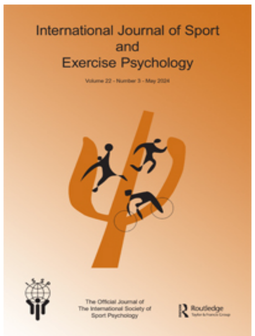

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Quantity and quality of memory and guesses in pattern recall of complex soccer scenarios

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ABSTRACT

In soccer, players need to keep in mind the locations of the ball and numerous teammates and opponents in complex scenarios. This study aimed to examine both the quantity and quality of players' memory and guess in pattern recall for complex soccer scenarios. We developed an adapted pattern recall task in which participants were required to reproduce player locations in complex scenarios through two stages, allowing for the separation of memory from guesses and the subsequent analysis of accurate memory and false memory. The results showed that soccer athletes could maintain the locations of about eight players, along with the ball, in accurate memory for complex soccer scenarios, showing a greater quantity of accurate memory than non-athletes, whereas the precision of memory did not differ between the two groups. On the other hand, non-athletes falsely memorised the locations of a larger number of attacking players and tended to make more guesses about the locations of defending players than soccer athletes. Moreover, soccer athletes displayed superior precision when guessing player locations compared to non-athletes. These findings suggest that soccer athletes leverage their knowledge to enhance the chunking of individual players to be maintained in short-term memory and facilitate the inferences about player locations exceeding the limit of short-term memory, providing them with an advantage in both memory quantity and guess quality in complex soccer scenarios.

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Introduction

Pattern recall

In association football (i.e., soccer), a player needs to keep in mind the locations of the ball and multiple teammates and opponents, so as to comprehend the current situation and to make proper decisions (Li et al., 2021; Roca et al., 2013; Romeas et al., 2016). To assess this ability to memorise locations, pattern recall tasks have been extensively employed (Allard et al., 1980; Raab & Farrow, 2015; Sherwood et al., 2019a). In the pattern recall paradigm, participants are presented with a static image or a video clip of a sport scenario lasting several seconds, and then required to reproduce the player locations in the scene. The distance between the participant's reproduced locations and the actual player locations (namely, radial error [RE]), is commonly employed to measure the performance of the participant's pattern recall (De Waelle et al., 2021; Ward & Williams, 2003). A large body of research shows that that pattern recall performance can serve as a valuable metric for distinguishing athletes' expertise level in soccer and various other team sports (Gabbett et al., 2011; Gorman et al., 2012; Schapschröer et al., 2016; Sherwood et al., 2019b; Ward & Williams, 2003).

Nevertheless, a limitation of current pattern recall research in soccer is that it mostly focuses on simplified scenarios. In many instances, these scenarios involve only a small number of players in the scene, or they require monitoring only a small subset of players (Ben Mahfoudh & Zoudji, 2022; van Maarseveen et al., 2015; van Maarseveen et al., 2018; Ward & Williams, 2003). While these studies offer valuable insights, they may not fully capture the intricacies of real soccer games, where a player encounters highly complex scenes featuring numerous attacking and defending players. The ability to recall complex scenes may hold profound significance for soccer players, as it may offers a window into their capacity of perceiving and remembering patterns on the field. Up to date, however, there has been little research on pattern recall of complex soccer scenarios.

Research on complex scenarios can lead to a deeper understanding on the cognitive structures and processes underlying pattern recall. Specifically, while studies on simple scenarios have focused on the quality of short-term memory (as measured by RE), research on complex scenarios featuring numerous elements can provide additional insights: (1) revealing both the quantity and quality of players' memory for elements in the scenes (2) differentiating between memory and guess, which may be either random guess or educated guess based on expert knowledge. Thus, the study of pattern recall in complex scenarios allows for a more nuanced assessment of experts' advantages, whether derived from the quantity or quality of memory, or the sophistication of guessing.

Quantity and quality of short-term memory

Cognitive research in recent decades has unveiled that short-term memory operates under the constraints of both quantity and quality, that is, the number of items maintained in memory and the precision of their representations (Ma et al., 2014; van den Berg et al., 2014). The quantity and quality are both essential, as they reflect different aspects of human cognitive processing and capability, and are processed by different yet related brain areas (Ku et al., 2015; Xie et al., 2023; Xu & Chun, 2006). This dual perspective is pertinent to soccer players as well. A precise memory about a teammate's or an opponent's location may be crucial for anticipating and deciding on potential passes, whereas memorising a substantial number of players may be critical for comprehending the global pattern, creating space in attack, and minimising space in defence (Sherwood et al., 2019b).

In previous research on pattern recall in soccer, the focus has primarily been on measuring the quality, represented by RE, without addressing the crucial question of how many locations a soccer player can effectively retain in memory regarding complex soccer scenarios and whether there exists an expert advantage. Drawing parallels with classical research on memorising patterns in chess, where expert chess players demonstrated an ability to recall more chess pieces constituting a structured pattern compared to non-experts, the need to explore this aspect in soccer becomes apparent (Chase & Simon, 1973). For instance, Chase and Simon (1973) found that a chess master could accurately recall about 16 pieces in briefly viewed patterns consisting of about 25 pieces, while a Class A player and a beginner correctly recalled about 8 and 4 pieces, respectively.

In recent years, there have been a few studies on pattern recall in team ball sports, measuring the number of locations that can be recalled in rugby (Sherwood et al., 2019a, 2019b). A 6-cell radius was set as the threshold for correct recalling. The recall instances falling within this radius were classified as correct, while those outside were deemed as erroneous. The results showed that rugby players could recall 2.9 out of 6 players in the scenes (Sherwood et al., 2019a), a relatively small number even when compared to the general working memory capacity for objects lacking meaningful context, which is around 4 objects (Cowan, 2001). It's worth noting that this modest number may, in part, stem from the setting of the radius threshold for correct recall. Participants might have memorised more player locations, albeit with larger deviations outside the predetermined radius threshold. Additionally, with this dichotomy method, only the quantity of memory could be analyzed, while the quality was missed.

Guessing and false memory

Furthermore, in the processing of complex scenarios, individuals may resort to guessing in conjunction with short-term memory, especially when attempting to reproduce items that exceed short-term memory capacity. Previous studies have commonly operated under the assumption that all reproduced locations originate from participants' short-term memory. While this assumption may hold in the context of recalling simple scenarios, it may not be entirely accurate in the case of complex soccer scenarios containing numerous players. Consequently, participants may resort to a degree of guessing for player locations that are not retained in short-term memory. Up to date, however, the delineation between memory recall and guessing in pattern recall has remained unexplored.

Importantly, guessing in pattern recall may extend beyond random guesses to include educated guesses based on expert knowledge, and thus research on guessing also holds the potential to offer insights into differentiating between experts and nonexperts. Experts' guesses may be underscored by their long-term working memory (LTWM) related to their expertise (Ericsson & Kintsch, 1995). Notably, research has shown that a sign of experts is that they can still provide correct report even when they think they don't know or they are not confident in their report, whereas nonexperts certainly do not know when they don't know (Kahneman & Klein, 2009).

Another cognitive process related to guessing is false memory. People cannot always memorise everything accurately. Guessing occurs when people think they don't know, whereas false memory occurs when people think they know, but their memory is actually distorted or even fabricated. In the context of soccer, false memory may lead to distorted comprehension of a given situation, and in turn erroneous decision-making, such as passing the ball to an improper location. This underscores the importance of conducting a nuanced analysis of false memory in pattern recall as well.

The present study

In the present study, we aimed to develop an adapted pattern recall task for complex soccer scenarios, and investigate soccer athletes' capacity and advantage in the quantity and quality of memory and guess in the recall for complex patterns. Specifically, we examined intriguing questions including how many locations athletes can accurately memorise in complex soccer scenarios, and how many will be false memory; compared with non-athletes, whether soccer athletes can memorise a greater number of player locations, or they memorise the same number but with higher precision, or they possess similar memory but makes better guesses.

To do so, we presented to participants complex scenarios from real soccer game video clips, which were stopped at a key moment. Participants were prompted to reproduce the player locations via two stages: first, reproducing the ones participants thought they memorised, and second, making guesses for the remaining player locations. Furthermore, participants' responses in the first stage were separated into accurate memory and false memory in the analysis. Thus, we assessed the number and precision of participants' accurate memory, false memory, and guesses for complex soccer scenarios, and examined where soccer players' expertise resided in by comparing their performance with non-players'.

Method

Participants

A total of 72 participants participated in the experiment, comprising 36 soccer athletes (20 males, 16 females) and 36 non-athletes (14 males, 22 females). The sample size was based on calculations using G*Power 3.1, which showed that 34 participants for each group provided sufficient power (0.9) to detect a medium effect. The average age of the soccer athletes and the non-athletes were 20.57 ($SD = 2.57$) and 20.11 ($SD = 1.92$) years old, respectively. Among the soccer athletes, one held master-level, 24 held first-level and 11 held second-level certificates of national athletes. The athletes had undergone systematic soccer training for 8.1 years on average ($SD = 3.55$, range 7-15), and were training 12.5 hours ($SD = 4.85$) a week on average. The non-athletes were college students who did not play soccer and were unfamiliar with soccer. Two athletes and one non-athlete were excluded from data analysis as they did not conduct the tasks following instructions. Thus, there were 34 athletes (20 males, 14 females) and 35 non-athletes (13 males, 22 females) included in the analyses. The participants have normal or corrected-to-normal vision. All the participants signed the informed consent, and received a small gift valued at about $2.5 after the experiment.

Stimuli and apparatus

The stimuli consisted of soccer video clips sourced from major European leagues and the European Championship League. The clips were selected with the assistance of three soccer coaches holding Asian Football Confederation Level A coaching accreditations. The video clips lasted for an average of about 10 s, depicting typical soccer scenarios with a number of moving players. Each video clip ended at a key moment, when the player in possession of the ball was just about to make a pass. The participants were required to reproduce the player locations at the key moment in the scene, which comprised around 12 players (mean = 11.9, $SD = 3.9$). The videos were presented without sound, and peripheral information on the videos such as the score board and team names was concealed by mosaic overlays. The stimuli were presented on a 22-inch screen with a resolution of 1280×720 pixels. The resolution of videos was 1280×720 pixels, and the frame rate was 30 frames per second. The distance between the computer screen and the participants' eyes was about 57 cm. The experiment was programmed by Python 3.7.3. There were 23 videos, 21 used in the experimental trials and 2 used as practice.

Experiment procedure and tasks

Participants were presented with soccer video clips on the screen. At the key moment, the clip stopped and all the players disappeared, leaving an empty field. The participants' task was to reproduce the locations of the players and the ball. They did this by using the mouse to click on the empty field, with the left and right mouse button reproducing the attacking and the defending players respectively, and the middle mouse button reproducing the ball. Participants could undo a reproduced icon by clicking the same location with the same mouse button. Once the participants finished reproducing the items they thought they remembered, they pressed the space bar. If the numbers of the attacking or defending players reproduced by the participant did not align with the actual numbers in the scene, the programme would prompt the numerical discrepancy for each team. The participant was then required to add or remove players accordingly, and then pressed the space bar again (see Figure 1). Once the numbers matched, the experiment proceeded to the next trial. There were 21 experimental trials, proceeded by 2 practice trials.

Data analysis

Participants' responses in the first stage (i.e., before pressing the space bar) were considered as reflecting their memory, which was further separated as accurate memory and false memory. Responses in the second stage (i.e., after pressing the space bar) were considered as guesses. The number and precision of accurate memory, false

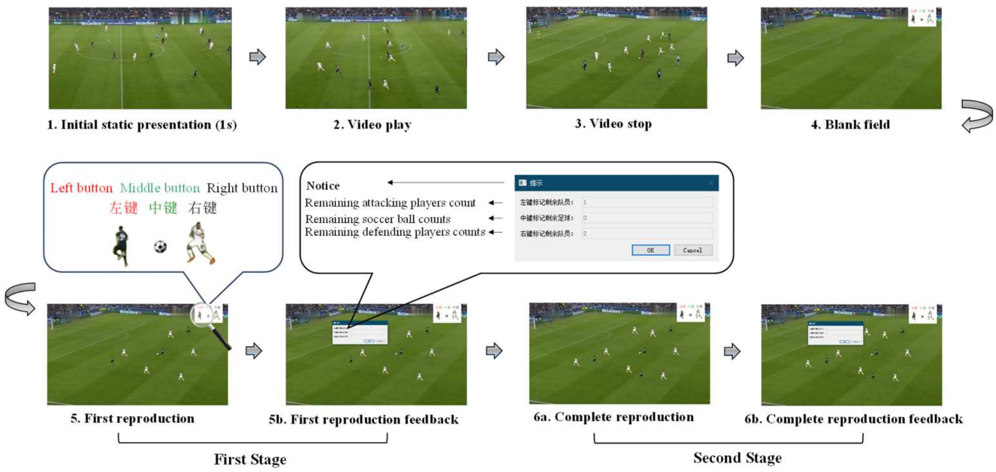

Figure 1. The procedure of the pattern recall task.

memory, and guessing for the attacking and the defending players were computed through the following processes.

Step 1: Establishing initial sets of accurate memory for the attacking and the defending players in each trial.

Participants' each reproduced player in the first stage was matched to an actual player in the scene. The matching was conducted separately for the attacking players and the defending players. As there are numerous players in the complex scenarios, there is ambiguity in which response matches to which actual player. We did the matching by a combination of two methods: minimum radial error for each individual player (namely, minimum individual RE) and minimum sum of radial error over all the players (namely, minimum overall RE).

The minimum individual RE method is similar to that usually used in previous pattern-recall studies. We calculated the RE between each reproduced player with all the actual players locations, and matched the response to the closest actual player. The matching was done one by one based on the order of participant responses, prioritising players reproduced earlier as they were more likely to be maintained in accurate memory (Sherwood et al., 2019a). Each actual player could only be matched to one reproduced player to avoid one-to-many matching.

In the minimum overall RE method, we exhausted all possible ways of matching the reproduced players set with the actual players set. For each set-match, the sum of RE between each pair of reproduced and matched actual players was calculated. Then the set-match with the minimum overall RE was identified.

The minimum individual RE method provided matches of player locations by prioritising the individual-level match, while the minimum overall RE prioritising global-level match. If a reproduced player was consistently matched to the same actual player across the two methods, it was corroborated that this was an accurate reproduction of the player location, suggesting that this player was likely to be accurate memorised by the participant. These consistently matched players formed the initial sets of accurate memory for the attacking and the defending players in each trial.

Step 2: Classifying the remaining responses in the first stage into the accurate memory set or the false memory set in each trial.

We did not set a predetermined fixed threshold of precision for accurate memory; instead, we examined whether each remaining response in the first stage was likely to fall in the distribution of the established accurate memory set. To do so, we firstly calculated the mean and *SD* of the RE of the initial accurate memory set. Then we matched each remaining reproduced player to a remaining actual player by the minimum individual RE method mentioned above, and calculated its RE. If the RE fell within the range of mean RE plus three deviation ($M + 3SD$) of the established actual memory set in this trial, this response was included into the accurate memory set, considering that vast majority data from a distribution shall appear within this range (Howell, 1998). And then the mean and *SD* of the RE of the accurate memory set was updated by including this RE into calculation. If the RE fell outside this range, the response was classified as false memory. The classification was done in the order of the participant responses, until all the remaining reproduced players had been matched with an actual player and classified into either the accurate memory set or the false memory set.

Step 3: Matching guesses with actual players in each trial.

For guesses (i.e., reproduced players in the second stage), we matched each of them with the remaining actual player closest to it using the minimum individual RE method mentioned above. The RE for each guess was then calculated.

Step 4: Calculating Averages

The number and the average RE for attacking and defending players in each set in each trial were calculated. Averaging across all trials provided each participant's average number and RE for accurate memory, false memory, and guesses.

Figure 2. Descriptive results of soccer athletes' and non-athletes' number and radial error (RE) of accurate memory, false memory, and guesses for attacking and defending players in the complex soccer scenarios.

Results

The descriptive results for the athletes and non-athletes' quantity (number) and quality (RE) of accurate memory, false memory, and guesses for attacking players and defending players are presented in Figure 2.

The results showed that the soccer athletes could accurately memorise 7.88 ($SD = 1.37$) players in the complex soccer scenarios, including 3.68 ($SD = 0.65$) attacking players and 4.20 ($SD = 0.83$) defending players. The non-athletes could accurately memorise 7.24 ($SD = 1.22$) players, including 3.45 ($SD = 0.56$) attacking players and 3.79 ($SD = 0.84$) defending players. We conducted a 2 (Participant Group: soccer athlete, non-athlete) × 2 (Element: attacking, defending) ANOVA on the quantity of accurate memory. The results (see Table 1) showed that the main effect of participant group was significant, $F(1,65) = 4.039$, $p = .049$, $\eta_p^2 = 0.059$, showing that the soccer athletes memorised more players than the non-athletes. The main effect of element was significant, $F(1,65) = 26.594$, $p < .001$, $\eta_p^2 = 0.290$, showing that more defending players were accurately memorised than attacking players. The interaction was not significant, $F(1,65) = 1.017$, $p = .317$, $\eta_p^2 = 0.015$.

In the same vein, we conducted a series of 2 (Participant Group: soccer athlete, non-athlete) × 2 (Element: attacking, defending) ANOVAs on the number and RE of accurate memory, false memory, and guesses. The results are listed in Table 1.

On both the number of false memory and the number of guesses, the main effect of element and the Participant Group × Element interaction were significant (see Table 1). Simple effect tests showed that compared with soccer athletes, non-athletes reproduced more attacking players (0.58 vs. 0.37, $p = .011$) but not defending players (0.61 vs. 0.58, $p = .808$) based on false memory, and there was a trend that non-athletes guessed more defending players (2.04 vs. 1.63, $p = .082$) but not attacking players (1.46 vs. 1.42, $p = .796$) (see Figure 2). On the RE of guesses, there was a significant main effect of participant group, $F(1,67) = 11.040$, $p = .001$, $\eta_p^2 = 0.141$, showing that the soccer athletes' RE of

Table 1. Results of ANOVAs on the number and radio error (RE) of accurate memory, false memory, and guess.

Measure	Effect	*F*	*p*	η_p^2
Number of accurate memory	Participant Group	4.980	.029*	0.069
	Element	27.448	<.001***	0.291
	Participant Group × Element	1.069	.305	0.016
Number of false memory	Participant Group	2.215	.141	0.032
	Element	11.272	.001**	0.144
	Participant Group × Element	7.186	.009**	0.097
Number of guess	Participant Group	1.572	.214	0.023
	Element	23.570	<.001***	0.260
	Participant Group × Element	4.991	.029*	0.069
RE of accurate memory	Participant Group	0.594	.444	0.009
	Element	0.276	.601	0.004
	Participant Group × Element	1.530	.220	0.022
RE of false memory	Participant Group	0.070	.792	0.001
	Element	2.644	.109	0.039
	Participant Group × Element	0. 602	.441	0.009
RE of guess	Participant Group	11.040	.001**	0.141
	Element	23.544	<.001***	0.260
	Participant Group × Element	1.913	.171	0.028

Note: * $p < .05$, ** $p < .01$, *** $p < .001$. The degree of freedom (*df*) of all the analyses was (1, 67).

the guesses was smaller than the non-athletes' (312.0 vs. 368.9). There was also a significant main effect of element, $F(1,67) = 23.544$, $p < .001$, $\eta_p^2 = 0.260$, showing that the RE of guessed players was smaller for defending players than attacking players (317.2 vs. 363.7). None of the other effect in these ANOVAs was significant.

Additionally, we calculated the RE of the ball. This has usually not been measured in previous pattern recall studies, though the ball location is critical in soccer scenarios. The results showed that the RE of the ball (90.1 and 90.5 for athletes and non-athletes, respectively) was comparable to that of the accurate memory of players (93.5 and 96.4 for athletes and non-athletes, respectively). Moreover, an independent *t*-test showed no significant difference in the RE of the ball between soccer athletes and non-athletes (90.1 vs. 90.5, $t(67) = 0.053$, $p = .958$).

General discussion

The present study developed an adapted pattern recall task and analytical algorithm, and thus examined both the quantity and quality of participants' memory and guess for player locations in complex soccer scenarios. The results showed that compared with non-athletes, one advantage of soccer athletes was that they maintained a greater number of players in accurate memory, while non-athletes falsely memorised more attacking players and tended to guess more defending players. Another advantage of soccer athletes was that their quality of guesses was higher than non-athletes, whereas their quality of memory was similar to non-athletes.

Quantity and quality of experts' memory for complex soccer scenarios

The two-stage pattern recall task allowed us to separate participants' memory from guesses, and our analyses further separated accurate memory from false memory. Thus, the present study was able to elucidate the authentic capacity for memorising player locations in complex soccer scenarios. Our findings revealed that soccer athletes were capable of accurately memorise about 8 players and the ball. This number is close to the classical capacity of short-term memory, which is 7 ± 2 (Miller, 1956). In contrast, the number is substantially larger than what was previously found in rugby, which was only 2.9 out of 6 players in the scenes (Sherwood et al., 2019a). This indicates that the settings used in the previous studies (Sherwood et al., 2019a, 2019b) may have led to an underestimate of the quantity of athletes' memory, and it is also possible that player locations in rugby may be more difficult to chunk and memorise than those in soccer. Additionally, rugby has a higher rate of concussion than soccer, which may have a negative impact on players' performance in the cognitive tasks (Koh et al., 2003). The results suggest that memory and pattern recall may exhibit sport-specific characteristics even within team ball sports, warranting targeted methods for exploration and comparison in research.

We also found that soccer athletes showed an expert advantage in the quantity of accurate memory over non-athletes. Plausibly, soccer athletes were able to adopt their knowledge to facilitate the chunking of individual players in the scenarios, so as to memorise a greater number of players (Chase & Simon, 1973; Sherwood et al., 2019b; Williams et al., 1993). Nevertheless, it is noteworthy that the difference between soccer athletes and non-athletes was not as pronounced as previously found in classical chess studies, where the memory capacity of chess masters, Class A player, and beginners doubled each other (16, 8, and 4, respectively) (Chase & Simon, 1973). In the present study, non-athletes were also able to maintain in accurate memory about 7 players and the ball. This may due to the difference between chess pattern recall and soccer pattern recall. In chess pattern recall, each piece has a distinct identity, and the participants need to memorise the identity as well as the location of each piece and then chunk the pieces by their relationships. In soccer pattern recall, the participants mainly need to memorise the locations of the players, in addition to their team identity (i.e., whether a player is an attacking player or a defending player), but not to memorise the identity of each player. In this case, the non-athletes may adopt some low-level information (such as jersey colour) to chunk the players, so that they also maintained a large quantity in accurate memory and did not differ substantially from athletes. Considering that in some scenarios the identity of each teammate or opponent in soccer may be critical, such as when playing with players of distinct physical or technical characteristics, future research may employ identity related tasks (Li et al., 2019; Oksama & Hyönä, 2008) to further investigate the expert advantages.

Interestingly, while soccer athletes demonstrated an advantage in memory quantity over non-athletes, there was no advantage in memory quality in complex scenarios. This is in contrast to previous studies on pattern recall for simple scenarios, which typically revealed difference in RE between experts and nonexperts (Ward & Williams, 2003; Williams et al., 1993). The results suggest that in complex soccer scenarios, memory quality may be less critical than memory quantity for players, that is, it may be more useful for players to maintain a large number of player locations in mind than to memorise them precisely. This warrants a shift in focus from solely assessing memory quality, as done conventionally, to encompassing the broader cognitive terrain required for pattern recall.

Guesses and false memory in complex soccer scenarios

In complex soccer scenarios, the number of objects exceeds the capacity of short-term memory, necessitating players to resort to guessing for some player locations. The present results showed that compared with soccer athletes, the non-athletes tended to guess more defending players, complimentary to the finding that non-athletes maintained fewer players in accurate memory. The results indicate that non-athletes were prioritising attacking players to be maintained in memory, whereas athletes were able to maintain the defending players as well.

Regarding the quality of guesses, the present results showed that athletes exhibited higher quality (i.e., smaller guessing RE) than non-athletes. This indicates that athletes may utilise their long-term working memory (LTWM) to support the guessing of player locations that are not maintained in short-term memory. LTWM is an account of working memory based on skilled use of storage in long-term memory (Ericsson & Kintsch, 1995). Pattern recall apparently encompasses both short-term memory and the supportive role of long-term working memory. The present results suggest that LTWM not only helps athletes to chunk individual players so as to memorise more players (Ericsson & Kintsch, 1995; Williams et al., 2006), but also helps to make more precise guesses.

Athletes' advantage did not reside in the precision of short-term memory representations, but in the precision of guessing underscored by LTWM.

Additionally, people may also make mistakes when they think they remember, leading to distorted or fabricated memories. The exploration of false memory, often overlooked in previous pattern recall research due to its perceived insignificance in simple scenarios, becomes pertinent in complex scenarios with heightened memory demands. In this context, our results revealed that athletes, compared to non-athletes, generated fewer instances of false memory concerning attacking players, which could potentially contribute to athletes making fewer errors in subsequent decision-making processes.

Attack and defence player locations in complex soccer scenarios

The present results also revealed differences in pattern recall for attacking and defending players in complex soccer scenarios. Previous research on basketball pattern recall found higher memory quality (i.e., smaller RE) for defending players than attacking players (Gorman et al., 2013). Yet the present study showed that in complex soccer scenarios, memory quality for defending players and attacking players was similar. Instead, when participants resorted to guessing, defending players were guessed with smaller RE compared to attacking players. This may due to that in complex soccer scenarios, the locations of defending players are more orderly than attacking players, so that some defending players' locations can be more precisely inferred from other players' locations even when not maintained in memory. Additionally, athletes also tended to make fewer guesses about defending players than the non-athletes did. The result indicates that non-athletes may more be more subjected to lose track of defending players when the number of players in the scene was overwhelming, whereas athletes were still capable of memorising the defending players while monitoring attacking players.

Potential implications for practice

The present study on soccer players' pattern recall in complex scenarios offers potential practical applications for player assessment and training. The performance of memory and guessing in the pattern recall may be used to distinguish between players at different skill levels or stages of development, and to assess their potential advantages and disadvantages in perceiving situations in soccer games. Coaches may integrate memory training for specific situations into training sessions to enhance players' perceptual-cognitive skills, potentially improving tactical strategies, team coordination and strategic decision-making in complex game scenarios on the field. Such training can also be adopted when players cannot practice on field, such as during injury recovery, so as to maintain or enhance cognitive performance.

Limitation and future directions

The present study acknowledges several limitations and identifies potential directions for future research. Firstly, further exploration into how soccer players' distinct roles on field impact pattern recall would be pertinent. Different roles may lead players to focus on specific aspects of situations, potentially resulting in preferential memorisation of certain elements and advantages in particular parts of scenarios. Secondly, it would be beneficial to introduce more diverse soccer scenarios, preferentially tailored to players' roles and specific perspectives on the field. While the current study focused on key moment in passing, investigating defensive scenarios is equally imperative. For instance, defenders need to recall their teammates' positions when facing away from them to effectively cover designated areas, whereas goalkeepers and central midfielders encounter the same situations from different field perspectives and with different task priorities in mind. Incorporating virtual reality to simulate realistic offensive and defensive scenarios from various perspectives may help to investigate these issues. Thirdly, a more nuanced examination of experts' advantages, including the intricacies of intuitive guessing in pattern recall of complex scenarios, warrants attention. Investigating how players leverage their knowledge to make informed guesses, and how these guesses interact with memory to facilitate situation assessment, could yield deeper insights through research. Fourthly, investigating the relationship between domain-specific memorisation and guessing skills in soccer scenarios and domain-general cognitive capabilities is crucial (Heisler et al., 2023). Incorporating standardised memory tests in future research would help mitigate differences among participants and elucidate the respective contributions of domain-specific and domain-general abilities. Lastly, comparative studies involving athletes from diverse sports would shed light on the generalizability of these findings. While the present study demonstrated soccer athletes' advantages over non-athletes, further investigations could explore whether these advantages are specific to soccer or generalise across athletic disciplines.

Conclusion

Soccer athletes can memories about eight players locations along with the ball, exhibiting advantages over nonathletes in quantity of memory and quality of guesses during pattern recall for complex soccer scenarios. These advantages may be underlined by soccer athletes' knowledge and long-term working memory, which facilitate the chunking of individual players to be maintained in short-term memory and the inferences about player locations beyond the capacity of short-term memory.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author.

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