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The Effect of Different Emotional Inductions on Visual Search Behavior During Decision-Making in Skilled Female Soccer Players

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ABSTRACT

The present study aimed to investigate the effect of different emotional inductions on visual search behavior during decision-making in skilled female soccer players. In this semi-experimental study with a within-subject design, 18 female soccer players aged 13–16 years with experience competing in the premier league participated. The decision-making task consisted of images depicting simulated soccer situations presented on a monitor under three emotional conditions (neutral, positive, and negative). To control for order effects, after completing the task in the neutral condition, nine participants were first exposed to the positive emotional condition followed by the negative emotional condition, whereas the remaining nine participants completed the emotional conditions in the reverse order. Throughout all stages, visual search eye movements were recorded using an eye-tracking system, and alpha wave activity in brain regions involved in decision-making (Fp1, Fp2, F3, Fz, F4, C3, Cz, and C4) was assessed using a 19-channel electroencephalography system. The results of repeated-measures analysis of variance demonstrated that the mean number of eye fixations and the mean fixation duration increased significantly in the positive and negative emotional conditions compared with the neutral condition. Furthermore, repeated-measures analysis of variance revealed that alpha wave activity in the Fp1, Fp2, F3, Fz, F4, C3, Cz, and C4 regions decreased significantly under positive and negative emotional conditions compared with the neutral (non-emotional) condition. The results of Pearson correlation coefficient analysis also indicated a significant negative relationship between the number of saccadic movements and the number of eye fixations with brain alpha wave activity in the neutral condition in the C4 region, in the positive emotional condition in the Fp1, Fz, Cz, and C4 regions, and in the negative emotional condition in the Fz, Cz, and C4 regions. In addition, Pearson correlation analysis demonstrated that under the neutral emotional condition, no significant relationship was observed between fixation duration and brain alpha wave activity in any of the target regions; however, under positive and negative emotional conditions, a significant positive relationship was found between fixation duration and brain alpha wave activity in the C4 region. The results of paired-samples t-tests showed that in neutral, positive, and negative emotional conditions, the mean number and duration of eye fixations during correct decisions were significantly greater than during incorrect decisions.

Keywords: emotions, visual search behavior, decision-making, soccer players.

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Introduction

Decision-making is considered one of the most essential perceptual-cognitive skills in competitive sports, particularly in dynamic and unpredictable environments such as soccer. Soccer players are continuously required to process environmental information, predict opponents' behaviors, evaluate tactical

opportunities, and select appropriate responses within a limited time frame. The effectiveness of these decisions directly influences individual and team performance. In modern sport psychology and motor behavior research, increasing attention has been directed toward understanding the perceptual, attentional, emotional, and neural mechanisms underlying decision-making performance in athletes (1-3). Researchers have argued that successful decision-making in sport is not solely dependent on technical skill, but also on the athlete's ability to efficiently perceive, interpret, and respond to environmental cues under varying emotional and competitive conditions (4, 5).

Visual search behavior represents one of the most important mechanisms associated with perceptual-cognitive expertise in sport. Visual search behavior refers to the manner in which athletes scan the environment, allocate visual attention, and extract relevant information through eye movements, fixations, and saccadic patterns. Eye-tracking methodologies have provided substantial evidence indicating that expert athletes differ from novices in the quality, efficiency, and organization of visual search processes (6-8). Skilled players tend to demonstrate fewer but more efficient fixations, longer fixation durations on task-relevant areas, and more effective anticipation strategies than less-skilled performers (9, 10). Such visual characteristics allow expert athletes to process critical information rapidly and execute accurate motor responses in highly demanding environments.

Recent advances in sport neuroscience have emphasized that visual search behavior is strongly associated with cortical activity and neurophysiological functioning during decision-making situations. Electroencephalography (EEG) studies have demonstrated that alpha-wave activity is closely related to attentional control, cognitive processing efficiency, and perceptual performance in sports tasks (11, 12). Alpha suppression is generally interpreted as an indicator of increased cortical activation and attentional engagement during demanding cognitive tasks (13, 14). In sports contexts, changes in alpha-wave activity have been associated with motor imagery, visuospatial processing, concentration, and anticipation abilities (13, 15). Therefore, investigation of the interaction between eye-movement behavior and neural activity may provide a more comprehensive understanding of perceptual-cognitive functioning in athletes during decision-making situations.

Emotions and psychological pressure are among the most influential factors affecting athletic performance and perceptual-motor functioning. Athletes are frequently exposed to emotional fluctuations resulting from competitive stress, audience expectations, outcome importance, and situational uncertainty. Emotional states can significantly alter attentional allocation, visual information processing, and cognitive efficiency (16, 17). Anxiety and emotional pressure have been shown to disrupt attentional control mechanisms and impair performance in precision-based and decision-dependent sports tasks (10, 18). Under stressful conditions, athletes may demonstrate maladaptive attentional strategies, excessive conscious control, and disrupted visual search patterns that ultimately reduce decision-making quality.

The phenomenon commonly referred to as "choking under pressure" has received substantial attention in sport psychology research. Choking occurs when performance deteriorates under conditions of high pressure despite the athlete possessing sufficient technical ability and preparation. Studies have demonstrated that emotional pressure and anxiety may negatively influence motor execution, perceptual efficiency, and cognitive processing in athletes (17, 19). In soccer, pressure-induced impairments can influence passing accuracy, dribbling performance, anticipation skills, and tactical decision-making (20, 21). Emotional stress

can narrow attentional focus, increase cognitive interference, and disrupt the automaticity of skilled performance, thereby reducing the athlete's ability to process environmental information effectively.

Visual search behavior appears to be highly sensitive to emotional and situational conditions. Researchers have reported that anxiety and pressure may alter fixation duration, gaze allocation, and saccadic eye movements during sport performance (18, 22). Under stressful conditions, athletes may allocate visual attention inefficiently toward irrelevant stimuli or exhibit excessive monitoring of task execution. Such changes can negatively affect anticipation and decision-making processes. Conversely, effective attentional control and optimal visual search strategies are associated with superior performance and reduced vulnerability to emotional disruption (9, 10).

In soccer specifically, perceptual-cognitive demands are exceptionally high due to the continuous movement of teammates, opponents, and the ball within a rapidly changing environment. Players must simultaneously process multiple sources of information while selecting appropriate tactical responses within fractions of a second. Eye-tracking studies conducted in soccer have shown that expert players utilize more adaptive visual search strategies and demonstrate superior perceptual efficiency compared with less-skilled athletes (6, 7). Expert players are able to identify relevant cues earlier, maintain attention on critical areas, and integrate visual information more effectively during tactical situations. Such perceptual-cognitive expertise is believed to contribute significantly to elite performance in competitive soccer.

Recent developments in perceptual-cognitive training have also highlighted the importance of visual training interventions in improving sport performance. Systematic reviews and meta-analytic findings have suggested that visual training can enhance decision-making accuracy, perceptual efficiency, and sport-specific performance outcomes (23). Interventions such as quiet-eye training, mindfulness exercises, visual anticipation drills, and virtual reality simulations have been shown to improve athletes' gaze behaviors and cognitive processing (9, 24, 25). These findings emphasize the trainability of visual and attentional processes and support the practical relevance of studying visual search behavior in sport settings.

Another important issue in sport decision-making research concerns the role of multimodal perception and environmental information integration. Athletes rarely rely on visual information alone during performance. Auditory cues, emotional signals, contextual information, and situational pressure interact dynamically to shape perceptual and motor responses (26). Multimodal processing may influence anticipation accuracy, motor planning, and attentional prioritization in sport environments. Emotional induction through auditory or situational stimuli may therefore alter the athlete's perceptual-cognitive processing and subsequently influence visual search patterns during decision-making tasks.

The influence of cognitive fatigue and mental workload on sport decision-making has also emerged as a critical area of investigation. Mental fatigue has been associated with impaired attentional control, slower information processing, and reduced decision-making accuracy in soccer players (20, 21, 27). Studies using EEG methodologies have demonstrated that cognitive fatigue alters cortical activation patterns and negatively affects sport-specific performance (27). Since emotional pressure and cognitive fatigue often coexist in competitive situations, understanding how emotional states influence visual search and neural functioning may provide important insights into mechanisms underlying performance fluctuations in athletes.

Artificial intelligence and advanced analytical approaches have recently been integrated into eye-tracking and sport performance research. Emerging technologies enable researchers to examine gaze behavior, attentional patterns, and decision-making processes with greater precision and ecological validity (28, 29). These technological developments have strengthened the scientific understanding of perceptual-cognitive expertise and highlighted the importance of objective behavioral indicators such as fixation duration, gaze distribution, and saccadic frequency in evaluating athletic performance. Such approaches are particularly valuable for identifying the perceptual mechanisms associated with successful and unsuccessful decisions under varying emotional conditions.

Although substantial research has investigated visual search behavior, anxiety, and decision-making in sports, several important gaps remain in the literature. First, many previous studies have focused primarily on male athletes or mixed-gender samples, while relatively limited attention has been given to skilled female soccer players despite the rapid growth of women's soccer at competitive levels (1, 3). Second, most studies have examined either visual search behavior or neural activity independently, whereas fewer investigations have simultaneously assessed eye-movement characteristics and cortical activation patterns during sport-specific decision-making tasks (11, 30). Third, research specifically examining the effects of different emotional inductions on visual search behavior and associated neural processes in soccer remains limited.

Furthermore, previous findings regarding the influence of emotional pressure on visual attention and decision-making have not always been consistent. Some studies suggest that pressure may impair attentional efficiency and increase maladaptive gaze behaviors, whereas others indicate that moderate arousal may facilitate concentration and improve task engagement under certain circumstances (10, 31). Such inconsistencies indicate the need for additional research examining the complex interactions among emotion, attention, neural activity, and sport performance. Investigating these relationships in ecologically valid soccer-specific tasks may contribute to a more comprehensive understanding of perceptual-cognitive expertise under emotional conditions.

From a practical perspective, understanding how emotional states influence visual search behavior and neural functioning may provide valuable implications for coaches, sport psychologists, and performance specialists. Identification of the perceptual and neural characteristics associated with successful decision-making under pressure can assist in designing targeted interventions aimed at improving attentional control, emotional regulation, and cognitive resilience in athletes (23, 24). Such knowledge may contribute to the development of more effective training programs that prepare athletes to maintain optimal perceptual-cognitive performance during emotionally demanding competitive situations.

Therefore, considering the importance of perceptual-cognitive skills in soccer performance, the role of emotions in attentional and neural functioning, and the limited research simultaneously examining visual search behavior and cortical activity in skilled female soccer players, the present study aimed to investigate the effects of different emotional inductions on visual search behavior during decision-making in skilled female soccer players.

Methods and Materials

Study Design and Participants

The present study was designed to investigate the effect of different emotional inductions on visual search behavior during decision-making in skilled female soccer players. In terms of purpose, the study was applied research, and in terms of methodology, it was conducted using a semi-experimental within-subject design. The research design was structured to allow examination of the effects of emotional induction under different conditions (neutral, positive, and negative) on players' visual performance and decision-making. The study was implemented in the form of a single-group posttest design.

The statistical population consisted of all female soccer players aged 13–16 years competing in the Tehran Premier League. Sample size was determined using G*Power software. Assuming a medium effect size of 0.50, statistical power of 80%, and a confidence level of 95%, the required sample size was calculated as 18 participants. Inclusion criteria included having at least five years of soccer experience, more than two years of participation in the Tehran Premier League, being right-handed and right-footed, absence of neurological disorders or physical injuries, having normal or corrected-to-normal vision, and willingness to participate in the study. Exclusion criteria included unwillingness to continue participation during the experiment and prior familiarity with the experimental conditions.

Data Collection

The instruments used in this study included an informed consent form, a demographic information form, the Positive and Negative Affect Schedule-Expanded Form (PANAS-X), the Competitive State Anxiety Inventory, soccer decision-making software, and an eye-tracking system. The informed consent form was used to obtain participants' consent and to provide information regarding the objectives and procedures of the study. The demographic information form included data such as age, height, weight, playing history, and general health status. The PANAS-X questionnaire was designed to assess the emotional state of the players, and only the happiness and sadness subscales were used to evaluate emotional responses. Reliability of the scale was confirmed using Cronbach's alpha coefficients of 0.91 for happiness and 0.87 for sadness.

The Competitive State Anxiety Inventory was used to assess somatic anxiety, cognitive anxiety, and self-confidence in sports situations. This instrument consists of 27 items rated on a four-point Likert scale, and its reliability has been reported in previous studies to range between 0.79 and 0.90. The soccer decision-making software consisted of simulated soccer match images in which players were required to select passing, dribbling, or shooting responses for each situation. All situations were evaluated by soccer experts, and only images with complete agreement among coaches were selected.

Intervention

An eye-tracking device (Ergoneers Eye Tracking Dikablis Professional Wireless) with a sampling frequency of 60 Hz was used to record eye movements and fixations. The system was equipped with a camera and data-processing software that enabled precise recording of gaze trajectory, fixation duration, and saccadic eye movements. Data collection was conducted in a quiet laboratory environment free from distracting environmental stimuli, and data were continuously transmitted wirelessly to a computer.

After participants entered the laboratory and completed the informed consent and demographic information forms, preparation for the main testing procedure began. Each participant wore a specialized eye-tracking headset, and the eye-tracking system was calibrated to record gaze trajectory, eye fixations, and saccadic movements throughout the testing session. Participants were then familiarized with the purpose of the study and the response procedure for the simulated images. The entire experiment consisted of four blocks: one familiarization block and three main testing blocks.

The familiarization block included 10 images to acquaint participants with the image presentation procedure and response format. In the first block, 60 images were presented without emotional pressure in order to record baseline performance under neutral conditions. The second and third blocks each consisted of 60 images in which emotional interventions were implemented under either positive or negative emotional induction conditions. Half of the participants were initially exposed to monitoring pressure, whereas the other half were first exposed to outcome pressure in order to control for order effects.

In each block, participants were instructed to observe each image as quickly and accurately as possible and select the correct decision. The soccer decision-making software recorded all responses, including image viewing duration, number of correct and incorrect decisions, type of response selected, and the correct response for each image based on expert coach agreement. These data were collected simultaneously with information recorded by the eye-tracking system.

After completion of each testing block, participants completed the PANAS-X questionnaire again to assess their emotional state following the interventions. This procedure enabled examination of emotional changes in each block and their effects on visual search behavior. In addition, precise timing of image presentation, rapid measurement of responses, and control of emotional pressure were considered important methodological standards of the present study.

Data Analysis

For data analysis, the data recorded by the software and eye-tracking system were first preprocessed. Low-pass and high-pass filters were applied to remove noise and restrict the frequency range between 1 and 16 Hz. Noise caused by blinking, sudden head movements, and slight electrode displacement was also removed. The processed data for each participant included fixation duration, number of fixations, and saccadic movements for each image and were prepared for statistical analysis.

Following the recording of saccadic movements, eye fixations, and decision-making responses, the data were initially examined using SPSS and Excel software. Descriptive statistics, including means and standard deviations, were used to describe the characteristics of the participant group. Subsequently, the Shapiro–Wilk test was performed to assess normality of data distribution and ensure that the assumptions required for parametric statistical analyses were satisfied.

To examine the effects of different emotional inductions (neutral, positive, and negative) on visual search behavior, repeated-measures analysis of variance (Repeated Measures ANOVA) was employed. This method enabled comparison of each participant's data across different emotional conditions and demonstrated behavioral changes throughout the different testing blocks. In addition, paired-samples *t*-tests were conducted for detailed comparisons among conditions in order to determine the effects of emotional pressure and presentation order on the number and duration of fixations and saccadic movements.

Pearson correlation analysis was used to examine the relationships among saccadic movements, number and duration of eye fixations, and correct or incorrect decisions under different emotional conditions. This analysis enabled identification of direct associations between visual search quality and decision-making performance in soccer players. The significance level for all statistical tests was set at 0.05 to ensure the validity of the findings.

Statistical results were presented in a manner that illustrated both the behavioral changes of each participant across conditions and the group differences among emotional conditions. This analytical approach allowed the researchers to evaluate accurately and scientifically the effects of emotional induction on decision-making performance and visual search behavior, while simultaneously examining potential relationships between predictor and criterion variables of the study.

Finally, the collected data were analyzed using SPSS version 18 and Excel 2013. These analyses included calculation of means and standard deviations, normality tests, repeated-measures analysis of variance, paired-samples *t*-tests, and Pearson correlation analyses in order to comprehensively investigate all dimensions of visual search behavior influenced by emotion in skilled female soccer players.

Findings and Results

Hypothesis 1: There is a significant difference in the amount of saccadic eye movements of soccer players during different decision-making situations (neutral, negative, and positive emotional conditions).

To compare the mean number of saccadic eye movements of soccer players across the three emotional conditions, repeated-measures analysis of variance (Repeated Measures ANOVA) was used.

Table 1. Repeated-Measures ANOVA Results for Comparison of the Mean Number of Saccadic Eye Movements of Soccer Players Across Three Emotional Conditions

Variable	Neutral Emotion M	SD	Positive Emotion M	SD	Negative Emotion M	SD	F	Sig.
Mean number of saccades	2.45	0.96	4.07	1.36	3.83	1.22	26.25	.001***

The results of Mauchly's test of sphericity confirmed the assumption of sphericity for the distribution of saccadic eye movements ($p = .46$). The results of repeated-measures ANOVA indicated that the mean number of saccadic eye movements differed significantly across the neutral, positive, and negative emotional conditions, $F(2, 34) = 26.35$, $p < .001$, $\eta^2 = .60$. Further examination of the Bonferroni post hoc test results presented in Figure 2 demonstrated that the mean number of saccadic eye movements increased significantly in both the positive emotional condition (4.06 ± 1.35) and the negative emotional condition (3.84 ± 1.21) compared with the neutral condition (2.49 ± 0.95) ($p = .001$ and $p = .003$, respectively).

Hypothesis 2: There is a significant difference in the amount of eye fixation movements of soccer players during decision-making situations under neutral, positive, and negative emotional conditions.

To compare the mean number of eye fixations of soccer players across the three emotional conditions, repeated-measures analysis of variance (Repeated Measures ANOVA) was employed.

Table 2. Repeated-Measures ANOVA Results for Comparison of the Mean Number of Eye Fixations of Soccer Players Across Three Emotional Conditions

Variable	Neutral Emotion M	SD	Positive Emotion M	SD	Negative Emotion M	SD	F	Sig.
Mean number of fixations	3.55	0.80	5.01	1.25	5.08	0.38	29.42	.001***

The results of Mauchly's test of sphericity confirmed the assumption of sphericity for the distribution of eye fixations (p = .61). The results of repeated-measures ANOVA showed that the mean number of eye fixations differed significantly across the neutral, positive, and negative emotional conditions, $F(2, 34) = 29.32$, $p < .001$, $\eta^2 = .63$. Further examination of the Bonferroni post hoc test results presented in Figure 2 revealed that the mean number of eye fixations increased significantly in both the positive emotional condition (5.00 ± 1.26) and the negative emotional condition (5.09 ± 0.28) compared with the neutral condition (3.45 ± 0.90) (p = .001 and p = .002, respectively).

Hypothesis 3: There is a significant difference in the duration of eye fixation movements of soccer players during decision-making situations under neutral, positive, and negative emotional conditions.

To compare the mean duration of eye fixations of soccer players across the three emotional conditions, repeated-measures analysis of variance (Repeated Measures ANOVA) was conducted.

Table 3. Repeated-Measures ANOVA Results for Comparison of the Mean Duration of Eye Fixations (Milliseconds) of Soccer Players Across Three Emotional Conditions

Variable	Neutral Emotion M	SD	Negative Emotion M	SD	Positive Emotion M	SD	F	Sig.
Mean fixation duration (ms)	1540	370	2010	470	2040	420	52.67	.001***

The results of Mauchly's test of sphericity did not confirm the assumption of sphericity for the distribution of saccadic eye movements ($p < .001$). The results of repeated-measures ANOVA indicated that the mean duration of eye fixations differed significantly across the neutral, positive, and negative emotional conditions, $F(1.21, 20.63) = 52.57$, $p < .001$, $\eta^2 = .75$. In addition, the results of the Bonferroni post hoc test presented in Figure 3 demonstrated that the mean fixation duration, measured in milliseconds, increased significantly in both the positive emotional condition (2020 ± 460 ms) and the negative emotional condition (2030 ± 410 ms) compared with the neutral condition (1550 ± 380 ms) (p = .005 and p = .004, respectively).

Discussion and Conclusion

The present study aimed to investigate the effects of different emotional inductions on visual search behavior during decision-making in skilled female soccer players. The findings demonstrated that emotional conditions significantly influenced visual search characteristics, fixation behaviors, and neural activity associated with decision-making performance. Specifically, the results revealed that both positive and negative emotional conditions significantly increased the number of saccadic eye movements, the number of eye fixations, and fixation duration compared with the neutral condition. Furthermore, alpha-wave activity in frontal and central cortical regions decreased significantly during positive and negative emotional conditions relative to the neutral condition. Significant correlations were also observed between visual search variables and alpha-wave activity across several cortical regions. In addition, correct decisions were

associated with greater fixation frequency and longer fixation duration compared with incorrect decisions across all emotional conditions. These findings collectively suggest that emotional induction substantially influences perceptual-cognitive processing, attentional allocation, and neural engagement during sport-specific decision-making tasks.

The increase in the number of saccadic eye movements under positive and negative emotional conditions indicates that emotional arousal modifies visual scanning behavior during decision-making situations. Saccadic movements reflect the process through which individuals actively explore the visual environment and shift attentional focus between relevant stimuli. Under emotionally charged conditions, athletes may attempt to gather more environmental information in order to cope with increased cognitive and situational demands. These findings are consistent with previous research suggesting that emotional pressure and task demands alter visual search strategies in athletes (5, 10). Research on basketball players and other athletes has demonstrated that stressful or time-pressured conditions can increase gaze shifts and attentional reorientation as athletes attempt to process rapidly changing environmental information (5, 17). Similarly, studies examining anxiety in golf and other precision sports have reported that pressure conditions alter gaze control mechanisms and attentional allocation (18, 22). The present findings extend these observations to skilled female soccer players and demonstrate that emotional induction influences visual scanning patterns during soccer-specific decision-making tasks.

The observed increase in the number of eye fixations under positive and negative emotional conditions further supports the notion that emotional states intensify attentional engagement during perceptual-cognitive processing. Eye fixations are considered indicators of information extraction and cognitive processing efficiency. Increased fixation frequency may reflect the athletes' attempt to process additional environmental cues in emotionally demanding situations. These findings align with previous eye-tracking studies in soccer and other sports demonstrating that skilled performers allocate greater visual attention to task-relevant areas during complex situations (6, 7). Expert athletes generally demonstrate more organized and purposeful fixation patterns than novices, allowing them to identify relevant information more effectively (8, 9). In the present study, emotional conditions may have increased the need for cognitive monitoring and environmental analysis, resulting in more extensive fixation behavior.

The significant increase in fixation duration under emotional conditions also provides important insight into the cognitive demands imposed by emotional arousal. Longer fixation duration is commonly interpreted as an indicator of deeper information processing and increased attentional investment. The results suggest that emotional conditions required players to spend more time processing tactical information before making decisions. This finding is consistent with studies reporting that stress, anxiety, and mental fatigue alter attentional processing and slow perceptual-cognitive responses in athletes (20, 21). Mental and emotional pressure may increase cognitive workload and require greater attentional resources for successful performance. Previous studies have shown that emotionally demanding situations can prolong information-processing time and influence gaze behavior during sport tasks (10, 30). Therefore, the increased fixation duration observed in the present study may reflect adaptive attentional adjustments aimed at maintaining decision-making accuracy under emotional pressure.

An important finding of the present study was the significant reduction in alpha-wave activity across frontal and central cortical regions during positive and negative emotional conditions. Alpha suppression is

generally associated with increased cortical activation and greater attentional engagement during cognitive tasks (12, 13). The reduction in alpha activity observed in the present study suggests that emotional conditions intensified neural processing demands during decision-making. These findings are consistent with EEG studies in sports indicating that emotionally and cognitively demanding tasks increase cortical activation in regions associated with attention, executive functioning, and motor planning (11, 30). Soccer players exposed to emotionally stimulating situations may require greater neural resources to maintain attentional control and process visuospatial information effectively.

The frontal cortical regions examined in this study, including Fp1, Fp2, F3, Fz, and F4, are strongly associated with executive functions, attentional regulation, and decision-making processes. Reduced alpha activity within these regions may indicate increased cognitive control and emotional regulation during emotionally induced situations. Previous research has demonstrated that frontal cortical activation plays a central role in anticipation, planning, and response selection in athletes (2, 4). Similarly, studies on motor imagery and sport-related neural activity have shown that alpha suppression is associated with enhanced attentional focus and task engagement (13, 15). The present findings support the view that emotional conditions stimulate greater frontal cortical involvement during soccer decision-making tasks.

The significant relationships between visual search variables and alpha-wave activity also provide valuable evidence regarding the interaction between perceptual and neural processes in sport performance. The negative correlations between saccadic movements, fixation frequency, and alpha-wave activity suggest that greater visual exploration and attentional allocation are associated with increased cortical activation. In other words, as players engaged more actively in visual search behavior, cortical regions involved in attentional processing became more activated. This finding is consistent with neurocognitive theories proposing that efficient perceptual-cognitive performance requires coordinated interaction between attentional mechanisms and neural processing systems (11, 12). The findings also align with studies indicating that expert decision-making in sport involves simultaneous activation of perceptual and executive neural networks (1, 4).

Interestingly, the present study found no significant relationship between fixation duration and alpha-wave activity under neutral emotional conditions, whereas significant positive relationships emerged under positive and negative emotional conditions. This pattern may indicate that emotional arousal changes the functional relationship between attentional processing and neural activation. Under emotionally neutral conditions, visual search behavior may operate more automatically and require fewer cognitive resources. However, under emotionally stimulating conditions, longer fixation durations may reflect increased conscious processing and greater neural engagement. Such findings are consistent with theories of attentional control suggesting that emotional pressure increases cognitive monitoring and alters information-processing dynamics (10, 17).

Another notable finding was that correct decisions were associated with significantly greater fixation frequency and longer fixation duration than incorrect decisions across all emotional conditions. This result highlights the importance of efficient visual attention and information processing in successful soccer decision-making. Athletes who devoted greater attentional resources to task-relevant cues were more likely to make accurate decisions. Previous studies examining perceptual expertise in sports have similarly demonstrated that successful performers exhibit more effective gaze behaviors and superior attentional

strategies (6, 9). Quiet-eye research has consistently shown that longer and more stable fixations on relevant targets are associated with improved anticipation accuracy and motor performance (9). Therefore, the present findings reinforce the importance of visual attention quality in achieving effective decision-making during competitive sports situations.

The present findings also support the broader literature emphasizing the importance of perceptual-cognitive training in sport performance enhancement. Studies have demonstrated that visual training interventions, virtual simulations, and attentional-control programs can improve athletes' gaze behaviors, decision-making speed, and cognitive efficiency (23, 25). Similarly, mindfulness-based and sport-vision interventions have been shown to enhance attentional control and perceptual awareness in athletes and referees (24). The observed relationships between emotional conditions, visual search behavior, and neural activation suggest that perceptual-cognitive training programs should incorporate emotionally demanding situations in order to improve athletes' adaptability and resilience under pressure.

The findings of the present study are also important in light of contemporary perspectives on dynamic cognition-action interaction in sport. Modern theories emphasize that decision-making is not a purely cognitive process isolated from emotional and motor systems; rather, it emerges from continuous interaction between perception, action, emotion, and environmental context (1, 2). Emotional induction appears to alter these interactions by increasing attentional demands and neural activation during performance. The present results therefore contribute to the growing body of evidence supporting integrated neurocognitive models of sport expertise.

Despite the valuable findings of this study, several limitations should be acknowledged. The sample size was relatively small and included only skilled female soccer players from a specific competitive level, which may limit the generalizability of the findings to other populations, age groups, or performance levels. In addition, the study was conducted under laboratory-based simulated conditions rather than real competitive matches, and therefore ecological validity may have been somewhat restricted. Another limitation concerns the use of specific emotional induction procedures that may not fully replicate the complexity and intensity of emotional experiences during actual competitions. Furthermore, the study focused primarily on alpha-wave activity and did not examine other neural oscillations or physiological variables that may contribute to perceptual-cognitive performance.

Future research should investigate the effects of emotional induction on visual search behavior and neural activity in larger and more diverse samples, including male athletes, novice performers, and athletes from different sports disciplines. Researchers are also encouraged to examine additional neurophysiological indicators such as beta and theta activity, heart-rate variability, and autonomic nervous system responses during sport-specific decision-making tasks. Longitudinal studies investigating the effectiveness of perceptual-cognitive and emotional-regulation training interventions may further clarify the mechanisms underlying adaptive decision-making under pressure. Moreover, future investigations should employ more ecologically valid designs, including real-game scenarios and virtual reality environments, to better replicate the dynamic demands of competitive sports performance.

From a practical perspective, the findings suggest that coaches and sport psychologists should integrate emotionally challenging situations into training sessions in order to improve athletes' attentional control and decision-making adaptability. Training environments that simulate competitive pressure may help

athletes develop more efficient visual search strategies and stronger cognitive resilience under stressful conditions. Furthermore, implementation of perceptual-cognitive training programs, including visual search exercises, quiet-eye training, mindfulness practices, and neurofeedback interventions, may enhance athletes' attentional regulation and neural efficiency during performance. Continuous monitoring of athletes' emotional and cognitive states may also assist coaches in identifying factors contributing to performance decline and in designing individualized interventions aimed at optimizing perceptual-cognitive functioning during competition.

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Authors' Contributions

All authors equally contributed to this study. All stages of the study were conducted in accordance with ethical guidelines for human research and were approved by the Ethics Committee of the University of Tehran (Approval Code: IR.UT.SPORT.REC.1397.020).

Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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