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Assessing visual attention using soccer game videos in elite female soccer players

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BACKGROUND: *Visual attention is critical in team sports, and multiple object tracking (MOT) task is a well-established experimental method for assessing it. This study aims to use a visual tracking task based on a soccer game video to compare the impact of different numbers of targets on the visual tracking performance of soccer players and that of non-soccer players.*

METHODS: *14 Chinese female soccer players (average age: 20.2±1.6 years) and 20 Chinese female non-soccer players (average age: 20.3±1.4 years) were selected to participate in the video-based MOT task with varying attentional load (four, six, or eight targets). This study examined the difference of dynamic visual attention features between female soccer players and non-players by changing the number of targets.*

RESULTS: *A significant main effect of target number on tracking accuracy was identified, with accuracy decreasing as the number of targets increased ($p < 0.001$). Additionally, group differences were significant ($p < 0.001$), with female soccer players demonstrating superior accuracy compared to non-players. Furthermore, there*

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was a significant interaction effect between group and target number ($p < 0.05$), indicating that female soccer players showed better tracking performance compared to non-players across various target quantities (i.e., 4, 6, and 8 targets). Specifically, within the group of female soccer players, tracking accuracy for 4 targets was significantly higher than for 6 and 8 targets ($p < 0.05$), yet no significant difference was observed between the tracking accuracies for 6 and 8 targets ($p > 0.05$).

Discussion: *This study examined MOT for the first time using a video-based assessment method. Overall, the results suggest that video-based MOT is a sensitive measure to assess the visual tracking ability of female soccer players. In addition, the effect of expertise in female soccer games was found transferable to attention tasks related to other types of sports games. In order to provide better suggestions on performance in sports games, future research can adopt a more realistic game environment and incorporate motor-cognitive tasks.*

Key Words: *Video-based assessment; soccer; multiple object tracking; female soccer player*

Introduction

The scale of women's soccer games has grown exponentially in recent years (McGreary et al., 2021). According to the first-ever Women's Football Strategy that FIFA launched in 2018, one of FIFA's concrete objectives is to increase the number of female soccer players to 60 million by 2026 (Griffin et al., 2021), which has demonstrated FIFA's ambition to promote women's soccer worldwide.

In this context, in order to achieve success at this top level of global competitions, the key is to identify the player characteristics of elite female soccer players and to optimize the potential of young female soccer players (Farahani et al., 2020). It is imperative for soccer coaches and sports scientists to find efficient methods to assess the ability of elite female soccer players. It is widely known that the attainment of soccer expertise is attributed to multiple factors (Bennett et al., 2019), including individual, collective, and environmental factors (Kristjánsdóttir et al., 2019). The individual factors include anthropometric conditions, body composition, physical fitness, psychological factors, etc.. In particular, psychological factors including mental toughness (Danielsen et al., 2017; Kristjánsdóttir et al., 2019), motivational climate (Cuenca, 2019; Domingues, 2019), executive functions (Beavan et al., 2022) and conscientiousness (Pettersen et al., 2022) have been shown to positively correlate with performance in female soccer (Pettersen et al., 2022). However, it was not until recently that sports scientists found that the effect of the psychological factors of female soccer players on their performance in soccer games was rarely studied, despite the rapid increase in the number of studies on female soccer players over the past decades (Pettersen et al., 2022).

Perception is a critical determinant of sports performance, and the relationship between visual perception and action is relevant to all behaviors (McGuckian et al., 2018). Among many visual perceptual abilities, visual attention is considered as essential for visual perception in sports, as it allows us to select useful information for reporting or memorization from stimuli in visual space, such as objects and locations (Cavanagh & Alvarez, 2005). It can be described as a noise-processing mechanism for information collection. Specifically, the sub-processes of visual attention include selective attention, attentional orientation, divided attention, and sustained attention (Martin et al., 2017).

One of the most established experimental techniques used to study dynamic visual attention was multiple object tracking (MOT), which was developed by Pylyshyn and Storm in 1988. And it has now become a standard paradigm for examining divided attention in dynamic environments (Scholl, 2009). In a typical MOT task, observers are shown a set of identical sample objects (typically 8 circles) on a computer screen, in which some that will flash during a brief period will be identified as targets and the others as distractors. During a specific tracking period, all objects move in independent and random trajectories, before they stop and the observers are asked to identify the targets (Pylyshyn & Annan, 2006; Thornton & Horowitz, 2015). After its invention, MOT has been commonly used to study some fundamental perceptual-cognitive abilities related to sports performance in the laboratory (Scharfen & Memmert, 2019).

In view of the complex nature of competitive sports performance, research has extensively been conducted on the MOT performance of elite athletes. The research utilizes the latest techniques, including typical MOT tasks (Pylyshyn, 1987), 360°-MOT (Ehmann et al., 2021), and VR-based tracking tasks (Vu et al., 2022). It has been conducted for various sports such as ice-hockey (Zhang et al., 2021), basketball (Mangine et al., 2014; Qiu et al., 2018), soccer (Vu et al., 2022), volleyball (Zhang et al., 2009), and ruby (Martin et al., 2017). In these sports, MOT serves as a performance assessment tool (Aden et al., 2019) or a training tool to improve athletes' decision-making ability (Harenberg et al., 2022; Komarudin et al., 2021; Romeas et al., 2016).

Among the above-mentioned techniques, typical MOT tasks (with 2D animation) have gained more attention due to less complex technical complexity in the production of example clips (Farahani et al., 2020). Qiu et al. (2018) studied the influence of sports expertise level on attention using MOT tasks, they found that the elite athletes achieved better performance than the intermediate athletes or the non-athletes in the tracking with three

or four targets, while no significant difference was found between the intermediate athletes and the non-athletes. Qiu and colleagues considered that the effects of expertise in team ball sports could transfer to a non-sports-specific attention task. These transfer effects occur only in elite athletes with extensive training under higher attention load (Qiu et al., 2018). Zhang et al. (2009) used MOT task and found that the overall reaction time was significantly shorter for expert volleyball players. The study by Memmert et al. (2009) was the only one to not find any difference between groups on a MOT task (Qiu et al., 2018), they found no statistical differences between experts in team sports, those in individual sports, and non-athletes. All of the aforementioned studies have used typical MOT task to explore the relationship between expertise and visual attention. It is still not clear whether specialized knowledge is helpful for improving visual attention.

Nonetheless, researchers have long questioned the ecological validity of a typical MOT task due to its limitations (Meyerhoff et al., 2017). In a real situation, team sports players must constantly extract information from a 360° environment. Moreover, with the aid of a 360° video, participants can perceive objects moving as if they were on the field (Musculus et al., 2021). Ehmann et al. (2021) designed a novel 360° MOT task as a new diagnostic tool to assess cognitive performance in a 360° environment. Ehmann et al. (2022) used the 360°-MOT task and found that the older age groups (U16, U17, U19, and U23) performed significantly better than the youngest age group (U12). The aforementioned studies suggested that the 360°-MOT task allows for a reliable assessment of visuospatial cognitive performance in a dynamic 360° environment (Ehmann et al., 2021). Additionally, it can be used to investigate differences in perceptual cognitive skills among football players (Ehmann et al., 2022).

On the basis of 360°-MOT, recent advances in technology have enabled the application of virtual reality in MOT-related soccer research. In a recent study, 15 soccer and 16 non-soccer players wearing a VR head-mounted display performed a VR-based task to track multiple moving virtual players (Vu et al., 2022). Surprisingly, the soccer players showed higher ability than the non-soccer players to track multiple virtual players, but the difference in tracking performance between soccer and non-soccer players in soccer-specific scenarios was not significantly greater than that in scenarios with pseudo-random movements (Vu et al., 2022). Unfortunately, their study used simplified humanoid mannequins without any other discernible visual features to be the virtual players, and therefore failed to observe the influence of postural cues on the visual tracking performance of the soccer players.

Although the above-mentioned studies have produced findings with important implications for perceptual-cognitive abilities, it is important to note that these studies were not free of limitations. One of the limitations is low flexibility. As all of the previous studies were based on computer simulation, the content of the tasks in these studies could not be freely edited in accordance with the real time needs. Another limitation concerns environmental fidelity, even though numerous studies have already made attempts to reduce the discrepancy between the simulated scenarios and the real sports fields. For example, in the above-mentioned study by Vu et al. (2022), the simplification of virtual players into humanoid mannequins canceled the possibility for the participants to extract postural information, while postural cues are conducive to the outcome anticipation in a game for players on the field.

Video-based assessment is an eligible solution for these limitations. It has been commonly used in the past decades by scientists for athletes' decision-making ability in sports. Video-based assessment in sports generally refers to the method of asking athletes to watch a series of short clips, and make decisions in specific scenarios via mouse-clicking or screen-tapping (Lorains et al., 2013). Videos have a lot of advantages over computer simulation. First, the video-based assessment is easy to implement, as the scenario information presented to participants can be controlled more easily by editing video clips at different key moments of a game. Second, a video-based environment can provide greater control and consistency of scenarios than a virtual scene (Lorains et al., 2013). Video-based methods present short game-based interactive scenarios where participants must give responses (Aden et al., 2019), when they offer the ability to control the environment and conditions for all players in a way that is not possible on the field.

However, no previous study has examined the ability to track multiple players to determine whether soccer expertise is associated with dynamic visual attention. In particular, there is a lack of relevant research in the field of women's soccer. The central goal of this study was to examine the difference in tracking performance in the specific attentional abilities of female soccer players. With the aim of addressing the aforementioned limitations of conventional MOT methods. To do so, we proposed a novel method of video-based assessment with a theoretical framework of typical MOT task. We hypothesized that female soccer players would show better visual tracking performance than non-players in a video-MOT task. In addition, we expected that the performance of both female soccer players and non-players would decrease as the number of targets increased.

Materials and methods

Participants

34 participants, including athletes and non-athletes, participated in this study. The soccer group consisted of 14 elite female soccer players (mean age: 20.2±1.6 years; age range: 18-24 years), and the non-soccer group consisted of 20 non-athletes with similar ages and educational backgrounds (mean age: 20.3±1.4 years; age range: 18-24 years). Soccer players were recruited from a Chinese women's football second division league club. In addition, they spent an average of 7.5 hours training per week prior to the recruitment. The recruited non-athletes were college students without experience in professional football training.

All participants were female, right-handed, and had normal or correct-to-normal vision (possibly with glasses or contact lenses). They reported no history of engagement in perception-cognitive research six months prior to the recruitment. The experimental protocol was approved by the regional ethics committee of the Capital University of Physical Education and Sports (No.2023A058). In accordance with the Declaration of Helsinki, all the participants had provided informed consent before participating in this study.

Test film

The female soccer players involved in the test film were not included among the participants (Natsuhara et al., 2020). For this purpose, 16 college female soccer players with more than 8 years of training experience at the university level in China were recruited to take part in the filming after accepting a one-week course with detailed instructions. An 8 versus 8 soccer game between them on a regular soccer field (a training pitch in a college) was then filmed from a bird's-eye view, which is an elevated perspective to the field (Machado & da Costa, 2020), to facilitate information collection from the soccer field for the participants. The game sequence was filmed using a wide-angle converter lens mounted on a high-definition digital video camera (JVCGC PX-100, Japan) from a position 15 m behind and 25 m above one of the goals to ensure that the ball and all the players were visible inside the frame at any given time. The soccer game was played within an area of 60×45 m for 60 minutes. The footage was then digitally edited using Adobe Premiere Pro 2022 (Adobe Systems Incorporated, San Jose, CA) to produce several short clips to be used in the task. Subsequently, a panel of three AFC (Asian Football Confederation) qualified soccer coaches independently selected the scenes among the clips.

The video clips were produced after we obtained permission from the team. Each video clip was required to contain three phases of a football game, i.e. offense, defense, and transition, thereby resulting in 203 valid clips. Afterwards, these valid clips were screened by the three coaches and were adopted as the test films for the task after obtaining the unanimous approval from the coaches (Woods et al., 2016). In the final set of 180 applicable clips, each of them lasted around 10-15 seconds, which was deemed long enough for the participants to derive sound decisions (Larkin et al., 2014).

The video streaming and experimental control were managed using E-prime 3.0, running on a Lenovo PC with a 14-inch monitor running at a screen resolution of 1920×1280 pixels and a refresh rate of 60HZ.

Procedures

All the participants were tested individually in a quiet and well-lit laboratory. Each of them was seated approximately 50 cm away from the screen, with a chin rest to reduce head movements and ensure the viewing distance, and giving responses using their dominant hand with the left and right buttons of the computer mouse. Before the test, the participants were given written instructions, which outlined the general procedures and presented an explanation with a trial sequence (Oksama & Hyönä, 2004). They were told to pay attention to the positions of any flashing objects at the start of each trial and to keep tracking them during the corresponding tracking period. At the end of each trial, the participants were asked to conduct target selection. In this phase, a trial clip stopped playing and each player in the clip was covered by a white cycle to hide their identities. The participants were then instructed to choose the target players as accurately as possible by clicking. Clicking the left and right mouse buttons means to choose target players in the red and gray teams, respectively, which can also change the marked colors.

At the beginning of each trial, a red circle flashed on and off for a brief duration of 150 ms 6 times on each of a subset of objects (four, six, and eight) selected as the target players, while other objects did not undergo any changes and were regarded as the distractors. As long as the red circle on each target disappeared, the trial clip started to stream on the screen. During a tracking period of 10-15 s, the participants deployed their visual attention to track each of the target players. As the clip stopped playing, the participants were required to identify the target players by clicking, before they pressed the space button to end the trial and initiate the next trial. Each of the participants needed to undergo a total of 30 formal cycles of trials, each of which consisted of three trials (4, 6, and 8 targets). In each trial clip, the target players were evenly distributed into the two teams. The streaming of the trial clips was conducted in a pseudo-random order across the cycles. Before the formal experiment, six practice trials in 2 cycles were conducted (Qiu et al., 2018). The entire test session took about 50 minutes. Figure 1 shows the procedures for a single visual stimulation trial in the soccer game video-based MOT task.

Design

A mixed experimental design of 2 (group: soccer and non-soccer) × 3 (target number: 4, 6, and 8) was employed in this experiment.

Data Analysis

The data analyses were completed using SPSS Statistics Version 20.0. The data were initially inspected for missing cases, and the distribution was evaluated for outliers and normality. No missing cases or outliers were identified, and the data exhibited a normal distribution, thus justifying the use of parametric analyses. To assess tracking accuracies, a two-way analysis of variance (ANOVA) was conducted, with "group" (soccer and non-soccer) as a between-subjects factor and "number of targets" (4, 6, and 8) as a within-subjects factor. Simple effect analysis of interaction was further conducted. Where necessary, Greenhouse-Geisser corrections were applied to repeated measures ANOVA to account for violations of the sphericity assumption. A statistically significant alpha level was set at $p < 0.05$.

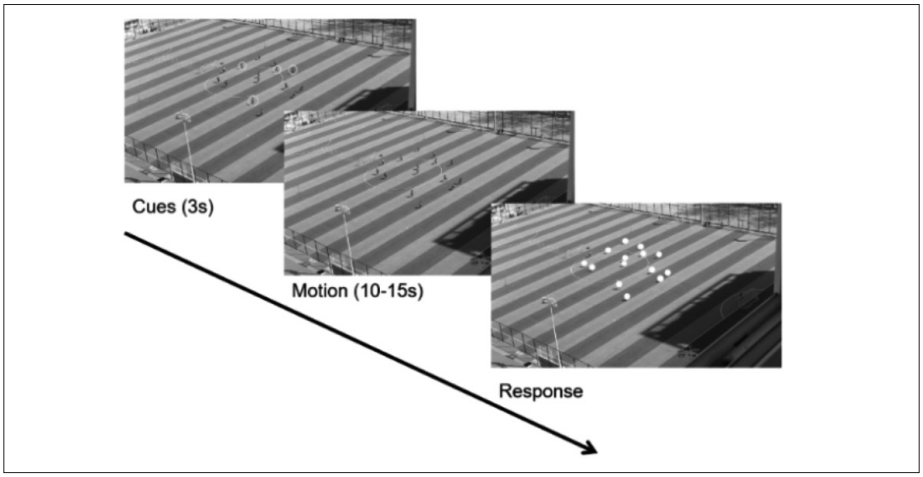

Fig. 1. - *Procedures for a single visual stimulation trial in the soccer game video-based MOT task. 16 players (including 2 goalkeepers) were presented and then a subset of players as the targets (4, 6, and 8) were highlighted with yellow circles for 3 s before the video started, in which the numbers of players from two different teams were equal. During a tracking period of 10-15 s, the participants were asked to watch the video, before it stopped playing and the participants were assessed for their performance to identify the target players.*

Results

A Two-way Analysis of Variance (ANOVA) demonstrated significant main effects in the presence of the factors of the group ($F(1,32) = 32.960$, $p < 0.001$, $\eta p2 = 0.507$) and the number of targets ($F(2,31) = 17.667$, $p < 0.001$, $\eta p2 = 0.356$). Moreover, a significant interaction effect was observed between the group and the number of targets ($F(2,31) = 5.372$, $p < 0.05$, $\eta p2 = 0.144$).

Post hoc analyses showed that the soccer group demonstrated better tracking accuracy than the non-soccer group. Moreover, the tracking accuracy decreased as the number of targets increased in both groups. Specifically, we found that the accuracy was higher in the soccer group (70.18 ± 4.11%) than in the non-soccer group (37.10 ± 3.44%) for the tracking of four targets ($F(1,32) = 38.10$, $p < 0.001$). Similarly, the soccer group (46.88 ± 3.30%) had higher tracking accuracy than the non-soccer group (30.82 ± 2.76%) when they were tracking six targets ($F(1,32) = 13.97$, $p < 0.05$). And the soccer group (43.03 ± 4.46%) had higher tracking accuracy than the non-soccer

group (28.95 ± 3.74%) when they were tracking eight targets ($F(1,32) = 5.85$, $p < 0.05$).

The participants' tracking task accuracy averaged 53.64±3.78% for four targets, 38.85±3.03% for six targets, 35.99 ± 4.10% for eight targets. A significant main effect of target tracking load was observed ($p < 0.001$), indicating that the tracking performance decreased significantly as the number of targets increased. Tracking accuracy also significantly decreased with increasing target numbers (4 vs. 6, MD=9.5, $p < 0.001$; 6 vs. 8, MD=0.9, $p < 0.05$). In addition, it was observed that the soccer group had significantly higher accuracy at tracking four (70.18 ± 4.11%) than six (46.88 ± 3.30%) or eight (43.03 ± 4.46%) targets. Figure 2 shows the tracking accuracy of the two groups as a function of the number of targets.

Discussion

This study aims to explore the differences in visual attention characteristics between female soccer players and non-players using a video-based MOT task. We have developed a representative task to reconstruct real-game scenarios using soccer game videos from a bird's-eye view under reproducible conditions in the laboratory. The main findings of this study are as fol-

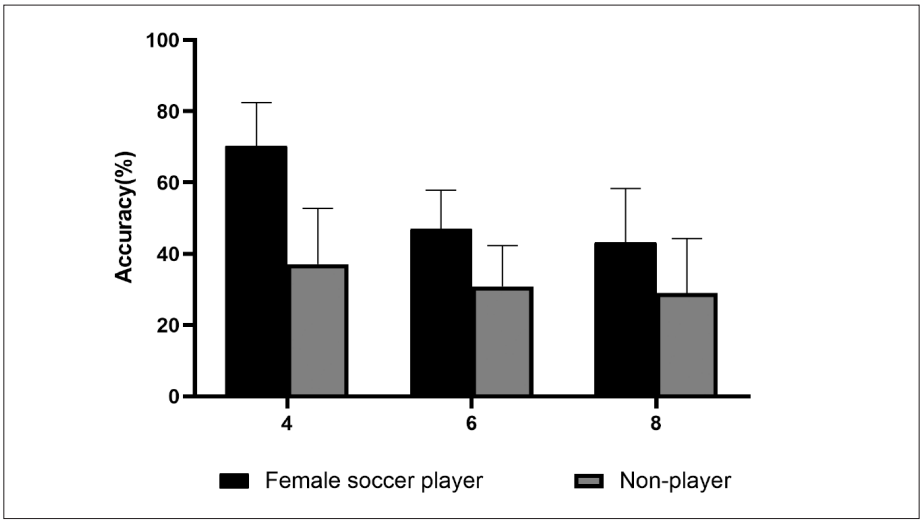

Fig. 2. - *Tracking accuracy as a function of the number of targets.*

lows: (a) the female soccer players had higher tracking accuracy, (b) tracking accuracy decreases as the number of target objects increases, and (c) the female soccer players performed significantly better when they were tracking four than six or eight targets.

When the tracking accuracy of the elite athletes and non-athletes was compared, regardless of the number of targets, the elite athletes had significantly higher tracking accuracy. This result is consistent with some previous findings (Martin et al., 2017; Qiu et al., 2018; Vu et al., 2022; Zhang et al., 2021), suggesting that expertise in sports may be associated with better performance in sports attention task. On the one hand, this result may be explained by the effect of athletes' training. Soccer games require the ability to track multiple moving objects, including the ball, the teammates, and the opponents (Vuet al., 2022), which is believed to be formed due to long-term professional practice in a complex and dynamic environment, such as what highly skilled athletes have prepared for soccer games (Qiu et al., 2018; Zhang et al., 2009). Therefore, it can be inferred that sports expertise may improve basic visual attention. On the other hand, female soccer players demonstrate higher tracking performance. This may be linked to soccer-specific knowledge stored in their long-term memory. After years of special training, they may have stored a large number of patterns in long-term memory, such as playing positions, team formations, and tactical systems. Previous research has suggested that experts demonstrate advantages in recalling and recognizing 'structured' stimuli (North et al., 2016). Also, soccer players can perceive and recognize global patterns on the basis of centrally located relational information (North et al., 2017). Therefore, female soccer players can also use templates to infer the position and identity of tracking targets. If so, specialized learning might help soccer players improve their MOT ability on the field. In the current design, real soccer games as the stimuli may not be sufficient to explain the effect of the two factors. Future research can take into account the influence of different scenarios (real soccer games versus random trajectories) on the performance in visual attention.

Although Alvarez and Franconeri (2007) found that the tracking accuracy was high (~94%) when tracking 1 to 8 targets at a slow speed, none of the results of the comparisons of the tracking accuracy with different numbers of the targets were significant. However, we found that subjects' tracking accuracy decreased as the number of targets increased in this study, replicating the results of some previous studies (Qiu et al., 2018; Yantis, 1992). According to flexible resource model (Alvarez & Franconeri, 2007), the number of targets that can be tracked depends on the available attentional resources. As the number of targets increases, the amount of resources allocated to each

object decreases, thereby reducing the tracking accuracy of the participants (Alvarez & Franconeri, 2007). In this study, the participants were not only asked to track the locations of the targets, but also to decide what identities the targets had. Thus, the large number of targets might disturb the participants' ability to pay selective attention to the targets, Therefore, future studies can also consider the difficulty of the task as a factor.

What is even more striking is that the tracking accuracy of the elite female soccer players declined rapidly as the number of targets increased (e.g., 70.18% for four targets, and 46.88% and 43.03% for six and eight targets, respectively). We found that the soccer players had significantly higher at tracking four targets than six or eight targets. There is no significant difference in accuracy in tracking six versus eight targets. The tracking accuracy is up to 85%~95% in a MOT task when tracking four or five targets (Intriligator & Cavanagh, 2001; Pylyshyn & Storm, 1988; Yantis, 1992). However, the tracking accuracy will decrease significantly as the number of targets continues to increase (Pylyshyn, 2004). According to Model of Multiple Identify Tracking (MOMIT) (Oksama & Hyn, 2008). A serial refresh mechanism is postulated, which makes resource to continuous attention switching, a capacity-limited episodic buffer for identify-location bindings, indexed location information stored in the visuospatial short-term memory, and an active role of long-term memory. Working memory is a temporary processing and storage system which may be involved in MOT (Kahneman et al., 1992), the amount of cognitive resources of the system is limited, the limited averages about four chunks in normal (Cowan & Nelson, 2001). In this study, the female soccer players showed a significant advantage when tracking four targets, which could be attributed to the fact that years of training may expand the soccer players' working memory capacity. Future research can design training tasks based on the results of this study.

Limitations

In this study, we have adopted a bird's-eye view in the filming of the stimulation material. It has been suggested that the benefit of the video-based assessment is the ability to control the environment and conditions for all players in a way that is not possible to achieve on the field. However, using computer-generated immersive VR technology is conducive to soccer players' access to in-depth cues for MOT. On the other hand, previous studies have noted that elite soccer players possess higher MOT ability than intermediate and non-soccer players in 360º-MOT (Pea et al., 2021) and VR-MOT

(Vu et al., 2022) tasks and the scores of accuracy in a 360°-passing task will increase after regular 360°-MOT training (Ehmann et al., 2022). Thus, if a real soccer game can be reconstructed in a VR environment, further research can explore the visual tracking characteristics of soccer players in the reconstructed game.

Furthermore, another limitation concerns the method of data collection. The participants in this study were required to simultaneously track the offensive and defensive players. Simply recording the overall tracking accuracy is no longer sufficient to satisfy the soccer-specific requirements. Although the proposed design, in our opinion, was closer to the soccer-specific requirements than a typical MOT task, it still failed to fully reflect the visual tracking characteristics of the soccer players. Indeed, soccer players not only need to monitor the positions of their teammates and opponents but also need to distinguish their identities accurately, so as to act properly at certain proper moments. In this study, we did not separately record the accuracy of tracking the targets in the red and the gray teams. Therefore, no statement can be made about the specific strategies the participants used to track different teams. Thus, it is important for a future study to systematically record and analyze the data that can reflect the visual tracking ability of the participants in a video-based MOT task.

Conclusion

This study has demonstrated that female soccer players possess higher ability than non-soccer players to track multiple players in a video-based soccer-specific environment. Moreover, the tracking accuracy of both groups decreased as the number of tracking targets increased. In addition, it can be observed that working memory capacity may affect the visual tracking accuracy of elite female soccer players. This study provides coaches and sports scientists with a reliable means to measure the visual tracking ability of athletes in soccer games. Overall, this study provides important information about the diagnosis and training of perceptual-cognitive skills of female soccer players.

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By the authors.

Human Ethics

Approving body and any reference numbers.

The experimental protocol was approved by the regional ethics committee of the Capital University of Physical Education and Sports (No. 2023A058). All participants provided written informed consent prior to the start of the experiment.

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