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A 'reality' check: comparing virtual reality and life-size video in football

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Abstract
Recent advancements in virtual reality (VR) have led researchers to question whether VR could offer a superior medium for perceptual-cognitive training in sport, above and beyond traditional representative task training such as video simulations. To address this question, 30 amateur and semi-professional footballers completed 96 trials of a 1-vs-1 drill, in both VR and life-size video conditions. The drill involved intercepting an oncoming attacker, whereby there were four possible outcomes: true right, true left, fake right, fake left. Participants responded significantly faster and reported significantly greater presence, face validity, enjoyment, and desire to repeat the session in the VR condition compared to the life-size video condition. There was no significant difference in response accuracy or susceptibility to deception between conditions. An additional thematic analysis of a coach's evaluations of participant responses to VR and video stimuli was conducted, representing a novel approach to practitioner-informed extended reality (XR) validation in sport. The coach perceived responses in the VR condition as more representative of live 'on-field' duels and perceived that the life-size video condition may have allowed participants to better detect opponent cues and respond in a more controlled manner. These practitioner-informed observations are exploratory and reflect the perceptions of one coach, rather than independently established differences between conditions. Overall, these results demonstrate the positive role that VR may offer in perceptual-cognitive training and the importance of on-going evaluation as VR technology develops at pace.

Keywords VR · Extended reality · Soccer · Perceptual-cognitive training · Anticipation · Decision making

1 Introduction

In recent years, there has been an increased desire to explore the possibility of training perceptual-cognitive skills in simulated environments (*e.g.,* Gray 2017; Harris et al. 2020a). Perceptual-cognitive skills refer to an individual's capacity to detect, recognise, and process environmental information, integrating it with their existing knowledge and motor capabilities to select and execute appropriate actions (Marteniuk 1976). These perceptual-cognitive

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skills combine to produce two judgements, *anticipation* and *decision-making* (Broadbent et al. 2015). Traditionally, these perceptual-cognitive skills have been trained using representative tasks.

Representative tasks capture the key elements of the real-world task, whilst recreating the situation under standardised and repeatable conditions (Broadbent et al. 2015). A commonly used representative task in the context of this research is a life-size video projection from the point of view of the athlete (*e.g.,* Moore et al. 2019). There are multiple benefits of representative tasks either as an addition to physical practice or in place of it, such as: (a) the ability to incorporate greater volumes of repetition (Düking et al. 2018); (b) the ability to identify the processes underpinning anticipation and decision-making in elite athletes (Roca et al. 2011); and (c) the ability to induce anxiety and train athletes for high-pressure situations (Stinson and Bowman 2014).

Despite the relative success of traditional representative task training, there is a question as to whether these environments accurately capture what athletes experience in competition, and whether the perceptual-cognitive skills learned during laboratory-based training can transfer effectively to real-world competition. In an attempt to assess the best methodology to promote transfer and improve sport performance in representative task training, Hadlow et al. (2018) proposed the modified perceptual training framework (MPTF). Here, modified perceptual training (MPT) includes both perceptual-cognitive training and sports vision training. The MPTF suggests that the greatest level of transfer and improved performance will be elicited in MPT which: (a) targets high-order perceptual-cognitive skills such as anticipation and decision-making (targeted perceptual function); (b) presents realistic stimuli comparable to real-world competition (stimuli correspondence); (c) requires a realistic, sport-specific response from the athlete (response correspondence). The authors discuss the use of computer or image projection technology as a MPT tool but note that this can often target low-order perceptual-cognitive skills (*e.g.,* visual attention) and in previous research has demonstrated low response correspondence (*e.g.,* verbal response or button press). Hadlow et al. (2018) posit that virtual reality (VR) has the potential to rate highly on all three criteria and may therefore be a more effective tool for enhancing perceptual-cognitive skills that transfer to improved sports performance.

VR here refers to "the simulation of an interactive three-dimensional environment that users can be immersed into and that they can interact with" (Sagnier et al. 2020, p. 993). VR addresses one of the major limitations of 2D video-simulations; that stereoscopic information cannot be extracted as it would be in real life (Vignais et al. 2015), with literature demonstrating the importance of stereoscopic information on motor responses (Mazyn et al. 2004). Indeed, Che et al. (2025) carried out a study exploring the difference in tracking ability between footballers and non-athletes across three conditions: two-dimensional multiple object tracking, flat screen three-dimensional multiple object tracking, and stereoscopic three-dimensional multiple object tracking. The authors found that the footballers performed significantly better than non-athletes only in the stereoscopic three-dimensional multiple object tracking condition, supporting the essential role of stereoscopic cues on perception and action.

Additionally, the immersive nature of VR allows participants to have a greater sense of presence, which can be defined as the subjective experience of being in the simulated environment (Harris et al. 2020b). Slater (2009) suggests that presence is composed of 'place illusion' and 'plausibility'. Place illusion can be considered the feeling of actually being there in the simulated environment, whereas plausibility can be considered the feeling that the depicted scenario is actually occurring. A product of this increased presence is that individuals are more likely to behave in similar ways during a VR experience as they would in the real world (Bailenson 2018), improving response correspondence (Hadlow et al. 2018). VR environments also allow the opportunity to more accurately recreate the real-world environment (increased stimuli correspondence) in comparison to 2D video simulations. Harris et al. (2020b) propose that physical fidelity (level of realism provided by the physical elements of the simulation) and face validity (subjective view of the level of realism) have indirect effects on the facilitation of transfer via user buy-in, and that these elements can be captured via self-report. Runswick (2023) explored player perceptions of face validity and physical fidelity in 360-video and VR cricket environments and found that whilst both types of training were perceived to offer high face validity, VR offered enhanced physical fidelity and a higher level of realism. There is evidence to suggest that high perceived physical fidelity, as well as face

validity and presence are associated with the participant behaving in a more realistic fashion (increased response correspondence), which will in turn support transfer of the skill (Slater 2009; Slater and Sanchez-Vives 2016).

There is now a growing evidence base demonstrating significant improvements in real-world performance after VR training, in sports such as baseball (Gray 2017), table tennis (Michalski et al. 2019), football (Fortes et al. 2021), basketball (Pagé et al. 2019) and more (see Kittel et al. 2024; Witte et al. 2025 for a review). However, there is also research which highlights possible negative aspects of VR, including increased cognitive workload (Harris et al. 2020c), transient reductions in oculomotor stability (Harris et al. 2020a), and concerns over whether VR adequately captures the key attributes of expert anticipation (Müller et al. 2023) that question its application to representative task training.

Previous research has utilised a number of methods to assess anticipation and decision-making during representative task training in 1-vs-1 scenarios. Here, a 1-vs-1 refers to an open-play situation whereby an attacker attempts to evade a defender, without direct support from their teammates. Usually, 1-vs-1 scenarios in research are explored from the perspective of the defender, with participants judging the attacker's intentions (Wilson et al. 2023). A common approach is for participants to indicate their prediction via a button press or joystick movement (*e.g.,* Brault et al. 2009), enabling both response accuracy and response time to be obtained. However, as outlined in the MPTF, these response types have low response correspondence so are unlikely to truly assess the mechanisms that underpin successful performance. In other studies, participants have shadowed a more representative physical response to videos presented on a large screen (*e.g.,* Jackson et al. 2020; Warren-Westgate et al. 2021). Harris et al. (2020b) built on this in relation to VR, stating that the representative task needs to have ergonomic and biomechanical fidelity. In other words, the task must allow for and promote realistic movement patterns in the user. This link between perception and action is known as perception–action coupling (Gibson 1979). In an *in-situ* task, researchers found that the accuracy of skilled cricket batters in judging the direction of the ball improved with the degree of perception–action coupling, an effect that was not evident in novice players (Mann et al. 2010). Further, research exploring perception–action coupling in a virtual handball goalkeeping task demonstrated that participants were significantly more accurate in their responses in the condition that required a motor response than in the condition requiring only a perceptual judgement (Vignais et al. 2009). Therefore, it is clear that in order to assess and improve performance, participants must respond as closely as they would in the real world (Hadlow et al. 2018; Jia et al. 2024).

The ability to accurately judge the intentions of an opponent in 1-vs-1 scenarios using a variety of visual cues offers an advantage in many competitive sport scenarios (Mann et al. 2007). However, by making early perceptual judgements using movement kinematics of opponents, athletes can be vulnerable to deception (Jackson et al. 2018; Warren-West and Jackson 2020). Indeed, there are instances whereby the opponent may look to deliberately disguise their true action or 'fake' in an attempt to deceive the individual in a 1-vs-1 situation (Jackson et al. 2006). As an immersive, interactive form of technology, VR has a potential advantage over traditional, video display methods when it comes to understanding deception in sport because it is able to depict simulated environments in three-dimensions that retain stereoscopic depth cues (Brault et al. 2012).

In one of the few studies comparing VR to video simulations, Vignais et al. (2015) found that goalkeepers in a handball goalkeeping task were significantly more accurate and started their interceptive move earlier in the virtual environment than with video clips. However, several limitations restrict the generalisability of the findings and justify further research. Firstly, the study employed a large semi-cylindrical projection system with stereoscopic glasses, a setup that differs considerably from the modern head-mounted display (HMD) used in the present study, especially with regard to immersion, portability, and the overall VR experience. Furthermore, no subjective perceptions were collected, meaning the comparison between factors such as presence, enjoyment, validity, and fidelity across the two modalities remains unexplored. The study also used a small sample of ten elite handball goalkeepers, limiting generalisability to broader athletic populations. As a result, despite the promising findings, it remains unclear whether modern HMD-based VR offers a meaningful advantage over life-size video simulations across different sports and populations, and how athletes experience and perceive the two modalities.

More recently, Hoyne et al. (2026) compared decision-making performance between 360-degree VR and 2D video in Australian Rules Football and found no significant differences in performance across modalities, despite significantly higher perceptions of presence in the VR condition. Whilst this represents an important contribution, 360VR was used to present film footage passively rather than allowing the participant to be in an interactive virtual environment, and participants were required to deliver a verbal response, which as previously discussed is an example of low response correspondence (Hadlow et al. 2018). In comparison, the present study placed participants in an interactive virtual environment and asked them to physically intercept the oncoming attacker, increasing both stimuli and response correspondence. Therefore, whether animated VR offers a genuine advantage over life-size video simulation in tasks requiring physical perception–action coupling remains an unanswered question.

Whilst the current findings are promising, more research is needed, especially in externally paced, 1-vs-1 scenarios such as those experienced in football. Therefore, the present study aims to advance the literature by directly comparing VR and life-sized video simulations within a representative, externally paced football task. In addition, it aims to provide a novel examination of participant responses alongside subjective perceptions of each modality, including enjoyment, immersion, perceived validity, and fidelity. By integrating behavioural and perceptual measures within a sport-specific context, this study offers a new perspective on the applied value of VR beyond existing comparisons. In doing so, it also offers technical insights relevant to extended reality (XR) researchers and developers regarding the design requirements for sport-specific virtual environments.

1.1 Aims of the present study

i. To compare the decision-making judgements (*i.e.,* response time and response accuracy) of football players when presented with a 1-vs-1 task in the VR and video display condition.
ii. To compare self-reported deception in the VR and video display condition.
iii. To compare self-reported face validity, physical fidelity and presence in the VR and video display condition.
iv. To generate preliminary, practitioner-informed insights into the nature of participants' responses across conditions using expert coach "think aloud" evaluations.

1.2 Hypotheses for the present study

H1 *Participants will respond significantly faster and more accurately in the VR condition than the video display condition.*

H2 *Deceptiveness ratings will be significantly higher in the video display condition than the VR condition, due to the absence of stereoscopic depth cues in the video display condition.*

H3 *Self-reported presence, face validity and physical fidelity will be significantly higher in the VR condition than the video display condition due to the immersive nature of the technology.*

2 Methods

2.1 Study design and philosophical assumptions

This study adopted a mixed-methods design, integrating quantitative self-report and performance measures with an exploratory qualitative component. The qualitative research was informed by a constructivist ontological and

epistemological perspective, which argues that reality and knowledge are constructed through social interaction and shared experience (Pretorius 2024). Consistent with this position, the "think aloud" methodology was conducted as a collaborative process between the lead researcher and an expert coach. This philosophical stance also underpins the choice of reflexive thematic analysis (RTA) as the analytical framework, which explicitly acknowledges the active role of the researcher in the analysis (*e.g.,* Park et al. 2022).

2.2 Participants

Thirty male footballers (*Mage* = 24.13, *SD* = 5.96) who had competed for a minimum of two years at amateur (*N* = 18) or semi-professional (*N* = 12) level participated in the study. Power analyses (G*Power; Faul et al. 2007) indicated that a sample size of 27 would be required to provide sufficient power (0.80), given an α of 0.05, to detect a medium effect size (Cohen's $d = 0.50$) via a paired-sample t test. All participants were over the age of 18 and provided written informed consent. This study was granted ethical approval prior to data collection from the lead author's institution.

2.3 Stimuli creation and clip ratings

Stimuli for the study were created using markerless motion capture software (Move AI, London, UK) to record a semi-professional footballer performing a change of direction task conducted on a full-size 'astroturf' football pitch (see Fig. 1). The task consisted of repeated accelerations and changes in direction within the motion capture perimeter. See Appendix A for full details on the stimuli creation. Markerless motion capture was selected for its ecological validity and practical suitability for sport-based tasks, as it avoids movement disruption and marker placement constraints associated with traditional systems (Kanko et al. 2021). Although markerless approaches generally show slightly lower spatial accuracy than gold-standard optical systems such as Vicon, with markerless systems typically producing spatial errors in the range of 1–3 cm, they have been shown to provide valid representations of whole-body movement patterns (Nakano et al. 2020). It should be noted that the present study used the multi-camera Move AI pipeline (six synchronised devices), which supports more comprehensive and robust three-dimensional reconstruction than single-camera markerless solutions (Noorbhai et al. 2025). However, validation findings for one system cannot be assumed to apply to another. At the time of revision, to the best of the authors' knowledge, no independent, peer-reviewed study establishing the validity of the Move AI system existed, nor was there peer-reviewed research examining its measurement error against a marker-based reference system. Whilst the accuracy of the reconstructed body kinematics could not be independently quantified, the change-of-direction action captured here falls within the category of whole-body movements for which markerless approaches have shown the closest agreement with marker-based systems (Nakano et al. 2020; Barzyk et al. 2024). Finally, the markerless system was unable to capture the football, and therefore this was superimposed after the motion capture by a games design developer. In order to retain important ball mechanics such as speed of rotation, the VR footage was paused and compared frame-by-frame with the real-life footage.

In total, 38 of the 40 clips from the recording were useable for the present study (i.e., fit the parameters of the task and were useable from a motion capture perspective). To validate the clips, one UEFA A-licence coach and one UEFA B-licence coach rated the clips according to three equally weighted factors: fluency of approach (1 = not at all fluent; 10 = very fluent); realistic game pace (1 = not at all realistic; 10 = highly realistic); technical execution (1 = poorly executed; 10 = very well executed). In total, four clips were excluded as both coaches gave them a mean rating below 6 out of 10. The 24 clips with the highest mean rating were then selected for the study stimuli, and the remaining 10 clips were used to form the familiarisation block.

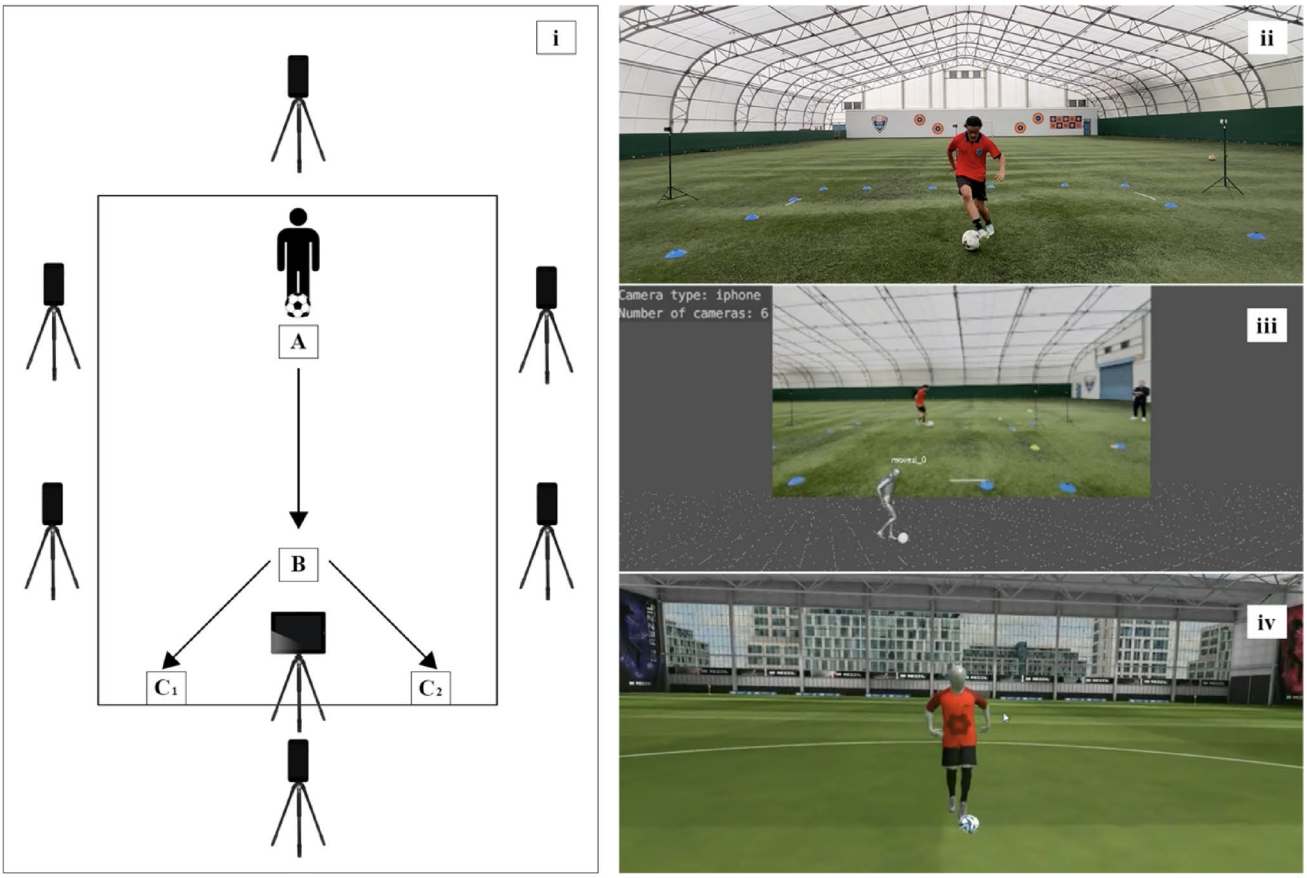


Fig. 1 Demonstration of the stimuli creation process. LEFT (i): Diagram to demonstrate the stimuli creation set up, including the mobile phone placements, the start point with the ball **A**, the cut point **B**, and the two finish points after the cut **C1** & **C2**. RIGHT: Visual representation of the video display simulation (ii), the process of converting this into a VR simulation using Move AI (iii), and the eventual VR simulation that was used to compare to the real-life video simulation (iv)

2.4 Task design

The task was a two-choice anticipation task, designed to simulate a 1-vs-1 defensive scenario in football. Participants were given the following instructions on the task: "You will be facing four blocks of 1-vs-1 drills from the perspective of the defender, where your aim is to intercept the oncoming attacker by stepping sideways into their path. We would like you to intercept naturally, as you would in a real match. The attacker may attempt to deceive you at points during the session. It is not critical that you 'win' the ball, as long as you step in the correct direction." The avatar could either go left or right and could either be true or fake (a single step over). This left four possible outcomes: true right, true left, fake right, fake left.

The study employed a repeated measures design, with participants undertaking both conditions: (1) VR; (2) life-size video display. Participants completed two blocks of 24 trials in each condition with a two-minute standardised rest period between blocks. Condition order was counterbalanced, with half of the participants experiencing the VR condition first, and half experiencing the video display condition first. Participants completed all blocks in a one-off session, lasting approximately 60 min in total.

Participants wore foot trackers in both conditions to record response time and response accuracy. Participants were required to step 0.3 m from their starting point in order for the foot trackers to register a response, and this was signalled on the floor in the VR condition via a decagonal line and in the video display condition via tape on the floor (see Fig. 2). Response accuracy was determined by whether the participant stepped in the correct



Fig. 2 The experimenter view during the trials **A**. The participants' first-person view of their feet in the VR condition; the decagonal line signals how far they needed to step to initiate a response **B**

direction; whilst response time was calculated from the point when the avatar's foot either (a) contacted the football in the true version; (b) passed over the ball in the deceptive condition, to when the 0.3 m response line was broken. The response was calculated based on the first movement, therefore if a participant stepped in the incorrect direction and subsequently corrected, only their initial response was registered. The distance of 0.3 m was chosen through extensive piloting as the minimum movement distance required to still capture all participants' true responses (*i.e.,* their interceptive steps), without the distance being so small that it also captured false positives (*i.e.,* loading, being on one's toes). The responses were also cross referenced with video footage to confirm that the responses were correctly captured.

2.5 VR stimuli

Data from the initial stimuli creation were captured using six iPhones and uploaded to the motion capture software for rendering. Each iteration was rendered into a film box (FBX) file, which consisted of a virtual avatar of the model along with the ball used for dribbling. The FBX file was then uploaded into Unity 3D, and VR sports company Rezzil used this to create a bespoke drill within a customised version of their Rezzil Index for use in this study. Further details regarding the creation of the stimuli for both the video display and VR conditions can be found in Appendix A.

In the VR condition, participants wore a VR HMD (HTC Vive Wired Headset) and accompanying trackers, which were securely fixed to footwear using large EOZ VR foot straps. The VR operating space was calibrated

as a 4 × 4 m rectangle using the SteamVR platform. Two base stations tracked three-dimensional movement and were fitted at 180 cm at both sides (along the coronal plane) of the participant, ensuring tracking was maintained throughout the procedure.

To assess their behavioural responses, participants' performance was also recorded using a GoPro Hero Black 7, recording in 4 k video at 60 frames per second (GoPro 2018). The GoPro was mounted on a Star 61 tripod at a height of exactly 0.9 m, placed directly behind the participant at a distance of 2.0 m. This allowed for visibility of the participants' body kinematics and the projector screen, without interfering with their movement.

2.6 Life-size video stimuli

The video clips were projected via a 3LCD ultra-short throw projector (Epson L1050U) with 1920 × 1200 resolution onto a 2.4 m (H) × 3.8 m (W) screen. The ultra-short-throw nature of the projector allowed participants to stand 1.5 m away from the screen to replicate where the camera was placed during the filming. Participants wore the same trackers and had the same camera set-up to measure kinematic performance as per the VR condition.

2.7 Procedure

Upon arrival, participants read the information sheet and gave written informed consent to take part in the study. Participants also completed a health screening form and were provided with the opportunity to warm-up before beginning. After the warm-up, they were given instructions on the task and given the opportunity to ask questions, before being fitted with the Vive trackers on their footwear and shown how to loosen and tighten the HTC Vive headset. Participants' virtual boots replicated their own foot size as closely as possible as this was the only body part of the avatar that was visible within the virtual environment. For both conditions, participants were required to calibrate the feet sensors by placing their feet within the provided templates (see Fig. 2). Before beginning the experimental trials, participants completed 10 familiarisation trials to ensure full understanding of the task.

After the familiarisation trials, participants completed the first of four blocks of 24 test trials, which were presented in a randomised order. Each trial lasted approximately 4–5 s with participants returning their feet to the start position before the experimenter could initiate the next trial. After the first block of trials, participants were given a two-minute rest period, before the second block began. After the two blocks of 24 trials in the first condition, participants were asked to complete the questionnaires. Participants then repeated this process for the second condition. Finally, participants were debriefed and provided with the opportunity to ask any questions.

2.8 Measures

2.8.1 Task performance

The two measures of performance were response time (ms) and response accuracy (%). Response time was recorded when one of the foot sensors crossed the pre-determined, standardised threshold of 0.3 m. Response accuracy on each trial was recorded as a binary measure (correct, incorrect), which was used to calculate the average score for each condition.

2.8.2 Presence

Participant presence was assessed using the Slater-Usoh-Steed Presence Scale (SUS; Slater et al. 1998). Participants rated six items on a 7-point Likert scale, considering items in relation to real-world interactions. The questionnaire is based on three themes: (i) the sense of being in the virtual environment; (ii) the extent to which the virtual environment becomes the dominant reality; (iii) the extent to which the virtual environment is remembered as a "place" (Usoh et al. 2000). For example, participants answered "to what extent were there times during

the experience when the virtual environment was the reality for you?" on a scale from "at no time" (1) to "almost all the time" (7). Each question has a different set of anchors. This scale has been used in previous VR sport research (*e.g.,* Mouatt et al. 2023).

2.8.3 Face validity and physical fidelity

To compare user perceptions of the simulated environments, this study utilised the framework for the testing and validation of simulated environments by Harris et al. (2020b). Within this framework, Harris and colleagues recommend using self-report methods to test both face validity and physical fidelity. Thus, four items were created, which participants answered on a 5-point Likert scale from 1 ("strongly disagree") to 5 ("strongly agree"), with 3 ("neutral") being the mid-point. Items 1 ("the simulation looks realistic") and 2 ("the simulation feels realistic") were averaged to give a mean score for face validity. Items 3 ("there is a high degree of detail in the physical elements of the simulation") and 4 ("there is a high degree of realism in the physical elements of the simulation") were averaged to give a mean score for physical fidelity.

2.8.4 Enjoyment and repeatability

Participants were asked to report how much they enjoyed the session they took part in and whether they would use that method again in the future. Participants answered on a 5-point Likert scale from 1 ("strongly disagree") to 5 ("strongly agree"), with 3 ("neutral") being the mid-point.

2.8.5 Deception

Participants were also presented with the statement "I felt as though the player 'deceived' me, and the fakes were realistic". Participants answered on a 5-point Likert scale from 1 ("strongly disagree") to 5 ("strongly agree"), with 3 ("neutral") being the mid-point.

2.8.6 Behavioural evaluation of participant interaction with stimuli

The video footage was filmed from directly behind each participant, providing full view of the participant's entire body and the screen in front of them. This provided the coach with clear visibility of key joints relevant to the participant's actions, including the ankles, knees, and hips, as well as overall posture, weight distribution and stride patterns. This footage was reviewed by a UEFA B-licence coach with over 20 years of coaching experience, who was independent of the coaches that rated the initial clips. The coach was recruited through purposive sampling, based on their relevant expertise and professional background. The present study employed a "think aloud" methodology, where the coach was asked to provide verbal evaluations of any noteworthy aspects relating to the participant's physical responses to the stimuli, with particular focus on the representativeness and technical quality of their movements relative to what would be expected in a live 1-vs-1 defensive scenario. Other than being informed that the videos would show players responding to VR and large screen video displays, the coach was not provided with any information about the study's aims, hypotheses, or quantitative findings prior to the session. It should be acknowledged, however, that the VR condition was necessarily identifiable from the visible HMD. As a result, these procedures may therefore have reduced, but could not eliminate, condition-related observer bias.

The coach evaluated 720 trials (25% of the 2,880 trials recorded), comprised of 24 trials from each participant with six trials from each block selected at random, to give a reasonable representation of the full dataset. Clips were presented one participant at a time, in blocks of six trials per condition, in a counterbalanced fashion, with VR trials first for half the participants and video display trials first for the remaining participants. The coach was informed at the start of each new block and each new participant. The evaluation was coach-led and open-ended. There was no set time allocated per block, with the coach given as much time as needed and free to re-watch any

clips or pause the recording at any point. The researcher clarified the meaning of any unclear or underdeveloped comments and checked that the coach had nothing further to add before moving on. A break was provided at the mid-point of the session, which lasted approximately four hours in total. The coach's verbal evaluations were audio recorded, and the researcher made notes throughout to assign the relevant comments to each participant and condition. The recording was subsequently transcribed verbatim.

2.9 Data analyses

2.9.1 Quantitative analysis

The data were analysed using SPSS version 30. To address H1–H3, paired-sample *t* tests were conducted between the VR and video display conditions for response time (H1), response accuracy (H1), self-reported deception (H2), and self-reported enjoyment, repeatability, face validity and physical fidelity (H3) as the dependent variables. All data were screened for univariate and multivariate outliers, with the three univariate outliers found retained in the analysis as they were determined to be genuine responses rather than data entry errors or anomalies. Their inclusion was deemed important to ensure that the findings reflected the full range of observed responses. Normality was assessed for all data using measures of skewness and kurtosis. For data that did not meet the assumption of normality, the non-parametric Wilcoxon signed-rank test was applied.

2.9.2 Qualitative analysis

The coach's verbal evaluations were analysed using RTA, following the six-phase process outlined by Braun and Clarke (2006). In Phase 1, the lead researcher familiarised themselves with the data through repeated reading of the full transcript of the coach's evaluations. In Phase 2, initial codes were generated to capture meaningful observations about participants' behavioural responses across conditions. In Phase 3 and Phase 4, codes were grouped into themes, before being reviewed and defined in relation to both the coded extracts and the full dataset. In Phase 5, each theme was defined and named to clearly reflect its content in relation to the study's exploratory aim. In Phase 6, the final report and thematic map were produced (see Fig. 4). The process was inductive, allowing themes to emerge from the data. Consistent with the constructivist epistemological position previously outlined, the analysis was conducted reflexively, with the lead researcher remaining aware of how their own role during the evaluation session may have shaped the data collected.

3 Results

3.1 Response time and response accuracy

There was a significant difference in response time (ms) between the VR and video display condition ($t(29) = 7.10$, $p < 0.001$, $d = 1.30$), with participants responding significantly faster in the VR condition ($M = 258.72$, $SD = 66.06$) than the video display condition ($M = 342.68$, $SD = 87.76$). There was no significant difference in response accuracy (%) between the VR ($M = 77.05$, $SD = 24.37$) and video display ($M = 78.58$, $SD = 22.91$; $t(29) = 0.65$, $p = 0.52$, $d = 0.12$).

3.2 Presence, face validity, and physical fidelity

Ratings of 'presence' were significantly higher for the VR condition ($M = 28.60$, $SD = 4.93$) than the video display condition ($M = 20.37$, $SD = 7.25$; $z = -3.83$, $p < 0.001$, $d = 0.90$). Similarly, ratings of 'face validity' were significantly higher for the VR condition ($M = 4.20$, $SD = 0.74$) than the video display condition ($M = 3.05$, $SD =$

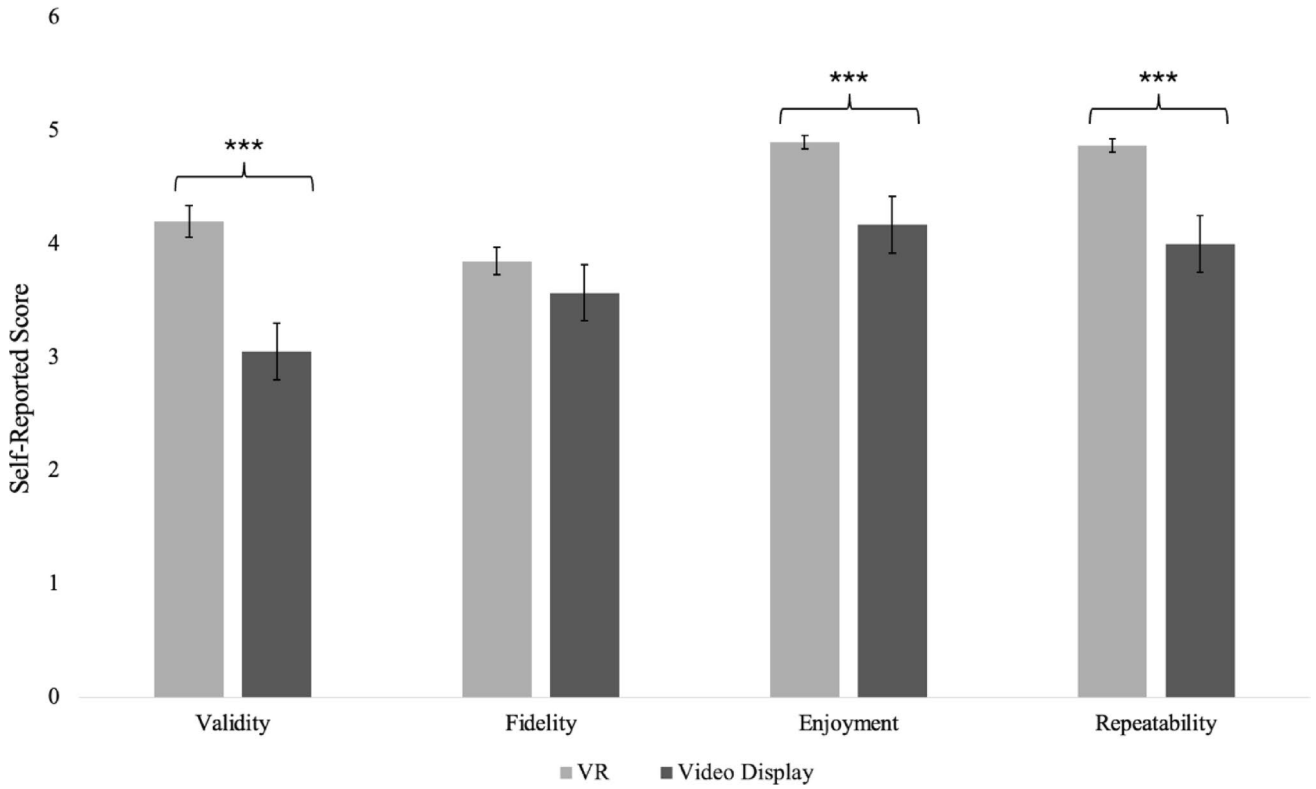


Fig. 3 Means and standard error (SE) bars for self-report responses to questions regarding face validity, physical fidelity, enjoyment, and repeatability (* = $p < .05$, ** $p < .01$, *** $p < .001$)

1.13; $t(29) = 2.10$, $p = 0.02$, $d = 0.38$). There was no significant difference between the 'physical fidelity' ratings for the VR and video display conditions ($t(29) = 1.41$, $p = 0.09$, $d = 0.26$; see Fig. 3).

3.3 Enjoyment and repeatability

Self-reported enjoyment was significantly greater in the VR condition ($M = 4.90$, $SD = 0.31$) than the video display condition ($M = 4.17$, $SD = 0.95$; $z = -3.48$, $p < 0.001$, $d = 0.72$). Likewise, there was a significantly greater desire to complete the session again in the VR condition ($M = 4.87$, $SD = 0.35$) than the video display condition ($M = 4.00$, $SD = 1.17$; $z = -3.33$, $p < 0.001$, $d = 0.71$).

3.4 Self-reported deception

There was no significant difference in the extent to which participants felt they had been deceived in each condition ($z = -0.17$, $p = 0.86$, $d = -0.23$), with similar ratings reported for the VR and video display condition.

3.5 Coach's behavioural evaluations

The coach's verbal evaluations of participants' responses generated 210 min of data, which were transcribed verbatim then analysed using RTA. After generating the initial codes and sub-themes, four overarching themes emerged (see Fig. 4 for the full model).

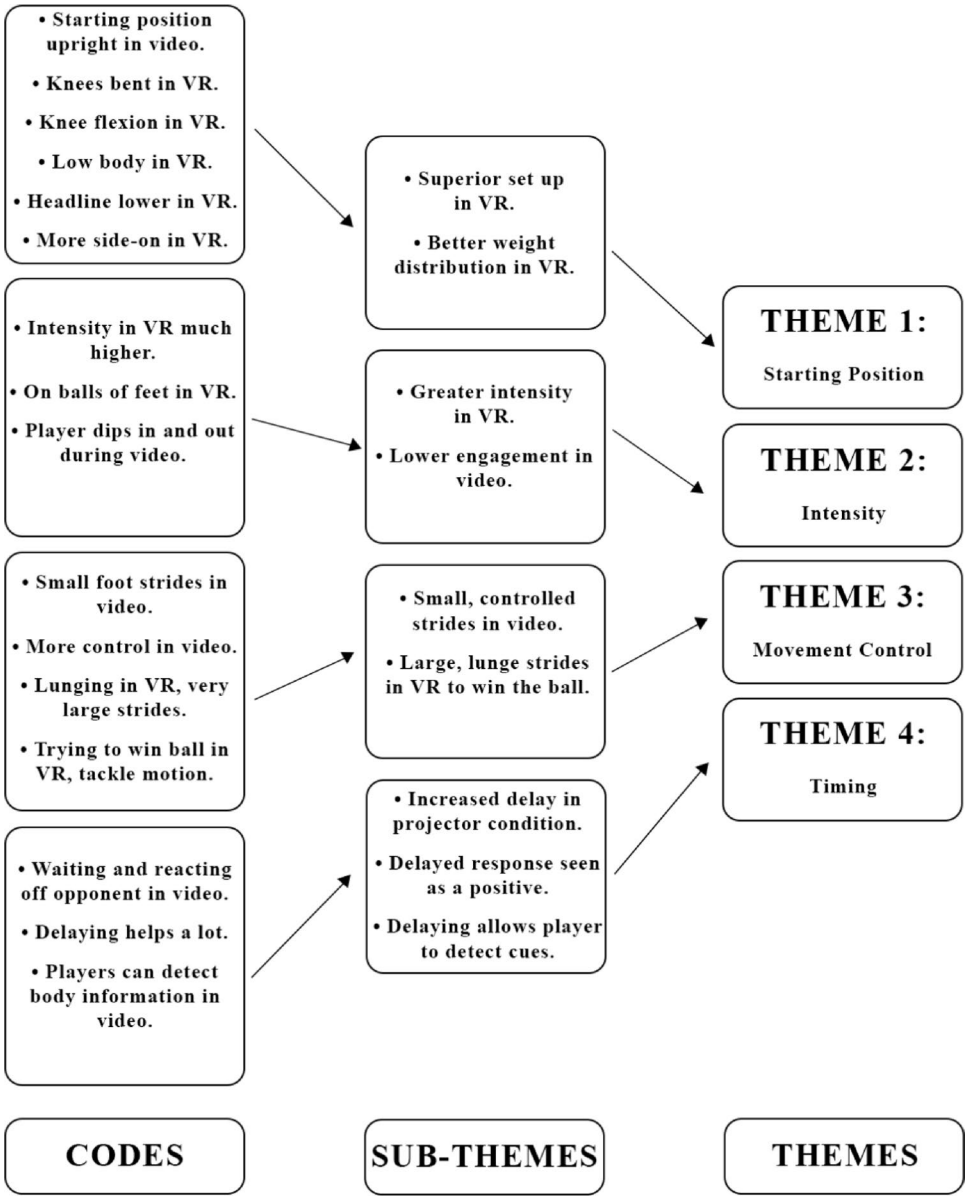


Fig. 4 The themes, sub-themes, and codes identified through thematic analysis. Arrows indicate the relationships and progression from data coding to theme development

3.6 Theme 1: starting position

The first theme captures the coach's perception that participants adopted starting positions with greater behavioural fidelity in the VR condition than in the video display condition, especially with regard to the stance and weight distribution. For example, when viewing Participant 2 in the VR condition, the coach stated:

> *"I think one of the things I spotted there was he's crouching down slightly. He's having to think, I need to get my headline slightly lower to the ball so I can react quicker. So that's a positive thing. That's recognising—okay—if I'm too upright in terms of my top of my body, I'm just not quite able to react in time."*

Comparing the same participant in the video display condition and assessing why he had some incorrect responses, the coach said:

"It's all due to his starting position—he's too upright… If you get it wrong, you get it wrong, it looks bad. If you imagine that's your legs there [coach uses two pens to signal straight legs], and you're almost like a stump. You need to be able to bend your knees and go and explode off. And it's very, very difficult to do that from that position."

The coach proceeded to make comments about the participants in the VR condition having a better technical set up than the video display condition, and this was raised for 11 of the participants. In particular, the coach commented often on the knee flexion in the VR condition: *"The one thing I would say there, the knees are slightly flexed and that does help to spring off."* As well as: *"Yeah, knee flexion is good there again."*

Overall, the coach perceived the starting position to be more natural in the VR condition, specifically regarding the loading through the knees, which they suggested should allow for a faster response time to the opponent's move, especially in the deceptive trials.

3.7 Theme 2: intensity

The coach also commented on engagement and intensity seemingly being higher in the VR condition than the video display condition. When discussing intensity for Participant 23, the coach said: *"I would say the intensity on the VR was very much higher, I would say, versus the projector."*

However, the coach did emphasise that the intensity levels were only marginally higher, before acknowledging that small differences can help in training: *"I think there's a bit more intensity there [in the VR condition compared to the video display condition]. Not loads, but it was noticeable. I think it probably helps. It actually does help."*

The coach also commented on a lack of engagement at points in the video display condition, with participants such as Participant 29 not showing the same intensity as they did in the VR condition: *"It's almost like he was dipping in and out really really quickly, like he just wanted it over and done with. He wasn't finishing necessarily the action."*

Whilst engagement levels and intensity are not always associated with increased performance, the coach spoke about the importance of aiming to achieve intensity with every session in real world training.

3.8 Theme 3: movement control

A large part of the discussion with the coach was oriented around the type of interceptive response from the participants, and whether the tackling/side-step movement differed across the conditions, especially in relation to movement control. The coach commented on how there appeared to be more control and small strides in the video display condition, which he associated with success:

"Look at the foot strides, they're really small. That's really important when you're jockeying. So, I think that's probably helping him because if you've got smaller strides and you're light on your feet you can react quicker. I think that is massively helping him here."

In comparison, he noted that in the VR condition, the participants had much longer strides, with them often lunging to get the ball: *"Massive strides, that's like too big, that's way too big. Once they've landed that foot, watch them trying to spring back to the position, like there you can see it's not just, it's not balanced at all."*

The coach and researcher continued to discuss that this could be the nature of the VR condition in comparison to the video display condition, where the participants are lunging as they are "trying to win the ball", in comparison to the video display condition where the ball disappears off screen as the participant steps.

3.9 Theme 4: timing

One element that the coach immediately picked up on is that the timing of the response was different across conditions, with participants appearing to be delayed in the video display condition, in comparison to the VR condition. For example, with Participant 13, the coach said: *"I think he's a lot more controlled there. So, what I mean by that is that he's waiting, he's patiently defending and then he's having to react off the [opponent's] movement."*

The coach also proceeded to comment about how important it is that defenders delay their response as long as possible, and how a longer response time could be a good thing: *"Delaying is such an important thing, honestly. If you can delay as long as possible, that does help massively. For me, the art of defending is not to dive in, it's to delay for as long as possible."*

Further, the coach explained that this delayed response time could be because of the additional cues that the participants are able to detect in the video display condition: *"You can pick up on knee positioning and if they're dribbling on the outside or the inside of their foot, that could help. That could also play into people's reaction times and anticipation."*

According to the coach, it appeared that the participants in the video display condition delayed their responses and were more controlled in their reaction, which he largely viewed as a positive in that condition. He also suggested that this could be the result of having more cues to pick up from the real-life opponent versus the VR avatar which lacked some of these fine details.

4 Discussion

The main aim of the present study was to extend research exploring the role of VR within football by comparing task performance, participant experience, and coach observations for the same task performed in a VR and video-based format. As hypothesised, response time was significantly faster in the VR condition than in the video display condition. There was no significant difference in response accuracy between the two conditions, which suggests there was no trade-off between the response speed and accuracy. Contrary to H2, there was no significant difference between ratings of deceptiveness in the two conditions. Overall, there was strong support for H3, with participants reporting greater presence, face validity, and enjoyment in the VR condition than the video condition, as well as a significantly stronger desire to repeat the session. Finally, the coach perceived participants' responses to the VR stimuli as more representative than their responses to the large-screen video stimuli. However, as an exploratory, practitioner-informed observation from a single non-blinded coach, this should be treated as a perceived pattern rather than an independently established difference between conditions.

4.1 Slower response time in video display condition

One of the key findings in the present study is that response time was significantly slower in the video display condition than the VR condition. There is some evidence to suggest that delaying a response in sport could be a positive sign. Previous research by Brault et al. (2012) in a similar study in rugby found that experts wait significantly longer than novices before initiating their interceptive movement, delaying the movement to pick up on more cues from the opponent. In the present study, whilst the VR avatar maintained the same key biomechanical elements that the opponent in the video display had, some social cues such as facial expressions and minor postural cues such as ankle and wrist movements were absent. Furthermore, whilst the frame-by-frame reconstruction process of superimposing the ball was intended to preserve important details, the ball information was reconstructed rather than directly measured, and therefore necessarily involved a degree of subjective judgement. In other words, if participants had more visual sources to attend to in the video display condition than the VR condition, this might account for the longer response times. Alternatively, it is possible that participants

responded slower in the video condition to detect later occurring (and potentially more predictive) information that was only present in the video condition.

Importantly, body kinematics are considered the pre-eminent source of anticipatory information when defending 1-vs-1 football actions, including deceptive step-overs viewed from the defender's perspective (Wright and Jackson 2014), which supports the faithful reproduction of these cues being central to the representativeness of the present task. Nevertheless, ball-related information accompanying the movement (*e.g.,* ball rotation and displacement relative to the attacker) plausibly contributes to anticipation and interception, so it cannot be ruled out that discrepancies between the actual and reconstructed ball may have influenced response time and/or accuracy. Accordingly, the findings are best interpreted as demonstrating the role of body kinematic information within an environment in which ball-related information was, to some extent, constrained, rather than as evidence that ball fidelity is unimportant provided body kinematics are faithfully reproduced. In contrast to the present findings, Janssen et al. (2023) suggested that, in comparison to responses made to video footage, less-representative VR animations could result in later decisions given that reliable kinematic information will not be available on which to make earlier decisions. Following this logic, the significantly faster response times in the VR condition in the present study suggest that the crucial kinematic elements of the movement were retained and gave participants enough information to make an equally accurate decision. The present results are more closely aligned with those of Vignais et al. (2015), who found faster, more accurate responses in the virtual environment in comparison to the video simulations in a handball goalkeeper task. Interestingly, Hoyne et al. (2026) found no significant differences in decision-making performance between 360VR and 2D video. This discrepancy in findings could be attributable to the fact that Hoyne and colleagues employed passive 360-degree video footage and required verbal rather than physical responses, both of which reduce perception–action coupling. It could therefore be that performance advantages for VR over video simulation are contingent on the nature of the task, the type of VR employed, and the response the task requires.

Not only were response times significantly faster, but participants also reported feeling greater presence and enjoyment, and the coach commented on the superior intensity and starting position in the VR condition. Therefore, it is possible that these positive elements in the VR condition could have contributed to the faster response time. It is also possible that the increased presence and enjoyment resulted in participants maintaining greater concentration levels, and there is recent research to suggest that increased concentration can improve performance in football (Mahardhika et al. 2023), as well as evidence of a significant negative relationship between concentration and response time in sports such as fencing (Aydin et al. 2024). Whilst the exact mechanisms underpinning this need to be further explored, the significantly faster response time in the VR condition without a significant drop in response accuracy would appear to be a positive sign for VR.

4.2 The advantages of VR

As previously stated, participants reported significantly greater presence, face validity, enjoyment and desired repeatability of the VR than the video simulations. These quantitative findings were complemented by the coach's perception of greater engagement and intensity in the VR condition. Richlan et al. (2023) argued that the key in a training context is to generate a state of 'experiencing', and that increased presence, validity, and engagement are likely to lead to a higher probability of learning and transfer. The finding of greater presence in the VR condition is also consistent with Hoyne et al. (2026), who reported higher presence, engagement, and ecological validity in 360VR compared to 2D video in an invasion sport context, reinforcing the idea that immersive environments generate stronger perceptions of being within the simulated environment. Providing physiological support for this, Che et al. (2023) found that adolescent female soccer players demonstrated higher learning efficiency and greater flow experience (as seen by lower low frequency heart rate variability) when completing multiple object tracking tasks in VR compared to 2D display, which the authors suggest could indicate that more immersive environments generate greater engagement and task absorption. Although in a slightly different task format, there is some evidence to suggest that using VR as a training method in football can significantly increase hedonic motivation (i.e.,

the fun or pleasure derived from using the technology), above and beyond related desktop applications (Krupitzer et al. 2022). This increase in hedonic motivation has been shown to play an important role in technology acceptance and use (Venkatesh et al. 2012). Therefore, the self-reported increased presence and enjoyment of the VR condition in comparison to the video display condition is a major strength, by allowing athletes to perform drills as if they are physically present in the virtual environment (Tieri et al. 2018).

As one of the only other similar studies, Runswick (2023) found that a VR cricket batting environment encouraged significantly higher physical fidelity than a comparable 360-video format but found no significant difference in face validity. The present study found the opposite, in that participants reported significantly greater face validity in the VR condition, but no significant difference in physical fidelity. Despite the inherent differences between the tasks in each study, as well as the medium through which the video simulations were presented, this is an interesting difference, nonetheless. Further research should take place to understand self-reported face validity and physical fidelity in line with the framework by Harris et al. (2020b). Finally, it should be noted that despite there being a significant difference between the two conditions in the present study for enjoyment and desired repeatability, the mean scores were very high for both conditions, which could perhaps signal a novelty effect of trying new technology for the first time.

4.3 Considerations

One of the strengths of the present study is that perception–action coupling was maintained to a high standard due to the relationship between the observed visual task and the paired behavioural response. As previously discussed in relation to the MPTF, this increased response correspondence is a predictor of increased transfer. However, there were still some elements of real-life decision-making that could not be upheld in the research. Firstly, participants were not fully aware if they won the ball as there was no ability to interact with the ball. Furthermore, in real life, athletes are rarely stationary with an attacker running at them—they would either step forward to approach the attacker or jockey backwards. In some situations, the defender may even choose not to engage in a duel and instead show the attacker down the line, away from the goal and centre of the pitch. One simple change from the defender may then impact the approach from the attacker, and therefore the absence of this interactive element will reduce the realism of the defensive actions. In the present study, the coach commented on how the drill was "pre-meditated" and viewed this as the biggest limitation of this type of training. Relatedly, the defender would usually have and potentially rely upon cues about where their teammates are, where the goal is, the context of the match, situational probability information, fatigue levels, and more (Levi and Jackson 2018). Another design consideration is the stationary starting position and 0.3 m response threshold used here, which were necessary to provide a clean indicator of the participant's interceptive decision. However, this precluded assessment of defensive, spatial positioning behaviours such as closing speed and distance management. Future research with a primary interest in such behaviours could relax the 0.3 m constraint by permitting free movement within a defined area (*e.g.,* 4 × 4 m), using kinematic tracking to capture movement trajectories alongside discrete decision outcomes. Despite these design considerations, participants engaged with the task in a representative manner, and all reported a desire to repeat the session, suggesting the paradigm retained sufficient realism for the comparative aims of the present study. More broadly, because the reconstructed ball could not fully reproduce every dynamic property of a real ball, the scope of the present conclusions should be tempered accordingly. The findings speak to how modality influences responses to reproduced body kinematics under partially constrained ball information and should not be read as establishing the relative importance of ball versus body information. Faithful reproduction of ball characteristics remains an important requirement for representative design, and future work directly measuring and manipulating ball information would allow its contribution to be isolated.

A further methodological consideration concerns the capture system itself. Although markerless motion capture offers clear ecological and practical advantages for sport-based tasks, the specific accuracy of the Move AI system relative to gold-standard optical capture has not, to the authors' knowledge, been independently established in the peer-reviewed literature. This was mitigated by capturing a whole-body action, using the multi-camera pipeline,

and validating quality of the original movement clips through independent expert coach ratings. Even so, minor inaccuracies in the reconstructed kinematics cannot be ruled out, and readers should interpret the present findings as reflecting participants' responses to a high but not perfectly verified kinematic representation. Establishing system-specific validation for Move AI and comparable tools is an important direction for future work.

For the present study, the authors chose not to present the video stimuli within a VR headset, which could have allowed for a more tightly controlled comparison by standardising the surrounding environment. Instead, VR was compared with traditional representative task training as it is typically implemented in practice (*i.e.,* large-screen video projection). This decision reflects the applied context in which practitioners are often choosing between adopting immersive VR systems or continuing with more traditional video-based options. However, it is possible that some of the observed differences could be the result of the immersive properties of the HMD itself (*e.g.,* complete visual occlusion of the real world), rather than the virtual environment. Future research may benefit from isolating these factors by directly comparing video and VR stimuli both within a VR headset.

A further consideration relates to the exploratory qualitative component, in particular the use of a single UEFA B-licence coach. Whilst this was a deliberate methodological choice suited to the open, discovery-oriented nature of the "think aloud" protocol and the aims of the study, the authors acknowledge that future work would benefit from the inclusion of multiple observers and the establishment of inter-rater reliability. Two features of the process further limit the transferability of these interpretations. Firstly, because the VR condition was identifiable from the headset, the coach was not blinded to condition, so his evaluations may have been shaped by expectations about the technology. Secondly, the "think aloud" session was collaborative. The lead researcher clarified unclear or underdeveloped comments, which, consistent with the study's reflexive, constructivist position, means the resulting data were co-constructed rather than independently generated. These qualitative findings should therefore be read as exploratory, context-bound, practitioner-informed perceptions rather than generalisable effects. It may even be that the observations from the coach in the present study could be replicated and extended using quantitative methods, to provide more objective biomechanical data. Nonetheless, the convergence between the qualitative themes (*i.e.,* the coach's perception of greater behavioural fidelity and intensity in the VR condition) and the quantitative findings (*i.e.,* significantly faster response times) provides some evidence of corroborating support.

Another element worth discussing is the one-off nature of the 'training', which in this study was more akin to a singular drill or task, especially given the lack of feedback and notes for improvement. This study may lay the groundwork for a future longitudinal approach with several training sessions, to see if response time and response accuracy improve over time and how the learning rate compares to that of other training methods (*e.g.,* video or traditional practice). This longitudinal approach would allow researchers to explore if there truly is an increased desire to use VR, even after the novelty wears off. Whilst it was beyond the scope of the present study, it is not possible to know whether VR training would positively transfer to the real world, even if there were to be a notable improvement in performance in the virtual environment. This is a larger scale criticism of the research exploring perceptual-cognitive training in general, with Le Noury et al. (2022) even suggesting that VR could cause negative transfer if certain elements of the training are not upheld.

A final consideration is the representativeness of the sample. All participants were male and drawn from amateur or semi-professional levels. As such, the findings may not generalise to other populations, including professional, elite, and female players. Moreover, the shared background and playing level of participants may have influenced their perceptions of realism and engagement with the task. As a result, caution should be exercised when extrapolating these results to wider football populations or to the use of VR training in different performance contexts.

4.4 Future research & practical implications

Whilst this study has provided some evidence to suggest that VR could be a useful tool in sport training, due to its infancy, this area of research requires more evidence to provide to sport organisations regarding its capabilities

and effectiveness. Another consideration is that for many participants in VR research, it is their first time using VR, at least in the context of their sport. As mentioned, this raises questions over findings associated with increased enjoyment and engagement, given the relative novelty of the technology. Research must take place exploring how repeated exposure to VR affects its proposed advantages, enjoyment and engagement with training, and critically on-field performance. As previously discussed, research should also seek to incorporate more objective behavioural metrics such as movement speed, kinematic analysis, and spatial data, to provide more in-depth analysis of performance differences between modalities. These behavioural metrics could also be used to provide a more objective measure of susceptibility to deception.

Given that a proposed benefit of using VR in sport is the ability to generate a state of 'experiencing' through increased presence, continuing to develop training which creates and allows for a multisensory experience is critical. As things stand, virtual environments are often only virtualised visually, which can result in multisensory conflicts, especially given the usual absence of haptic feedback (Harris et al. 2019; Witte et al. 2025). Some participants in the present study explained to the lead researcher the strange feeling of bracing for impact in the VR condition, only for there to be no 'feeling' when they tackled the avatar. Continuing to develop these elements of VR will likely only increase feelings of presence, and in turn the positive transfer to real-world performance. Linked to this, future research should monitor the cognitive costs (*e.g.,* mental fatigue, attention overload) that may result from the use of VR, especially as more additions are made to increase the realism and immersion of the virtual environment (Che et al. 2024).

From the perspective of the MPTF (Hadlow et al. 2018), the findings could be interpreted as reflecting a continuum of representativeness rather than suggesting that one modality is superior. The VR condition appeared to enhance response correspondence, evidenced by greater behavioural fidelity, intensity, and perceived presence, supporting stronger perception–action coupling. In contrast, the video display condition may have offered advantages in stimulus correspondence, with participants appearing to utilise more subtle kinematic cues and adopt more controlled, delayed responses. This suggests that each modality may be suited to different training objectives. If this is true, these approaches should be viewed as complementary tools, to be applied based on the specific perceptual-cognitive processes being targeted, but also the practical constraints at each organisation (*e.g.,* budget, space, time). To better understand these differences, future research should also consider developing sport-specific self-report items tailored to the demands of 1-vs-1 football scenarios, which would complement the standardised measures used here.

Researchers exploring VR need to continue having an open line of communication with developers and the practitioners and athletes that would utilise these systems (Dowsett et al. 2023). It is important that there is an alignment between these three pillars, to ensure that researchers are providing rigorous, science-based evidence and frameworks which can assist organisations in implementing VR within their existing procedures, should they choose to do so (Wilkins 2024). Finally, VR research also faces the challenge of the ever-changing nature of the technology. Each year, the technology improves and changes at a rapid rate, and therefore researchers will need to continue to update their understanding and research to keep pace with this (Runswick 2023). Ensuring that VR sports applications have proven construct validity will be a continual challenge for researchers, but a necessary prerequisite for applied practitioners, in order for them to have confidence in its effectiveness. Recent work by Runswick et al. (2026) in cricket, Wilkins and Middleton (2025) in golf, and Egiziano et al. (2025) in athletics provides useful frameworks for how construct validity can be rigorously tested across different VR applications in sport.

The present study also demonstrates how the integration of expert practitioner knowledge can offer technically meaningful insights for XR researchers and developers. Here, the "think aloud" methodology surfaced captured one coach's perceptions of differences in response quality and behavioural fidelity between conditions. These exploratory observations suggest that practitioners evaluation may be useful as one component of VR validation, but this potential should be examined using multiple observers and/or objective behavioural measures. As XR systems become increasingly accessible, future research should continue to position the technologies

within frameworks such as the MPTF, examining how XR design choices interact with the perceptual-cognitive demands of sport-specific tasks.

5 Conclusions

Despite the increased use of VR in research and practice, the validity of VR training in sport has not been properly established in comparison to traditional representative task training (Müller et al. 2023). The main goal of this study was to better understand how use of a VR format compares to a video format when completing a representative 1-vs-1 football task. The findings have implications for the efficacy of VR training in football, with participants responding significantly faster without a reduction in accuracy. Moreover, they reported significantly greater presence, face validity, enjoyment, and desire to repeat the VR session again versus the video session. Taken together, this suggests the VR format created a more immersive, enjoyable experience that resulted in faster responses, with an expert coach also perceiving greater behavioural fidelity and intensity in VR, an exploratory observation that warrants confirmation using blinded and/or quantitative methods. Whilst video simulations allow researchers to measure and train perceptual skills in a controlled, precise manner, the present data suggest that the more immersive VR experience may result in player responses that are more tightly coupled to the actions they perceive. From an MPTF perspective (Hadlow et al. 2018), these findings could position VR and video simulations along a continuum of representativeness, with each offering distinct advantages depending on the objectives of the training. As VR technology continues to develop at pace, ongoing assessment of its validity for assessing and training perceptual skills in sport, alongside how well skills learned in the virtual world transfer to in-situ competitive environments, is critical.

Appendix A—Stimuli creation

To create the stimuli required for the present study, markerless motion capture software was used (Move AI, London, UK). The Move AI software uses a machine learning based approach to estimate body pose data. Whereas a 'gold-standard' optical tracking solution such as Vicon (e.g., Brault et al. 2012) is optimal, the chosen solution allowed for simultaneous recording of the real-world and virtual conditions, in an ecologically valid environment (indoor football pitch).

The model for the present study was a semi-professional footballer, playing at an international level at the time of recording. To capture his movements for the virtual avatar, six iPhones (Apple Inc., models ranged from 12–14) were used in a 6×6 m configurated capture area (see Fig. 1). Each camera was placed on a tripod at a height of 150 cm, facing inwards. To calibrate the motion capture perimeter, a tablet (iPad 10, Apple Inc.) was used and then removed before recording. Calibration allowed for synchronisation between the phone cameras for post-capture rendering.

The change of direction task consisted of repeated accelerations and changes in direction within the motion capture perimeter (see Fig. 1). The model was required to begin at the start point (A) with a ball (Mitre delta max) at their feet. On the researcher's instruction, they were required to dribble the ball to the change of direction point (B) 4 m away and perform one of the following actions (1) non-deceptive cut—left, (2) non-deceptive cut—right, (3) deceptive cut—left, and (4) deceptive cut—right, to finish their dribble at one of the end point(s), which were placed at a 45-degree angle to the change of direction point, 1 m out, at both the left and right side (C1 & C2). For the deceptive cut, the model was asked to perform a single step over. For all trials, the model was instructed to accelerate from the start point while dribbling the ball with both feet, at their maximum intensity, without losing control of the ball. Each action was repeated ten times (40 in total), and the model self-prescribed their rest between attempts. Outside of the capture perimeter, a second tablet (iPad 10, Apple Inc) was placed on a tripod

at a height of 1.7 m and was used to video record (in 4 k at 60fps) the model in the frontal plane so it could be used in the video display condition.

Data from the phones were uploaded to the motion capture software for rendering. Each iteration was rendered into a film box (commonly known as FBX) file. The FBX file consisted of a virtual avatar of the model along with the ball used for dribbling. The FBX file was uploaded into Unity 3D (Unity Technologies, 2023). Rezzil Inc. used this to create a bespoke program that used the iterations from the motion capture and included them in commercially available software (Rezzil Index). This was titled the 'VR condition'. The bespoke software also included the matching iterations captured through the second tablet and was titled the 'video display condition' (see Fig. 1). Therefore, the software consisted of two conditions, with matching and equal number of iterations.

Appendix B—Face validity and physical fidelity

The following four statements are to be considered in relation to real-world performance.

On the five-point Likert scale below, please circle a response from strongly disagree to strongly agree to indicate the extent to which you agree with the statement based on your own experience.

1. The simulation looks realistic (face validity)

Strongly disagree | Slightly disagree | Neutral | Slightly agree | Strongly agree

2. The simulation feels realistic (face validity)

Strongly disagree | Slightly disagree | Neutral | Slightly agree | Strongly agree

3. There is a high degree of detail in the physical elements of the simulation (physical fidelity)

Strongly disagree | Slightly disagree | Neutral | Slightly agree | Strongly agree

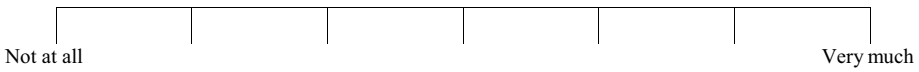
4. There is a high degree of realism in the physical elements of the simulation (physical fidelity)

Strongly disagree | Slightly disagree | Neutral | Slightly agree | Strongly agree

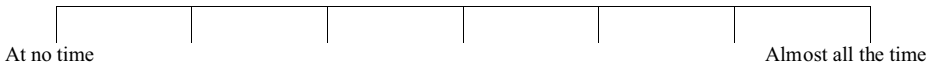
Appendix C—Slater-Usoh-steed presence (SUS)

The following six statements are to be considered in relation to real-world interactions. On the seven-point Likert scale below, please circle a response to indicate the extent to which you agree with the statement based on your own experience. Please read the statements carefully.

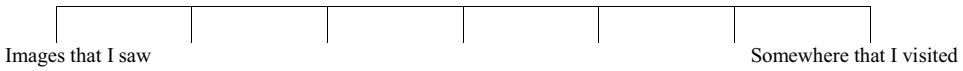
1. Please rate your sense of being in the virtual environment, on the following scale from 1 to 7, where 7 represents your normal experience of being in a place.



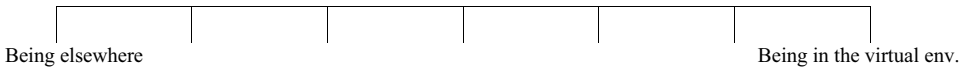
2. To what extent were there times during the experience when the virtual environment was the reality for you?



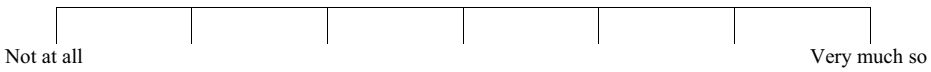
3. When you think back about your experience, do you think of the virtual environment more as images that you saw, or somewhere that you visited?



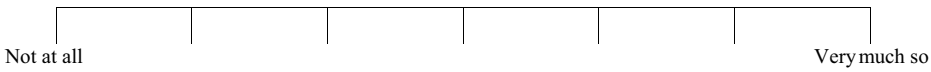
4. During the time of the experience, which was strongest on the whole, your sense of being in the virtual environment, or of being elsewhere?



5. Consider your memory of being in the virtual environment. How similar in terms of the structure of the memory is this to the structure of the memory of other places you have been today? By 'structure of the memory' consider things like the extent to which you have a visual memory of the virtual environment, whether that memory is in colour, the extent to which the memory seems vivid or realistic, its size, location in your imagination, the extent to which it is panoramic in your imagination, and other such structural elements.



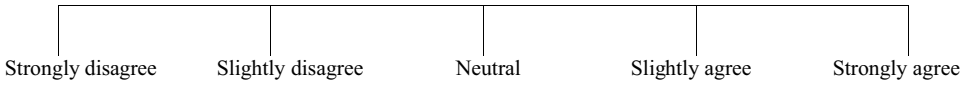
6. During the time of the experience, did you often think to yourself that you were actually in the virtual environment?



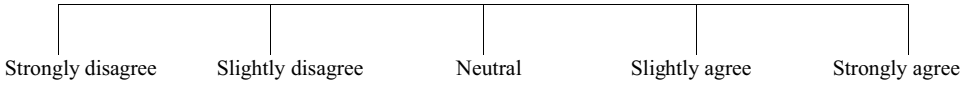
Appendix D—Self-report questions

The following three statements are to be considered in relation to the training you have just experienced. On the five-point Likert scale below, please circle a response from strongly disagree to strongly agree to indicate the extent to which you agree with the statement based on your own experience. Please answer truthfully.

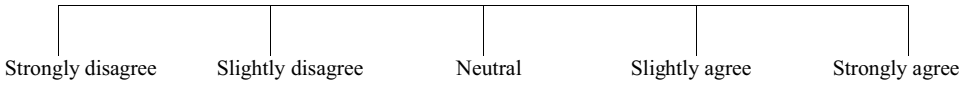
1. I enjoyed the football training I just took part in.



2. I would like to use this training method again in the future.



3. I felt as though the player 'deceived' me, and the fakes were realistic.



Appendix E—Demographics questionnaire

For questions with multiple options, please circle to signify your response.

1. **What is your age?**

.....……

2. **What position do you play?**

Goalkeeper Defender Midfielder Attacker

3. **How long have you been playing competitive football for?**

1-2 years 3-4 years 5-6 years 7+ years

4. **What is the highest level of football you have played at?**

Amateur Semi-Professional Professional

5. **How often do you play competitive football?**

Once per month Once every 2 weeks Once per week Multiple times per week

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