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Optimizing Decision-Making in Soccer: Analyzing Visual Search Strategies Across Skill Levels

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Abstract

This study examines the impact of visual search features on decision-making among soccer players, specifically analyzing the different search strategies employed based on athletes' skill levels. The research aims to understand how athletes at varying levels use visual cues to enhance decision-making during gameplay. To achieve this, a comprehensive review of relevant literature from domestic and international databases was conducted, selecting studies based on predefined inclusion criteria to extract data and analyze the visual characteristics of athletes across skill levels. The findings reveal that high-level athletes exhibit faster reaction times, are better at extracting critical information from key areas of interest, and that their psychological state influences reaction time. High-level athletes possess response templates for sports scenarios, leading to shorter gaze durations, fewer fixations, and quicker gaze transitions. These athletes also show a more extensive eye movement range, which allows for the collection of more information and, through long-term training, enhances the efficiency of their information-processing strategies. Consequently, high-level athletes demonstrate optimized visual search strategies compared to novice players, resulting in more accurate and rational decision-making during gameplay. The study recommends further developing visual training programs to support novice athletes in improving their information processing and decision-making capabilities, which could ultimately bridge the gap between skill levels and enhance performance.

Keywords: *Information collection, Judgmental decision-making, Soccer players, Visual search*

A. Introduction

Soccer is a competitive and challenging sport that demands high skill levels and adaptability. In modern soccer games, athletes must perform actions such as receiving, passing, shooting, tackling, and controlling the ball, which requires quick, accurate decision-making in unpredictable game scenarios. To meet these demands, players must be able to visually gather relevant game information and read the game to make swift, appropriate decisions on the field. Visual search is how athletes quickly locate necessary information within complex sports scenarios and transform it into actionable insights (Li, 2021). The effectiveness of visual observation and the accuracy of judgmental decision-making are prerequisites for soccer players to execute tactical anticipation effectively. In sports scenarios, athletes search for critical information across a broad visual field, connecting the dynamics of the game with their actions to facilitate flexible decision-making (Wang, 2013).

Visual search characteristics are typically obtained by recording eye movement trajectories using eye-tracking instruments. Key eye movement indicators include the number of fixations, fixation duration, reaction time, focus points, areas of interest, and saccadic (eye-hopping) distances. Studies have shown significant differences in visual search characteristics between athletes of different skill levels (Liao, 2007; Huang & Qi, 2014; Roel et al., 2007). However,

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some research has reported no significant differences in these characteristics across different levels of athletic expertise, with conflicting results potentially arising from inconsistent definitions of athletic skill levels, variations in experimental controls, inconsistent application of stimuli, and differing experimental materials. To address these inconsistencies, this study aims to evaluate the visual search characteristics of soccer players using a systematic review and meta-analysis, which synthesizes quantitatively similar findings to minimize the influence of these variables and provide more reliable results (Li et al., 2023; Zhi & Zhang, 2014; V., 2011).

This study reviews previous research on the "visual search characteristics" of "soccer players," consolidates the results of existing studies, and proposes two hypotheses aligned with the study's objectives: (1) High-level athletes are more capable of making accurate judgmental choices in game situations, and (2) low-level soccer players can significantly improve reaction time, fixation frequency, and fixation duration through structured visual training. The findings of this study are expected to be valuable for soccer coaches, offering targeted guidance on technical and tactical training and for players striving to achieve peak performance.

Optimal decision-making is crucial in soccer, where players must interpret fast-moving visual cues to make effective, strategic choices under high pressure. Skilled soccer players often demonstrate superior visual search strategies, allowing them to identify relevant patterns, anticipate opponent movements, and execute precise responses. These skills, built through experience and targeted training, enable expert players to focus on critical visual stimuli while disregarding irrelevant information (Roca et al., 2011). By analyzing visual search behaviors across skill levels, researchers can uncover the cognitive and perceptual processes that set expert players apart from novices, ultimately informing training programs that could help less experienced players improve their decision-making abilities. Such insights are essential for enhancing individual performance and strengthening team tactics and cohesion, as rapid and accurate decisions impact the outcome of competitive matches (Li et al., 2023).

The urgency of this study lies in the rising demand for advanced cognitive training techniques in soccer. Visual search training can help bridge the gap between novice and advanced players, offering teams and players a competitive edge in both professional and developmental settings. In an increasingly data-driven sports industry, where analyzing players' cognitive and perceptual skills is gaining importance, understanding visual search strategies is key. These insights could lead to customized training programs that accelerate the cognitive development of emerging players, enhancing their resilience and effectiveness in high-pressure situations. Thus, studying visual search strategies in soccer contributes to the science of sports cognition and addresses a practical need for optimized decision-making to boost overall team performance and competitive success.

B. Methods

This study employs a systematic literature review and meta-analysis to identify and understand key trends in research on eye movement and tactical decision-making among soccer players. Data for the study were obtained from multiple databases, including Wikipedia, Wanfang Database, CNKI China Knowledge Network, and Web of Science, with a publication date limit of February 2024. Keywords used in the search include "visual search features," "soccer player," "tactical decision," "tactical judgment," "eye movement trajectory," "behavioral decision-making," "Soccer Penalty Kick," and "Eye Movement." The search focused on articles with experimental components that involved soccer players as primary research subjects.

The research procedure consists of several stages, beginning with a literature search using the specified keywords. The next stage is literature screening based on inclusion

criteria, which require that studies involve soccer players and include measurement variables such as reaction time, gaze duration, number of gazes, areas of interest, eye movement distance, and fixation points. Additionally, the screening considers the skill level of the players, categorized into level 1 and level 2 players, and assesses them based on fitness and playing experience. Only studies meeting these criteria proceed to the further analysis stage.

Data collection for this study is conducted through a systematic literature review and data extraction. Each study that meets the inclusion criteria is analyzed using a standardized extraction form that captures data such as the skill level of the soccer players, experimental design, measurement methods (e.g., eye movement tracking tools), and the variables and results reported (e.g., reaction time, gaze duration, eye movement distance, and other related metrics). This approach ensures consistent data organization from various studies, facilitating descriptive and quantitative analysis.

Data analysis in this study is divided into two main stages: descriptive analysis and meta-analysis. Descriptive analysis involves calculating the frequency and distribution of key variables within the literature and identifying general trends in research methods, including data collection tools and analytical procedures. If adequate quantitative data are available, meta-analysis is conducted to evaluate the effects of specific variables, such as the impact of players' skill levels on reaction time or eye movement distance. Through this method, the study aims to provide deeper insights into eye movement patterns and decision-making processes among soccer players and reveal how player skill levels may influence these processes.

C. Findings and Discussion

1. Reaction Time

According to the previous research literature, reaction time is one of the performance characteristics of visual search, and high-level athletes' reaction time is more rapid in different sports scenes. Tingting Zhang measured the reaction and judgment of the signals between athletes of different levels in the reaction flexibility test through comparative experiments; according to the results of Pearson's correlation test, the level of soccer players and reaction time showed a significant negative correlation (e.g., r=−0.385, P=0.009r = -0.385, P = 0.009r=−0.385, P=0.009; r=−0.525, P<0.001, r =-0.525, P < 0.001r=−0.525, P<0.001), indicating that the higher the athletic level of soccer players, the faster their reaction time (Zhang et al., 2022). The higher the athletic level of the athlete, the shorter the time required when reacting. Furthermore, reaction time is influenced by athletes' emotional states; athletes in a passive-negative state require more focus to complete target tasks, which increases their reaction time, whereas positive emotional states require a shorter reaction time (Zhang, 2022). Research by Yucong Zhang further supports this, showing that positive emotional subjects have faster reaction times than negative emotional subjects, and individuals with high emotion regulation self-efficacy respond more quickly than those with lower self-efficacy when reacting to emotional faces (Zhang, 2021; Zhang et al., 2020).

In summary, the higher the sports level of soccer players, the lower the mental load, and in a positive emotional state, the shorter the reaction time, enabling them to make correct and reasonable judgments and decisions on the field.

2. Gaze time

In the context of tactical decision-making, high-level soccer players exhibit shorter gaze times and a more remarkable ability to gather information to make effective tactical decisions

efficiently. Shi Peng et al. conducted a comparative experiment involving soccer players of varying skill levels (n=72), divided into expert and novice groups. The study's results indicated that the expert group had fewer gaze counts than the novice group (t=-2.331, p=0.021; Shi et al., 2023). Additionally, a study on the visual search characteristics of soccer players during 1-on-1 defense found that high-level players exhibited shorter average gaze times and fewer gaze frequencies during these scenarios (Wang & Ren, 2021). Research from overseas on visual search characteristics revealed that high-level soccer players have shorter gaze times when observing markers, more gaze points, and quicker gaze transitions (Roca et al., 2011). However, some studies have questioned these findings, suggesting no significant differences between expert and novice athletes' gaze duration, gaze count, gaze points, and search smoothness (Li, 2016).

The present study concludes that high-level soccer players generally demonstrate shorter gaze times, fewer gaze counts, more gaze points, and quicker gaze transitions when processing game information in sports scenarios.

3. Eye-hopping distance

As one of the visual search features, eye-hopping distance reflects the spatial characteristics of visual search. It mainly refers to the rapid movement of the eyeballs from one area to another, a phenomenon known as “eye hopping” (Xu, 2023). The size of the eye-hopping distance reflects how much information the athlete acquires, and the larger the distance, the more information the athlete collects. Some studies have concluded that the difference in eye-hop distance between high-level and novice athletes is insignificant (Lu & Shi, 2020). However, some studies also state that high-level athletes have better eye-hop distances than novice athletes (Liao et al., 2009; Yuan, 2023). The reason for such conflicting studies may be that high-level athletes with extensive sports experience can efficiently extract critical information and require less gaze to acquire the information. Different stimulus materials also significantly affect the distance of the athlete's eye jump, and high-level athletes in collective sports have a short gaze time. Moreover, high-level and novice athletes process and select critical information differently, leading to significant differences in eye-hopping distance.

Different sports, rich or poor sports experience, different types of stimulus materials, athletes' psychological state, and information processing methods are the reasons for the differences in eye-hop distance. Soccer players must increase the eye-jump distance to obtain adequate game information, providing the conditions for the next judgment decision.

4. Zone of Interest

By comparing the differences in the cognitive levels of different tennis players in the specialties of serve technique, cutting technique, forehand technique, interception technique, and high-pressure technique, Hongyuan Huang and Yang Pengfei (2013) found differences in the way information is processed among athletes at different skill levels. High-level athletes direct their initial attention to critical areas of interest, minimizing focus on irrelevant information, while novice athletes primarily focus on non-essential areas of interest (Huang & Yang, 2013). Foreign scholar Vickers (1996) studied basketball players in the context of free throws and observed that advanced players maintained longer attention in areas critical to performance, demonstrating a higher relevance in attention allocation toward essential information (Vickers, 1996). Other studies have shown that high-level athletes have significantly more fixation points in areas of interest than novices, allowing them to gather more information and process it more thoroughly (Xiong, 2021). Additionally, Ishibashi et al. (2010) recorded the visual search behaviors of basketball players at different levels in a free-throw shooting situation using an eye-tracking device, revealing that high-level and novice athletes differed in their focus on areas of interest, reaction times, and overall accuracy (Ishibashi et al., 2010).

Current domestic research has yet to focus on the study of soccer players' areas of interest; however, findings from previous studies suggest that high-level athletes' areas of interest are characterized by longer fixation times, greater access to critical information, optimized information processing, and more concentrated attention allocation in crucial areas. It is, therefore, plausible to infer that similar results may also apply to soccer players.

5. Visual Search Strategies for Judgmental decision-making in Soccer Players

Studies have used eye-tracking technology to analyze the visual search characteristics of athletes, coaches, and referees in specialized and non-specialized scenarios across various sports, revealing that distinct visual search strategies and attentional resource allocations impact athletes' behavioral performance. High-level athletes, for instance, demonstrate faster visual information processing than novice athletes (Feng & Zhou, 2011; Xiong, 2021). Obtaining adequate information is essential for soccer players to make on-field judgment decisions. In fast, dynamic, and complex sports contexts, the visual search characteristics of soccer players are crucial for gaining a comprehensive understanding of the game, perceiving shifts in the field, and gathering sufficient information to make optimal tactical decisions (Shi et al., 2023). High-level soccer players, in particular, can make more accurate and reasonable decisions, outperforming novices in searching, extracting, and processing field information. Their advanced performance is attributed to extensive game experience, prolonged training, and a solid technical and tactical knowledge foundation, enabling them to have adequate channels for information collection, efficient decision-making processes, and heightened sensitivity to stimuli in the sports environment. Consequently, elite athletes can adjust attentional distribution effectively in response to game dynamics, read the game to search for crucial information, and make efficient, well-informed judgments (Lu & Shi, 2020).

In contrast, the rapid pace of play poses significant challenges for novice athletes, who often struggle to perceive game nuances and adjust strategies promptly. Novices require extended viewing time of rapidly shifting scene information and have longer reaction times for judgments, necessitating more time to gather sufficient game information. Unlike high-level athletes, novices face difficulty identifying critical areas for timely decision-making, which increases their eye movement distance. This extended visual search range demands more excellent attentional resources for identifying vital game information, leading to a cascade of difficulties in decision-making effectiveness (Zhang et al., 2022; Wang & Ren, 2021). Novice athletes also lack extensive competitive experience and sufficient training time, resulting in limited technical and tactical skill development and insufficient situational awareness. Without these "response templates," they must engage in a stimulus-driven visual search strategy, relying heavily on conscious attention to locate pertinent game information, ultimately hindering their decision-making efficiency (Ishibashi et al., 2010; Vickers, 1996).

6. The specific performance of visual search characteristics of soccer players' judgment and decision-making

Specialized high-level athletes' visual search abilities are more advantageous, specifically demonstrated through a more stable and effective visual search strategy, extensive information search breadth, a wide field of vision, and high information processing efficiency. These athletes also exhibit fast decision-making reaction speeds and high accuracy (Sha, 2022; Shi et al., 2023). High-level athletes have a wealth of experience in competition and sports training, which enhances their information-processing abilities, making them more effective and accurate. This expertise, coupled with rich technical and tactical reserves and cognitive enhancements, allows high-level athletes to quickly extract relevant information during gameplay, reduce reaction times, and improve decision-making efficiency. The increased distance in eye movements enables athletes to gather more information from the scene. However, this increase in information requires greater focus and efficient processing to avoid interference from irrelevant

data. Novice athletes without systematic visual training often struggle with essential judgments, such as recognizing the ball's rotation, predicting the trajectory of a soccer ball in motion, identifying the positioning of opponents and teammates, and determining the landing point and direction of incoming balls. Due to the lack of relevant technical and tactical training, novice athletes do not form rapid responses to critical situational stimuli. This gap in experience leads them to search for information more frequently and react more often to the information they collect, resulting in less efficient decision-making (Sha, 2022; Shi et al., 2023).

This study notes that the amount of quantitative data on visual search in athletes is relatively tiny compared to computerized quantification studies. Some findings are inconsistent, indicating a need for further exploration in future studies. Additionally, the influence of specific roles, tasks, and positions among soccer players may lead to variations in visual search characteristics depending on the player's duties. Future research could optimize experimental designs by refining sports material stimuli, adding player position variables, and seeking methods to provide practical advice on decision-making skills for soccer players. Given the study's constraints, this research used textual data, books, and publications as material, which limited its ability to replicate real-time, live-action scenes. Consequently, the study's ecological validity was lower than ideal.

D. Conclusion

Firstly, high-level athletes show shorter reaction times in sports scenarios and shorter reaction times as they gain more experience in the game. High-level athletes have fewer gazes, more gaze points, and faster gaze transitions than novice athletes. Secondly, novice athletes gaze less on the area of interest, have less access to critical information, and need to mobilize more attention to process the data, resulting in less efficient judgmental decision-making about the sports scenario. Finally, the increase in eye hopping distance increases the load of information athletes collect. For new high-level athletes, their training over a long period will increase the efficiency of information processing for high-level athletes.

It is recommended that novice athletes increase visual training in the process of sports training to improve their perceptual ability and the ability to capture essential information. Secondly, they should enhance their exceptional cognitive level, generate response templates for corresponding sports scenes, and improve the efficiency of clinical judgment and decision-making. Finally, the athlete's psychological state also affects the collection and processing of information, and attention should be paid to the simulation of different sports scenarios in the actual training for real practice to accumulate sports experience and enhance visual search at the same time.

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