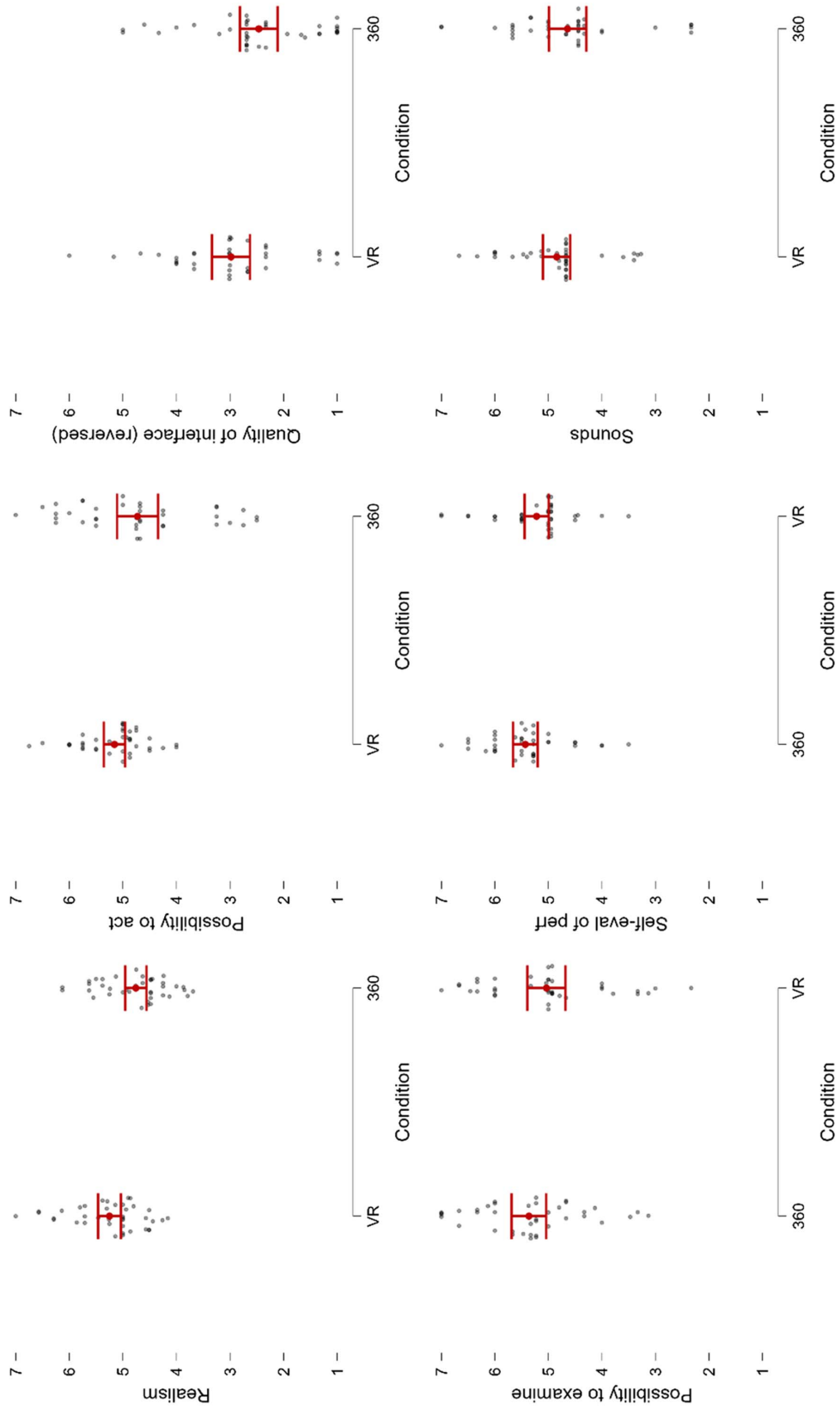


Figure 2 — Mean and SE of scores for VR and 360-video across the six visual factors of the presence questionnaire. VR = virtual reality.

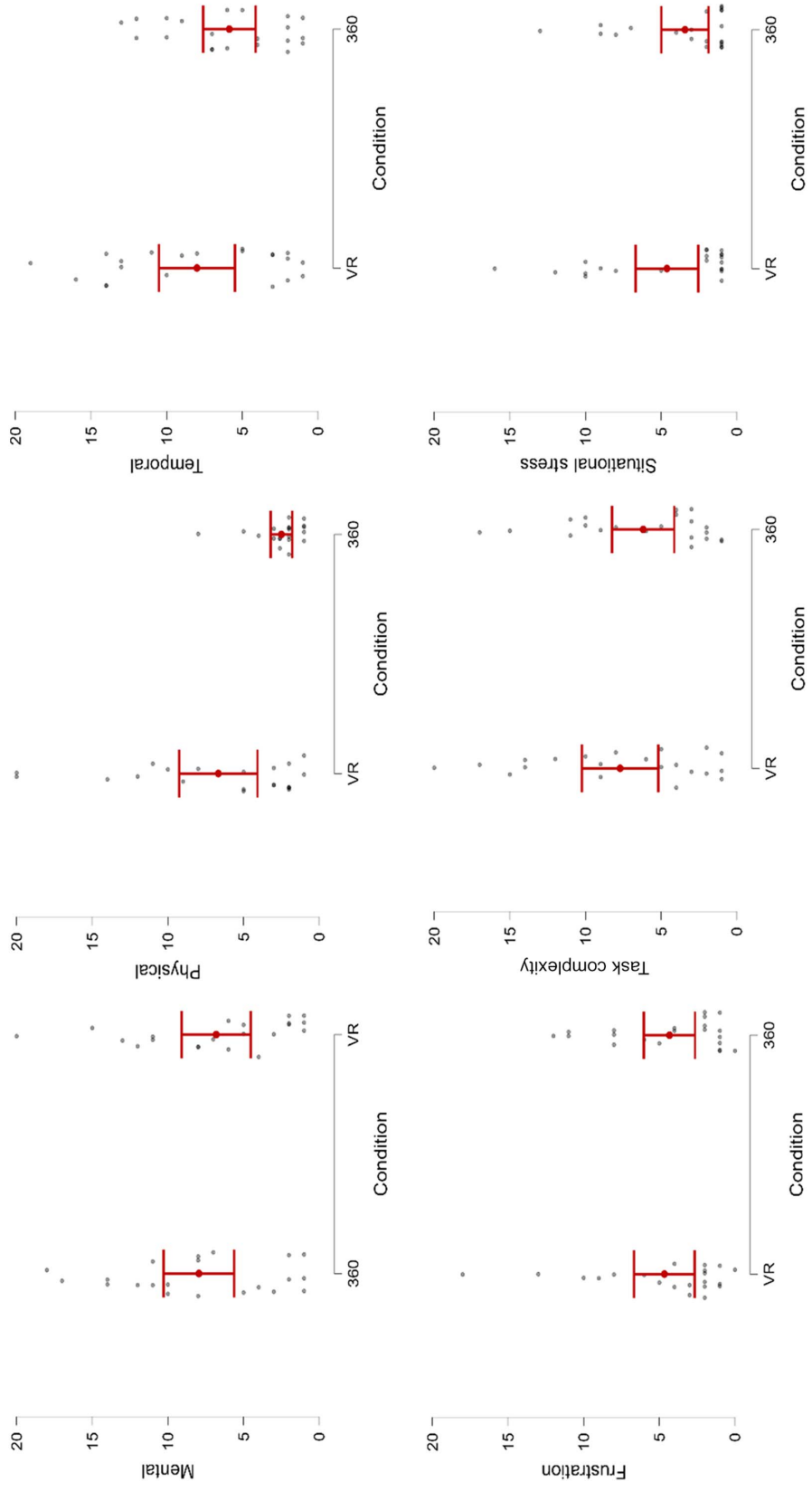


Figure 3(A) — Scores ($M \pm SE$) for six of the nine Simulation Task Load Index factors in the VR and 360-video conditions: mental, physical, temporal, frustration, task complexity, and situational stress. VR = virtual reality.

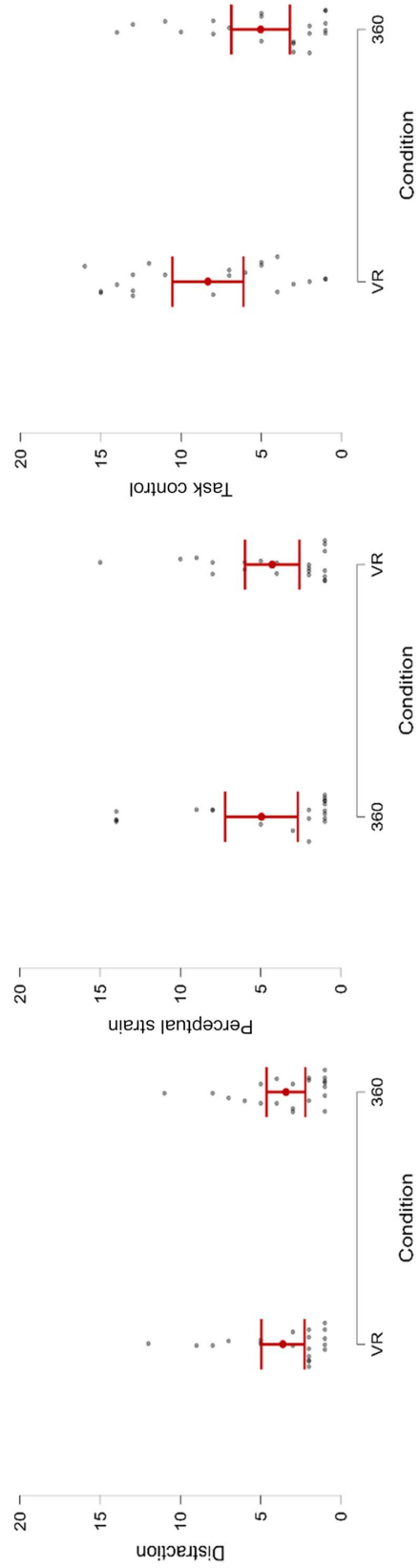


Figure 3(B) — Scores ($M \pm SE$) for three of the nine Simulation Task Load Index factors in the VR and 360-video conditions: distraction, perceptual strain, and task control. VR = virtual reality.

that involving both ventral and dorsal processing through the integration of perception and action is important when aiming to develop simulations that players perceive to have high levels of realism (Dicks et al., 2010; Van Der Kamp et al., 2008). The data here show significant, but often small differences in the player's perceptions of VR compared to 360-video. The small effects can be understood in terms of the use of information at different stages of the process of intercepting a cricket ball, where information for visual perception is used early in the sequence of the delivery and then updated during control of action later (Harris et al., 2022; Runswick et al., 2018; Van Der Kamp et al., 2008). VR includes all stages, but the 360-video used here occluded prior to ball interception. It is possible that, while the interception is missing, enhanced ventral processing prior to striking the ball is still representative of the real world.

From a practical perspective, the size of these differences should also be viewed in terms of the cost and benefit of each method for a specific task and suggests there is potential value in both. Generally, coaches and support staff in performance organizations agree that monetary cost, coach buy-in, and limited evidence base are barriers toward use of these technologies (Greenhough et al., 2021). Therefore, the cheaper and easier to develop 360-video are likely to have some utility for visual tasks, such as measuring perceptual and cognitive skills (e.g., Runswick et al., 2018, 2019) and tactical-based training (García-González et al., 2013), but VR environments will be needed to engage in realistic and interactive training that maintains action-based elements (Craig, 2013; Stafford et al., 2022).

The data here help to confirm the value in future research investigating the use of both 360-video and VR simulations, depending on the needs of the task and resources available. However, findings should be considered understanding the limitations of data collected during a large-scale performance testing day. Participants had limited time periods to engage with and reflect on use of the technology, and not all completed both surveys. This also meant participants did not have time to answer more in-depth questions about the technology's utility in training and how players can see it being applied. However, working within time constraints did allow access to a highly skilled sample who are likely to be the population exposed to these technologies throughout their playing careers.

Further work is now required to capture construct validity, and affective and biomechanical fidelity of both methods (Harris et al., 2020) as well as feasibility, acceptability, and initial efficacy for use in skill development (Birkhead et al., 2019). Sports like cricket, baseball, golf, and table tennis offer unique opportunities for further research into these questions as they offer a relatively stable and comparable viewpoint. As the field progresses, researchers must ensure they keep pace with the rapid development of technology and continue to ensure sporting organizations can make informed decisions about implementation.

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