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Using 360-video to investigate visual exploratory activity in 7v7 and 9v9 sided games in women's soccer

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ABSTRACT

Immersive technology such as 360-video offers opportunities to analyse visual exploratory activity (VEA) under varying task constraints in controlled experimental settings. The study aimed to investigate the effect of pitch location and sided-game format on VEA and verbal action responses in 360-video. Nineteen sub-elite female soccer players (21 ± 4 years) viewed 40 soccer videos in a head-mounted display. Footage was recorded using a stationary GoPro 360 Max camera at eye height in defensive and attacking central midfield locations. VEA was measured as the number of "scans" away from the ball across 32 analysed trials. Upon receiving a pass in 360-video, participants simulated and verbalised an action to continue play. A 2×2 repeated-measures ANOVA showed a significant main effect of pitch location ($p = 0.016$), with higher scan frequencies in defensive (0.31 ± 0.15 scans/s) than attacking midfield (0.29 ± 0.15 scans/s), with no significant effect of sided-game or interaction effect ($p > 0.05$). Findings demonstrate players had significantly higher scan frequencies in defensive central midfield compared with attacking central midfield, with the most verbal actions per trial in the 9v9 attacking midfield condition. Future research should assess agreement between VEA measured in 360-video and on-field activities.

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KEYWORDS

Small-sided game; scanning; women's football; visual perception; head-mounted display; 360° video

Introduction

Visual exploratory activity (VEA) is a key perceptual skill that helps soccer players adapt to an ever-changing environment (Hintermann et al., 2024). Visual exploratory behaviour has been defined as the "active, whole-body coordination of the visual system to support the informational needs of the observer" (Franchak, 2020, p. 60). In sport, VEA refers to the broader process by which players actively seek information from the surrounding performance environment. In this study, VEA was operationalised through scans, defined as discrete head-orientation events in which the ball temporarily left the participant's head-mounted display (HMD) field of view. Previous research has focused on identifying factors related to VEA in soccer, such as pitch location (McGuckian et al., 2020), opponent pressure (Aksum, Pokolm, et al., 2021) and pass success (Jordet et al., 2020). Researchers have frequently used observational designs to study 11v11 matches (Caso et al., 2024; Feist, Datson, et al., 2024; Pokolm et al., 2023), yet 11v11 matches rarely occur in training settings, opening new avenues for research to understand VEA in small, medium and large-sided games that occur more frequently during training.

Small-sided games (SSGs) are modified soccer games used in training to develop physical, tactical and technical skills without requiring a full match (Mara et al., 2016). SSGs expose players to frequently occurring micro-patterns, such as 2v2 scenarios that are common in 11v11 games (Feist, Runswick, et al., 2024). Alongside SSGs, the literature defines medium-sided games (MSGs) as 5v5 to 8v8 and large-sided games (LSGs) as 9v9 to 11v11 (Beato et al., 2023; Owen et al., 2014). The average squad size of a professional women's team is around 17 players (Oliveira et al., 2021), typically smaller than male squad sizes, meaning medium-sided games are common. Professional players' on-field training typically is tracked across a weekly microcycle, with evidence showing players may spend as many as 4 days training per week (Mara et al., 2015), with the greatest distances covered usually occurring on match day -4 (Myhill et al., 2022). Considering squad sizes and a typical weekly microcycle, outfield players engage in various SSG formats, with indications that medium and large-sided games occur on match day -4 and -3 (Posse-Alvarez et al., 2025) making them a core element of weekly training. Match day -4 and match day -3

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typically occur during the middle of a training week and involve players performing at greater intensities (Romero-Moraleda et al., 2021), typically involving larger-sided games.

Research has shown that changes in task informational constraints can modify players' opportunities for action, leading to adaptive movement behaviours (Coutinho et al., 2020). Evidence also shows differences in technical and tactical actions across sided-game formats (Garcia et al., 2014), and that manipulating task constraints can alter the time, space and pressure available to players, potentially affecting their landscape of affordances (McGuckian et al., 2017). Therefore, manipulating sided-game formats may provide insights into the potential applicability of perceptual skills developed during training to real-world competition. Smith and Conway (2025) examined VEA across 7v7, 9v9 and 11v11 game formats in youth male soccer. Scan frequency was higher in the 7v7 and 9v9 game formats compared with 11v11, alongside a greater number of technical actions (e.g., ball retention) in the 7v7 game format. However, despite the 7v7 game format yielding the highest number of total scans and successful technical actions, the number of scans per technical action was greater in the 9v9 and 11v11 game formats. While these findings show differences in scan frequency by player numbers on each team, larger-sided games show more scans per technical action. In the context of the present study, this suggests further research is needed to investigate VEA across different sided-game formats. Therefore, given the aforementioned findings, it appears important to investigate how players scan their environment in different-sided game formats to inform whether these formats present different perceptual demands.

One approach to measuring VEA, operationalised through scans, in different-sided game formats in a controlled setting is through immersive technology, such as 360-video. 360-video presents users with pre-recorded footage of a real-world environment, typically via a HMD, where the camera is positioned in a fixed location but allows head movements to explore the environment (Le Noury et al., 2022). In contrast, animated virtual reality (VR) is a computer-simulated environment where users experience artificial stimuli through a HMD and can interact with the stimuli (e.g., pick up virtual objects) with their movements (Jia et al., 2024; Le Noury et al., 2022). 360-video is an off-field tool gaining popularity in soccer, as it captures all directions simultaneously (Höner et al., 2023), allowing participants to experience realistic, first-person game scenarios while executing head movements to explore the visual environment (Runswick, 2023). Furthermore, 360-video

allows all participants to view the same trials under identical viewing conditions, providing greater experimental control in a more natural context (Musculus et al., 2021). While game situations vary between trials and conditions, the presentation of each trial can be standardised across participants. Unlike on-field training, this approach does not require the whole squad to be present. Researchers have investigated the validity of 360-video for measuring scans (head-orientation-events) where the ball leaves the HMD visual field in women's soccer, demonstrating construct validity through differences in scan frequency and verbal action responses between soccer players and novices (Feist et al., 2025). Soccer players showed significantly higher scan frequencies and verbal responses than novices and players also rated the task highly for acceptability, tolerability and physical fidelity, indicating they felt immersed in the real-life scenarios while away from the training pitch (Feist et al., 2025). 360-video enables the comparison of VEA in female players across different-sided game formats (e.g., 7v7 and 9v9 games). If players are found to scan more frequently in 7v7 than in 9v9, this would support previous findings that overall scan frequency increases in smaller-sided games, despite scans per technical action being higher in 11v11 game formats (Smith & Conway, 2025). Increased scan frequency in 7v7 may be driven by reductions in space, leading to more technical actions and a heightened need to explore the environment to guide performance with the ball. Conversely, if scan frequency were higher in 9v9, the additional space and greater number of players may create more time and opportunities for exploration, enabling players to engage more deliberately with their surroundings. Therefore, measuring scanning across 7v7 and 9v9 formats in 360-video may provide preliminary evidence of whether player-number constraints influence scanning behaviour when the viewing environment, task instructions and pitch-location perspectives are standardised.

Previous studies have examined the effect of pitch location (Aksum, Pokolm, et al., 2021; Jordet et al., 2020; McGuckian et al., 2020) and opponent pressure on VEA in soccer (Pokolm et al., 2022). Scan frequencies are highest in central midfield areas of the pitch compared with wide locations (Aksum, Pokolm, et al., 2021; Jordet et al., 2020). In women's international soccer, pitch location significantly predicts scan frequency in competitive matches, controlling for the number of players analysed per team by nesting players in their team as a random effect (Feist, Datson, et al., 2024). Players' highest scan frequencies were in defensive central midfield (DCM) positions compared with attacking locations. One explanation could be that attacking midfielders receive

greater opponent pressure (Feist, Datson, et al., 2024), suggesting reduced space and time to scan due to the close proximity of opponents. Therefore, understanding variables that affect VEA can provide valuable knowledge to help inform training design to enhance the frequency and timing of scans.

Experimental research designs investigating VEA in soccer remain limited. One experiment by McGuckian et al. (2019) analysed players' head movements using multiple computer screens to simulate a passing football scenario. The authors found that exploration time significantly influenced head movement frequency, with higher head-turn frequencies resulting in faster decisions. However, the study did not manipulate game-related areas such as pitch location. Experimental research into VEA in women's soccer has received minimal attention. One exception investigated the scanning activity of under-19 female soccer players in 4v4 SSGs, showing skilled youth players scanned the field more often before receiving the ball than grassroots players of the same age (Hintermann et al., 2024). These findings suggest SSGs can support our understanding of VEA in women's soccer. Previous research has provided preliminary construct-validity evidence for using 360-video to examine head-orientation-based scanning behaviour in soccer (Feist et al., 2025). This enables experimental research to be undertaken by presenting controlled scenarios across various game formats and pitch locations. With studies beginning to explore VEA in women's soccer in SSGs (Hintermann et al., 2024, 2025), there is a need to examine how pitch location and game format impact VEA and verbal action responses in 360-video in women's soccer. These findings could provide evidence-based strategies for how to effectively measure VEA and better understand players' ability to scan their environment in women's soccer.

This study aims to examine the effect of pitch location and sided-game format on VEA and verbal action responses using a 360-video task in women's soccer players. We hypothesise there will be significantly higher scan frequencies and number of verbal action responses generated per trial in central defensive midfield compared with central attacking midfield locations. We further hypothesise that there will be a significant difference in scan frequency and number of verbal action responses generated per trial between the medium (7v7) and large-sided game (9v9), with higher scan frequencies and more verbal actions per trial in the medium-sided game (7v7). Lastly, we hypothesise that there will be a significant interaction effect between pitch location (defensive and attacking) and sided game (7v7 and 9v9) for scan frequency and for the number of verbal action responses generated per trial.

Method

Participants

An *a priori* power analysis was conducted using G*Power (version 3.1; Faul et al., 2009) for sample size estimation. Feist, Datson, et al. (2024) investigated the VEA of elite central midfield soccer players in match situations ($n = 30$). Cohen's d effect sizes were reported between different central midfield pitch locations. The mean Cohen's d effect size was 0.69, which converted to effect size f (0.35), is considered to be a medium effect (Cohen, 1988). With a medium effect size f (0.35), a power ($1-\beta$) of 0.80, one group and two measures, the minimum sample size required to achieve this effect is $n = 19$. In the present study, 19 female soccer outfield players with a mean age of 21 years (± 4) were recruited, with a mean competitive playing experience of 12 years (± 4). Of the 19 outfield players, nine players' primary playing position was defender, seven players' primary position was midfielder and three players' primary position was forward. Participants were required to be 16 years of age or older, report normal or corrected-to-normal vision and be injury-free. Participants were also required to be competing in Tier 6 or higher of the English women's football pyramid (Canning, 2023). Ethical approval was granted from the lead author's university (approval number code: 2324_10). Written informed consent was provided by all participants, including those featured in the video stimuli.

Filming 360-video soccer stimuli

360-video footage was created by filming a medium (7v7) and a large-sided (9v9) soccer training game (see Figures 1 and 2). All visual stimuli were recorded on a soccer pitch with a GoPro 360 Max camera (30 frames per second at 5.6 k). The camera was fixed on a tripod at eye height (1.68 m) in four locations: Defensive midfield centre-left (DMCL); Defensive midfield centre-right (DMCR); Attacking midfield centre-left (AMCL); Attacking midfield centre-right (AMCR). The direction of play for the attacking direction was fixed across all trials, as shown in Figures 1 and 2 allowing for consistent classifications of defensive and attacking scenarios independent of momentary changes in possession. The camera height was similar to that used in previous studies (Kittel et al., 2019; Runswick, 2023). This camera angle gave a first-person view in the HMD and, while immersion can be influenced by multiple factors such as the participants' perceptual ability, the intention was for this to contribute to immersion in the environment (Feist et al., 2025). The football started in one of three locations: (1) with the right back, (2) from a throw-in by the

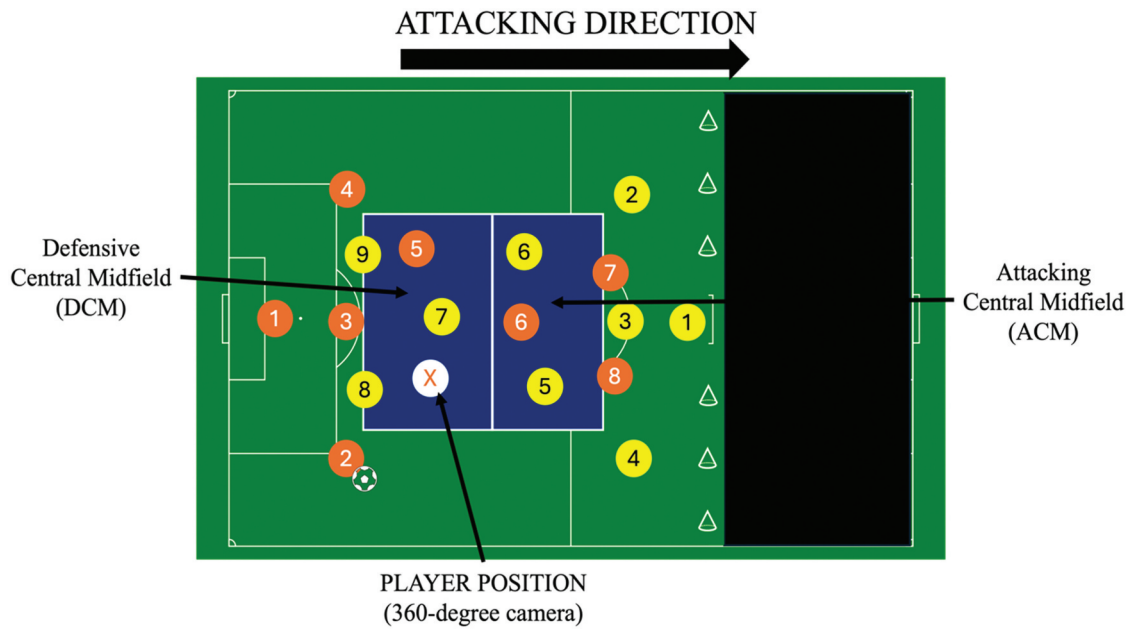


Figure 1. Schematic illustration of the 9v9 large-sided game. The central midfield player (orange cross located in the white circle) represents the position of the 360-video camera positioned in a defensive central midfield pitch location. *Note.* The arrow indicates the fixed attacking direction of play used to classify pitch location. Defensive and attacking central midfield zones were defined relative to this direction of play.

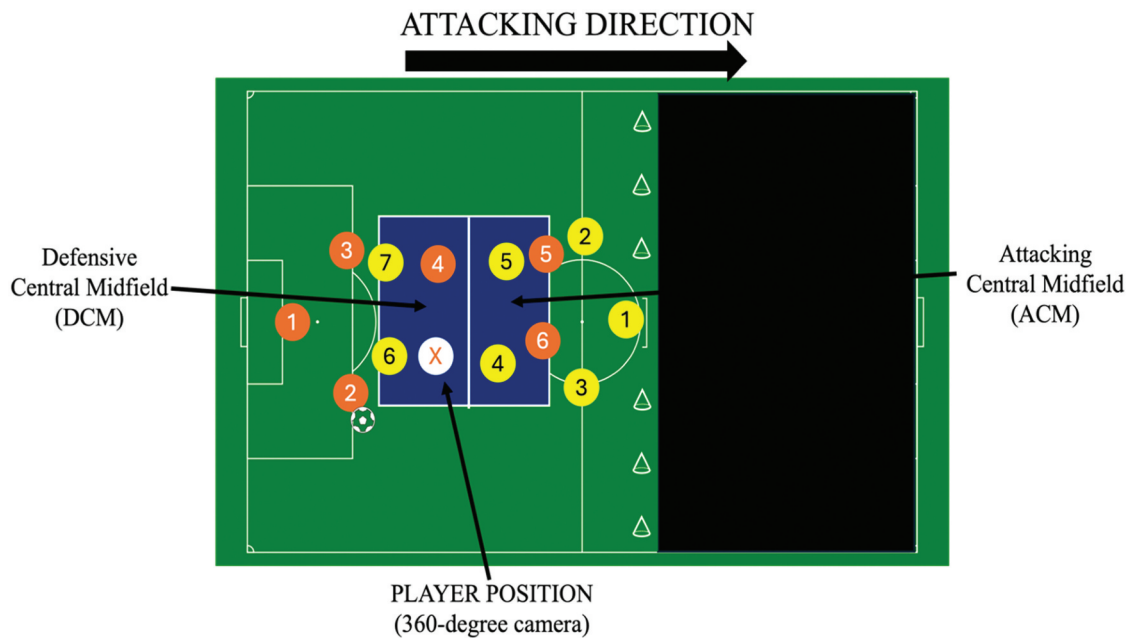


Figure 2. Schematic illustration of the 7v7 medium-sided game. The central midfield player (orange cross located in the white circle) represents the position of the 360-video camera positioned in a defensive central midfield pitch location. *Note.* The arrow indicates the fixed attacking direction of play used to classify pitch location. Defensive and attacking central midfield zones were defined relative to this direction of play.

left back in a defensive midfield area, or (3) at the striker's feet in a central attacking location. These starting locations were frequently occurring situations from the UEFA Women's EURO 2022, based on findings by Feist, Datson, et al. (2024). This also aligns with previous

research in soccer that controlled the ball's starting position with 360-video (see Höner et al., 2023). Play started with the "in-possession" team in orange bibs. The "in-possession" team were provided with basic tactical instructions such as maintaining possession, creating

and scoring goals, and, when the opportunity presented itself, passing the ball through central areas of the pitch. Players were instructed to keep playing until a whistle ended the scenario. For recorded clips, this typically occurred 5 s after the ball struck or came within 1 m of the tripod. Players were given information about the match (0–0; first half) and asked to play as if it were a real game. Although players were encouraged to play naturally, basic tactical instructions were provided at the start of the filming session to progress play through central areas when appropriate. Therefore, some request bias (e.g., players were aware the ball needed to arrive near the tripod when an opportune moment arose) should be acknowledged, as this may have influenced some patterns of play and participants' verbal action responses. The lead author, with 10 years of soccer coaching experience, supported by the authorship team with expertise in men's and women's soccer, reviewed all scenarios and excluded trials in which possession was lost before reaching the camera. A total of 40 scenarios were chosen for testing. Trials were excluded if possession was lost prior to the ball reaching the 360-degree camera and if the ball was passed a distance greater than 1 m away from the tripod location. There were 20 trials in a medium-sized game (7v7) and 20 trials in a large-sized game (9v9).

After selecting the final testing scenarios, videos were imported into Adobe Premiere Pro (San Jose, CA, USA) to create two testing videos: one 7v7 video and one 9v9 video. The videos each had a mean duration of 11 min. After pilot testing, videos were edited to include a five-second freeze frame at the beginning, showing the football's starting location and attacking direction. Scenario order (pitch location and football starting locations) was randomised, but remained consistent across participants (Discombe et al., 2022).

Apparatus

All trials were presented through a HMD (Meta Quest 2) connected to an ASUS G533QS gaming laptop. The HMD had a horizontal field of view of $\sim 97^\circ$ and a display resolution of 1832×1920 pixels per eye which supports 90 and 120 Hz refresh-rate modes (Runswick et al., 2026). An adapted strap was used to tightly secure the headset on participants. Trials were presented through SkyBox VR on the Meta Quest 2.

Procedure

The following method has been developed from Feist et al. (2025) and has been modified to reflect the current

aims of the study. All participants took part in one testing session. Participants wore sports shoes and clothing, along with an orange bib. Participants watched two three-minute videos in the HMD while standing. One video explained operational definitions and the other provided testing instructions. Next, participants completed five self-guided practice trials, similar to those in Höner et al. (2023). This helped participants understand the viewing perspective and the task requirements (Murphy et al., 2018). Participants were instructed to imagine themselves as the player who was in the position of the camera on the pitch and to observe each scenario until the trial ended.

Participants completed 40 trials in total. They completed two blocks of 20 trials. Twenty trials in a large-sided game (9v9) and 20 trials in a medium-sided game (7v7). While 7v7 and 9v9 trials were presented as two separate testing blocks, the order in which the two trial blocks were presented was counter-balanced between participants. There was a five-minute seated rest between the blocks, similar to Musculus et al. (2021). Out of the 40 trials, eight were classified as "washout" trials. These trials were presented consistently to each participant as part of the 7v7 and 9v9 testing block. The washout trials aimed to keep participants engaged in the task. In five of the eight washout trials, the ball did not reach the participants' feet, leading to no verbal action response being required. In three of the eight washout trials, the 360-camera was positioned in a wide midfield location on the pitch. The data from all eight trials were removed before statistical analysis. The final analysis used a total of 32 trials, 13 from the 7v7 game format and 19 from the 9v9 game format. The imbalance of trials is accounted to stimuli being recorded in real-life game scenarios where more passes were recorded in 9v9 compared to 7v7.

In all 32 trials analysed, participants received a pass from a teammate. They were asked to perform a "shadow" action with the ball. This involved miming the physical action they intended to make, similar to the method used by Roca et al. (2013) and Discombe et al. (2022). This was included to provide a limited physical response, with previous research in soccer demonstrating how players make richer verbal reports when they move and interact with a video-based screen, compared with being stationary (Roca et al., 2013). Thus, despite differences in stimuli presentation (life size screen vs HMD), by having participants perform a "shadow" action, the intention was to support their verbal action responses. After performing their "shadow action", participants verbalised their intended action with the ball. Players were verbally presented with a list of potential "actions" to provide guidance: "pass", "dribble", "shoot", "receive and protect the ball", "turn with the ball"

and “unsure”. Participants were encouraged to be explicit with their verbal action responses and, if deemed appropriate, to provide multiple action responses for a single trial. Action responses were classified in the following way: (i) a singular action (e.g., a pass) was classified as one verbal action (e.g., “I would pass to the centre back”); (ii) two actions (e.g., turn with the ball and dribble) were classified as two verbal actions (e.g., “I would turn with the ball and dribble forward”). For example, a participant might respond by saying, “I would turn with the ball and pass to the left winger”, which would be classified as two verbal actions. As participants could not physically perform their verbal responses and we could not judge whether players were physically capable of performing their verbalised action, decision quality was not assessed. Verbal and physical actions were recorded in two ways. First, a GoPro Hero 4 was positioned at an elevated angle in the real world, recording at 30 FPS and 720p to capture participants’ “shadow” actions and verbal responses. Second, participants’ first-person viewing perspective of the 360-video trials was recorded using QuickTime on an Apple MacBook Pro (Version 12.7.3), providing their exact viewing perspective to enable the detection of scans measured as head-orientation events in which the ball temporarily left the participant’s HMD visual field. As eye movements were not measured, scans should be interpreted as head-orientation-based behavioural proxies for VEA rather than direct measures of gaze or visual search. Scans were analysed using first-person Oculus footage, while “shadow” actions and verbal responses were recorded using the GoPro Hero 4. The entire procedure lasted approximately

55 minutes for each participant. A total of 122 trials (20% of all trials) were cross-checked against the external GoPro footage. The purpose of cross-checking 20% of all trials was to ensure consistency between the number of scans recorded from the Oculus footage and the number of scans recorded from the Go-Pro footage.

Measures

All measures are detailed in [Table 1](#).

Data analysis

Reliability

A senior lecturer in sport psychology, with VEA coding experience, conducted additional coding on all variables, including participants’ verbal action responses. The lead author and second coder jointly reviewed 91 trials containing verbal responses, with discrepancies discussed and resolved to ensure consistent classification of the number of actions generated per trial. For “number of scans” a total of 91 trials (15% of all trials) were re-analysed for both inter- and intra-rater reliability, which aligns with previous VEA research (Aksum, Pokolm, et al., 2021; Feist, Datson, et al., 2024). Intra-rater reliability was completed following a six-week gap to minimise potential learning effects. Intra-class correlations (ICC) were calculated for the continuous variable “number of scans”. This variable serves as the basis for scan frequency. Cicchetti’s (1994) criteria were utilized to assess the strength of agreement between different coders and repeated coder observations. See [Table 2](#) for details.

Table 1. Operational definitions and descriptions of dependent and independent variables.

Variable	Definition
Dependent Variables	
Scan	An active head-orientated movement directed away from the ball that temporarily causes the ball to fall outside the participant’s visual field (measured using the first person footage viewed in a head-mounted display). It is presumed that a player performs this action to perceive information such as the movements of teammates, opponents, or identify empty space, or other environmental factors (Jordet, 2005). Definition was adapted from Aksum, Brotangen, et al. (2021) definition of scanning from a first person perspective. Definition aligns with that of Feist et al. (2025).
Scan frequency	The total number of scans in the final 10 seconds before the ball reached the 360-video camera divided by the elapsed time (Feist et al., 2025).
Scan timing	The time in seconds before trial end when players scanned their environment (Feist et al., 2025). Data is presented as mean scan frequencies across the final five seconds prior to participants receiving the ball in the video.
Action Type	The type of action with the ball verbalised by participants summarised as frequency scores.
Number of actions generated per trial	Dividing the total number of actions verbalised by the number of trials completed.
Independent Variables	
Pitch Location	Data initially recorded in four pitch locations: defensive midfield centre left, defensive midfield centre right, attacking midfield centre right and attacking midfield centre left. Defensive central midfield: Trials in which the 360-video camera (representing the participant) was positioned in a 20 m × 20 m zone located along the central axis in the half of the pitch furthest from the attacking goal, relative to the predefined direction of play. Attacking central midfield: Trials in which the 360-video camera (representing the participant) was positioned in a 20 m × 20 m zone located along the central axis in the half of the pitch closest to the attacking goal, relative to the predefined direction of play.
Sided Game	Data subsequently collapsed into two pitch locations: attacking central midfield (ACM) and defensive central midfield (DCM). Data recorded in one medium sided game (7v7) and one large sided game (9v9). Sided game classifications based upon previous literature in soccer (Beato et al., 2023; Owen et al., 2014).

Table 2. Intra-class correlations for number of scans (continuous variable).

Variable	Inter-rater		Intra-rater	
	ICC (95% CI)	Strength of Agreement	ICC (95% CI)	Strength of Agreement
Number of scans	0.894 (0.843–0.928)	Excellent	0.945 (0.918–0.963)	Excellent

Statistical analysis

Shapiro-Wilk tests were used to assess univariate normality ($n < 50$) which indicated all data came from a normal distribution ($p > 0.05$; Mecklin, 2007). Histograms and boxplots were examined as part of visual checks, along with further numerical checks of Z_{skewness} and Z_{kurtosis} , with all data falling within the boundaries of ± 1.96 criteria (Field, 2013). Descriptive statistics are presented as means and standard deviations, with the exception of scan timing, where means and standard errors are reported. Verbal action response categories were treated as repeated measures, like those of Roca et al. (2011). The number of actions generated per trial was calculated as the total number of actions verbalised divided by the total number of trials. Scan timing data are presented descriptively, similar to those of Feist, Datson, et al. (2024), due to a lack of statistical power. Scan timing and action type data are presented as means and standard deviations. A 2 pitch location (defensive central midfield; attacking central midfield) $\times$ 2 sided game (7v7; 9v9) within participants repeated measures analysis of variance (ANOVA) was performed to examine differences in scan frequency and number of actions generated per trial. Effect sizes are reported using partial eta squared (η^2_p) classified as small ($\eta^2_p = 0.01$), medium ($\eta^2_p = 0.06$) and large ($\eta^2_p = 0.14$; Cohen, 1988; Lakens, 2013). The alpha level was set at $p < 0.05$. Data were analysed using JASP (version 0.16.4; JASP Team, 2022).

Results

A total of 608 trials were analysed and included in the final dataset. Across all 19 players, a combined total of 1,636 scans were recorded.

Visual exploratory activity

Scan frequency

Soccer players' mean scan frequency prior to receiving the ball in 360-video was 0.30 ± 0.15 scans/second. Analysis indicated a significant main effect of pitch location, $F_{(1, 18)} = 7.038$, $p = 0.016$, $\eta^2_p = 0.281$, with a large effect size. Higher scan frequencies were observed in defensive central midfield (0.31 ± 0.15 scans/s)

compared to attacking central midfield (0.29 ± 0.15 scans/s), regardless of sided game format (see Figure 3). There was no significant main effect of sided game, $F_{(1, 18)} = 0.002$, $p = 0.962$, $\eta^2_p < 0.001$, with a trivial effect size, and no significant interaction between pitch location and sided game, $F_{(1, 18)} = 3.448$, $p = 0.080$, $\eta^2_p = 0.161$, with a large effect size. Although the observed effect is considered large, this interaction did not reach statistical significance and should therefore be interpreted with caution.

Scan timing

A total of 937 scans were performed across the final 5 s prior to players receiving a pass from a teammate. The highest mean scan frequency across the final 5 seconds prior to players receiving the ball was observed between ball contact – 1 second, $M = 0.36$ scans/s ($SE = 0.02$), with the lowest mean scan frequency observed between 4.01 and 5 seconds, $M = 0.26$ scans/s ($SE = 0.02$; see Figure 4).

Verbal action responses

Number of actions generated per trial

On average, soccer players generated $1.26 (\pm 0.17)$ verbal actions per trial. Analysis indicated a significant main effect of pitch location, $F_{(1, 18)} = 5.083$, $p = 0.037$, $\eta^2_p = 0.220$, with a large effect size. A greater number of verbal action responses were generated per trial in attacking midfield (1.30 ± 0.22 actions per trial) compared to defensive midfield (1.22 ± 0.12 actions per trial), regardless of sided game format (see Figure 5). There was also a significant main effect of sided game, $F_{(1, 18)} = 6.392$, $p = 0.021$, $\eta^2_p = 0.262$, with a large effect size. Soccer players generated a greater number of verbal action responses per trial in the 9v9 game (1.29 ± 0.15 actions per trial) compared to the 7v7 game (1.23 ± 0.18 actions per trial), regardless of pitch location. No significant interaction was found between pitch location and sided game, $F_{(1, 18)} = 0.348$, $p = 0.563$, $\eta^2_p = 0.019$, with a small effect size.

Action type

Results indicated that the most frequently reported action with the ball was “pass”, with this action being

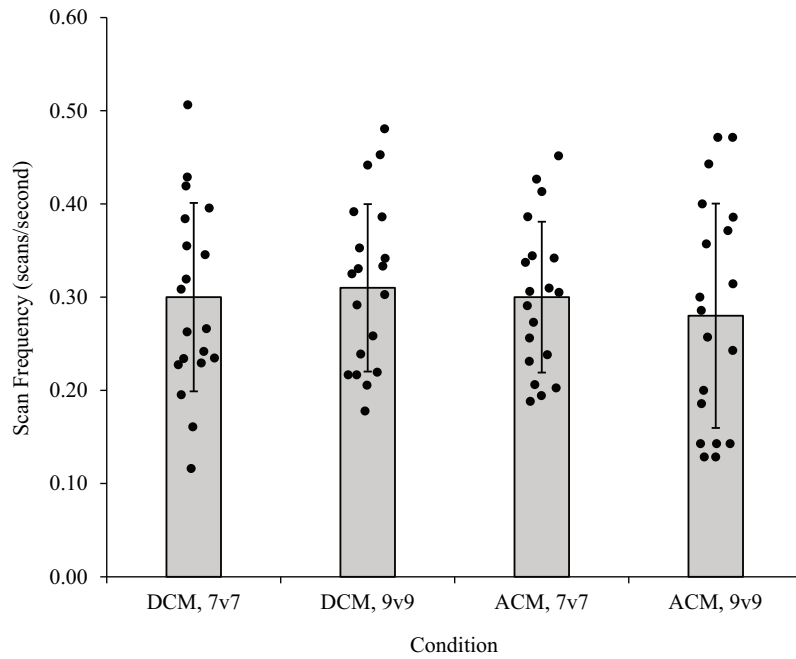


Figure 3. Scatter bar displaying mean scan frequency (scans/s) across the four conditions. Bars represent mean scan frequency scores. Black dots represent individual data by participant. *Note.* DCM = defensive central midfield, ACM = attacking central midfield.

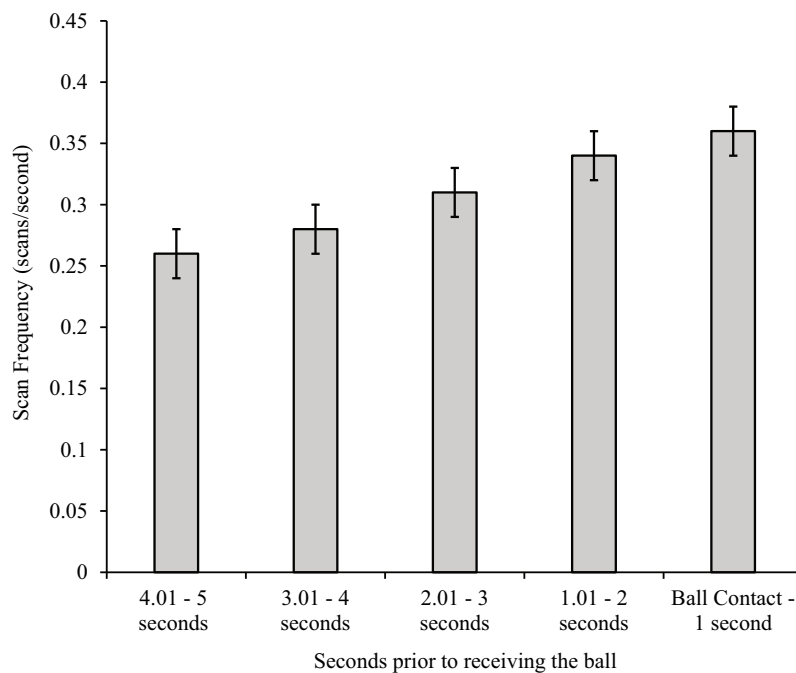


Figure 4. Means and standard errors (presented as error bars) across the final 5 seconds prior to receiving the ball.

verbalised a total of 405 times, accounting for 53% of the total actions. There was a consistency in the number of times soccer players verbalised the actions of “shot” (88, 12%) and “turn with the ball” (82, 10%).

The least frequently reported action was “unsure” (4, 1%), with soccer players almost always being able to verbalise an action to perform with the ball immediately after receiving a pass from a teammate. [Table 3](#)

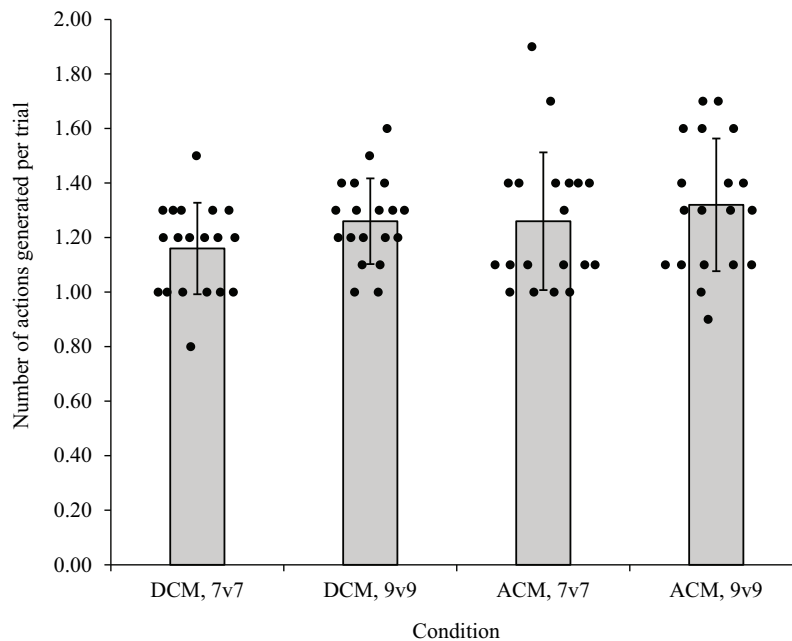


Figure 5. Scatter bar displaying mean number of actions generated per trial across the four conditions. Bars represent mean number of actions generated per trial. Black dots represent individual data by participant. *Note.* DCM = defensive central midfield, ACM = attacking central midfield.

Table 3. Descriptive analysis of soccer players' verbal action response types.

Action Type	DCM, 7v7	DCM, 9v9	ACM, 7v7	ACM, 9v9	Frequency	Percent of verbalisations
Pass	84	182	78	61	405	53
Dribble	22	57	25	56	160	21
Shot	3	9	38	38	88	12
Turn with the ball	15	30	25	12	82	10
Receive and protect the ball	6	6	4	8	24	3
Unsure	2	1	0	1	4	1
Total	132	285	170	176	763	100

Note. DCM = defensive central midfield, ACM = attacking central midfield.

contains soccer players' verbal action responses by category.

Discussion

The study aimed to examine the effect of pitch location and sided game format on VEA and verbal action responses using a 360-video soccer task in women's soccer players. Soccer players displayed significantly higher mean scan frequencies in defensive central midfield (DCM) compared to attacking central midfield (ACM) locations, with no significant main effect of sided game and no interaction effect between pitch location and sided game. Despite the reported large effect for the interaction between pitch location and sided game for scan frequency, the result did not reach statistical significance, and so this finding should be interpreted with caution. The highest mean scan frequency across the final 5 seconds prior to players receiving the ball was observed

between ball contact and 1 second scan timing window. Players generated significantly more verbal action responses per trial in ACM locations of the pitch compared to DCM, as well as in 9v9 compared to the 7v7 sided game. In summary, soccer players tended to scan close to ball reception (0–1 seconds prior to receiving the ball) and scanned more frequently in DCM compared to ACM suggesting VEA may vary based upon contextual demands (i.e., pitch location) presented in 360-video.

As hypothesised, soccer players displayed significantly higher mean scan frequencies in DCM positions on the pitch compared to ACM positions. Although a significant main effect of pitch location was found, mean scan frequencies observed across the four conditions were similar and should be considered when interpreting these findings. Findings suggest players were more active in searching their environment for the most important information when closer to their own goal, possibly under less opponent pressure (Aksum,

Pokolm, et al., 2021; Jordet et al., 2020) in order to inform their subsequent verbalised action upon receiving the ball (Aksum, Pokolm, et al., 2021). Additionally, the findings could be attributed to a player's awareness of not wanting to concede possession close to their own goal. Our data align with previous research in male and female soccer, with observational studies consistently finding that players display higher scan frequencies in defensive midfield compared to wide and attacking midfield pitch locations (Feist, Datson, et al., 2024; Jordet et al., 2020; McGuckian et al., 2020). The mean scan frequencies reported in the current study (0.30 scans/s across all participants) are similar to those of female soccer players in 360-video (*median* = 0.31 scans/s, Feist et al., 2025) and in 11v11 matches (0.35 scans/s, Feist, Datson, et al., 2024). No significant main effect of sided game was found, with soccer players displaying similar scan frequencies between 7v7 and 9v9 sided game formats. This finding may be a result of the two sided games being similar in game structure and relative pitch size per player, leading to no differences in scan frequency. Overall, our data provide additional preliminary evidence supporting that of Feist et al. (2025) for using 360-video as a tool for analysing head-orientation-based scanning as a proxy for VEA, with differences found in scan frequency across pitch locations. Further evidence is provided for the important role of pitch location in understanding VEA in soccer.

Previous literature investigating VEA in women's (Feist, Datson, et al., 2024) and men's soccer (Jordet et al., 2020) has identified a need to understand the optimal time point at which players should scan their environment in the seconds prior to receiving a pass to inform coaching interventions. Across the final 5 seconds prior to players receiving a pass from a teammate, the highest scan frequency was observed between the ball contact and 1 second scan timing window. Despite participants being unable to perform a physical motor response and therefore not achieving full perception-action coupling, affordances perceived during the final scan may play a role in guiding verbal action responses. Participants showed increased scan frequency in the final second prior to ball contact, later than reported in elite women's soccer 11v11 matches, where peak scan frequency occurred in the final 1.01–2 seconds in central midfielders (Feist, Datson, et al., 2024) and in youth male players who scanned most frequently 1–2 seconds before ball contact (McGuckian et al., 2018). One explanation could be attributed to trial-selection bias, where trials in the present study were only analysed when the ball reached the camera/player location and so the stimulus set may have over-represented successful possession sequences and

increased the predictability of ball delivery compared with live match play. Further explanations for increased scanning closer to ball reception in 360-video compared to live-match contexts may include reduced action consequences (i.e., physically losing the ball), increased predictability of ball delivery, and altered perception-action coupling due to the absence of locomotion from a stationary viewing perspective. In youth male soccer, defender proximity has been shown to influence VEA (Aksum, Pokolm, et al., 2021). Therefore, the absence of real-world in-person pressure in 360-video may explain why participants scanned most frequently in the final second. Additionally, earlier scans observed in live-match contexts (e.g., Feist, Datson, et al., 2024) may reflect the need to physically receive and control the ball, which is absent in 360-video. Therefore, the present findings are consistent with previous literature suggesting scans close to ball reception may provide more up-to-date environmental information (Aksum, Pokolm, et al., 2021). However, reduced action consequences, opponent pressure and perception-action coupling may contribute to differences in scan timing between 360-video and live matches. Future research could consider combining 360-video with haptic feedback, with previous research highlighting this as an avenue for further investigation (Kittel et al., 2020).

Contrary to our hypotheses, descriptive analysis showed that the highest observed mean for the number of actions generated per trial was in the ACM 9v9 condition, with the lowest in the DCM 7v7 condition. Separate main effects of sided game format and pitch location showed soccer players generated significantly more verbal action responses per trial in the 9v9 than the 7v7 game format and in ACM compared to DCM. This suggests that, when placed in an attacking midfield position, players are presented with a richer landscape of options (e.g., shooting opportunities; Loutfi et al., 2023). Unlike when placed in a DCM, where players typically receive the ball from defenders or the goalkeeper facing their own goal, players in attacking positions have the additional option of shooting at goal. Players therefore may be more inclined to combine actions with the ball (e.g., turn with the ball, dribble and shoot) which may not be directly connected to the quantity of their VEA, but rather to their proximity to the goal. Furthermore, this finding could be attributed to soccer players having more opportunities for action, with a greater number of interactions between players and the game being a closer representation of an 11v11 game. While acknowledging methodological differences (e.g., verbal action responses vs on-field technical actions), this finding contrasts with that of previous research where more technical actions were found in

a 7v7 game format compared to 9v9 (Smith & Conway, 2025). When examining verbalised action responses across conditions, the number of “pass” actions in the DCM 9v9 condition was more than double that observed in the ACM 9v9, ACM 7v7 and DCM 7v7 conditions. This may relate to the increased number of players on the pitch (compared to 7v7) creating more passing opportunities. In particular, when operating in a DCM role, players support the build-up phase, aiming to progress the ball towards the opponent’s goal. When placed in the context of elite women’s soccer, research investigating ball movement characteristics emphasises how successful teams are those that are able to maintain possession of the ball more effectively in the defensive third of the pitch (Dipple et al., 2022). Although players’ decision-making was recorded by a verbal response and not through a real-world motor action, we provide empirical evidence that the frequency and nature of players’ responses vary depending on the location of the pitch they are standing in and the number of players on the pitch.

When evaluating the present findings, task familiarity relative to players’ primary playing positions is an important consideration. Seven of the 19 participants were midfield players and may have had greater familiarity with the task environment when positioned in a central midfield pitch location and verbalising action responses. This should be considered when interpreting the findings. While a primary focus was to compare players’ verbal action responses across 7v7 and 9v9 games and between pitch locations to examine differences in response type and detail, verbalisation alone did not allow for assessment of whether players could physically execute these verbalised actions; therefore, decision quality was not assessed. It should also be noted that presenting videos via a HMD, this could limit the field of view available to participants during the 360-video task which could lead to alterations in how players scan their environment (Postuma et al., 2025; Vawser et al., 2025) and with participants verbalising their actions with the ball and miming physical movements, we may not have captured the full capabilities of the participants (Panchuk et al., 2018). In spite of these limitations, we propose some practical implications. 360-video provides opportunities to investigate game-realistic, soccer-specific situations demanding an all-around view (e.g., for a central midfield player), with our results showing players visually explored their environment differently when placed under different environmental conditions such as the location of the pitch a player is standing in. Furthermore, practitioners should look to utilise 360-video as a cheap, easy-to-use tool for placing players under different contextual and perceptual demands to

challenge soccer players VEA. Since we do not test the relationship between scan frequency and decision-making performance, these practical implications should be interpreted as recommendations for how 360-video can expose players to first-person game situations when standardising task instructions, pitch-location perspectives and the viewing environment.

In light of the present findings, we suggest several avenues for future research. In the context of designing effective practice activities that may enable one to develop a player’s VEA, it appears important to understand the extent to which what players do in an HMD transfers to the real world on the soccer pitch (Harris et al., 2020; Höner et al., 2023). Future research should aim to assess the agreement between scans measured in 360-video compared to on-field practice activities, as well as consider theoretical questions as to whether VEA is driven by the individual or the environment. Determining whether VEA is primarily driven by the individual (i.e., skilled players scan more regardless of their position on the pitch) or the environment (i.e., all players scan more in midfield pitch locations compared with other pitch locations) is important for informing practice design. One approach to assessing this is to place soccer players in different positions on the pitch to measure the frequency and timing of their scans while coupling this to their performance with the ball during small sided games. Future research could also explore the use of multiple 360-degree cameras to expand the perceptual information available by presenting players with alternative viewing perspectives of the same scenario, as demonstrated in teacher education contexts (Kosko et al., 2022).

Conclusion

The study aimed to examine the effect of pitch location and sided game format on VEA and verbal action responses using a 360-video soccer task in women’s soccer players. Soccer players had significantly higher scan frequencies in DCM compared to ACM, albeit similar scan frequency values being observed between conditions. Main effects of sided game format and pitch location showed soccer players generated significantly more verbal action responses per trial in the 9v9 than the 7v7 game format and in ACM compared to DCM pitch locations. No interaction effects were found between pitch location and sided game format for scan frequency or the number of verbal action responses generated per trial. Given the aforementioned methodological limitations and potential implications of participants’ natural playing positions, the present study contributes to an evolving body of

research utilising 360-video as a tool for understanding perceptual cognitive skills in soccer (Feist et al., 2025; Höner et al., 2023; Musculus et al., 2021). We provide initial evidence that the frequency with which soccer players scan their environment may change depending upon the location of the pitch a player is standing in. Considerable research is still required to further validate the use of 360-video as a tool for measuring scans in an HMD by considering eye-tracking and comparison with on-field behaviour. Future research is now required to assess the agreement between scans measured in 360-video compared to on-field practice activities and to understand whether VEA is a skill driven by the individual or the environment.

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