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International Journal of EXERCISE SCIENCE

Original Research

Distinct Visual Processing Patterns in Female Elite Athletes: A Comparative Study of Gymnastics, Soccer, and Esports Using Visual P300 Event-Related Potentials

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ABSTRACT

International Journal of Exercise Science 17(5): 1595-1604, 2024. Visual processing is crucial for sports performance, influencing athletes' ability to interpret and respond to visual stimuli. This study investigated distinct visual processing patterns among Thai elite athletes in gymnastics, soccer, and esports, utilizing visual P300 event-related potentials (P300 ERPs). Forty-two female athletes (14 gymnasts, 14 soccer players, and 14 esports athletes) participated. Visual P300 ERP responses were stimulated using the visual oddball paradigm. One-way ANOVA was employed to assess significant differences among the groups in P300 ERPs data, including amplitude and latency of waveforms, response time, and accuracy rate. Significant differences were found across the groups in various parameters. Esports athletes exhibited longer P300 ERP latencies at the frontal electrode sites compared to gymnasts ($p = 0.01$), suggesting slower visual processing in the frontal brain regions. Gymnasts demonstrated the fastest response times, significantly quicker than esports and soccer players ($p < 0.01$). In contrast, soccer players exhibited the highest accuracy rate ($p = 0.03$). These findings underscore athletes' diverse visual processing strategies in different sports contexts, reflecting sport-specific adaptations. Understanding these distinct visual processing patterns can guide targeted interventions aimed at improving cognitive abilities and decision-making processes among elite athletes, ultimately contributing to better overall performance.

Key Words: Sport-specific adaptations, visual attention, visual P300 ERPs

INTRODUCTION

Visual processing in the brain plays a crucial role in sports performance, influencing athletes' abilities to interpret visual stimuli, predict movements, and make quick decisions with precision

(9). Different sports demand specific visual skills, which can vary significantly depending on the nature of the sport. For example, gymnastics, as an individual sport, requires athletes to develop specific visual acuity, coordination, and visualization skills to perform intricate movements with precision and elegance (23). In contrast, dynamic, reactive team sports like soccer necessitate strong visual skills to interact effectively with teammates and opponents, anticipate their actions, and make quick decisions (15). The rise of esports highlights the essential role of visual skills, as players must navigate digital landscapes, communicate with teammates, and maintain an intense focus on screens (14).

Generally, the neural response mechanisms to visual stimuli consist of two main components: bottom-up and top-down mechanisms (17, 18). Bottom-up mechanisms involve initial visual information processing, starting with light entering the eye and stimulating photoreceptors. This information is then transmitted via the optic nerve to the brain, where it is analyzed and interpreted, leading to motor output. Top-down mechanisms involve the brain's processing of visual information, incorporating previous visual experiences, such as those gained from training, competition, or visual skills, to influence the interpretation of new information and determine appropriate responses (1, 19).

Advancements in technology, such as the use of event-related potentials (ERPs), have improved our understanding of the neural mechanisms involved in athletes' visual processing. Specifically, the visual P300 component of ERPs reflects the brain's response to visual stimuli, providing insights into the speed of information processing and selective attention (12). The latency of the P300 wave correlates with processing time, where shorter latencies indicate faster processing (7), while the amplitude of the P300 wave relates to the level of selective attention (12). Previous research has shown differences in the visual P300 ERPs between athletes and non-athletes, indicating variations in visual processing and attention based on athletic experience (10, 13, 16, 28). For example, Matsutake et al. (16) found that collegiate soccer players had significantly shorter P300 latencies than amateur athletes, suggesting a more refined visual processing specific to soccer. Similarly, Wang et al. (28) reported higher P300 amplitudes in professional table tennis players compared to amateurs, indicating greater information processing capabilities. Additionally, Gostilovich et al. (10) observed higher P300 amplitudes and shorter latencies in professional esports players, highlighting their enhanced visual attention and processing speed. However, these studies have typically compared professional and amateur athletes within the same sport without examining differences across various sports. Since it remains unclear whether sports shape athletes' visual processes, this study compares athletes from sports with distinct visual skill requirements: gymnastics, soccer, and esports.

This study aimed to analyze the visual P300 ERPs across athletes from gymnastics, soccer, and esports to explore differences in visual processing. The authors hypothesized that athletes in different sports, due to varying visual skill demands, exhibit distinct neural processing of visual information, with gymnastics athletes expected to demonstrate superior visualization and coordination skills reflected in their P300 amplitudes, while soccer players were anticipated to show enhanced reaction times due to their team dynamics. Additionally, esports players were expected to have the shortest P300 latencies due to their intensive screen time and rapid decision-making processes. This study enhances our understanding of how specific sports influence visual processing, providing valuable insights for developing targeted training strategies and optimizing performance.

METHODS

Participants

Forty-two female professional athletes participated in this study, including 14 gymnasts, 14 soccer players, and 14 esports athletes. The sample size was determined based on a previous study (27), using Cohen's *f* effect size of 0.5, an alpha level of 0.05, and a power of 0.8, resulting in a requirement of 14 participants per group. All participants had over three years of experience in their respective sports and were active competitors at national or international levels. They ranged in age from 18 to 25 years, had normal or corrected-to-normal vision, and were right-handed. Exclusion criteria included cardiovascular, orthopedic, neuromuscular, metabolic, sleep, or psychiatric disorders, attention impairments, antidepressants, antihistamine medications, or other known medical conditions. All participants provided written informed consent prior to testing, and the study was approved by the Mahidol University Ethics Committee (MU-CIRB 2021/485.2311). This study was conducted strictly with the ethical standards outlined in the Declaration of Helsinki and the ethical guidelines of the *International Journal of Exercise Science* (21).

Protocol

Participants arrived at individually scheduled times between 9:00 a.m. and 12:00 p.m. to be assessed for their physical attributes, including weight and height. This was followed by an electroencephalogram (EEG) recording during rest and subsequent measurement of visual P300 ERPs. Each participant's session was held at the same time of day across visits to minimize potential circadian effects on performance and neural measurements.

Electroencephalogram (EEG) Acquisition: Participants were instructed to abstain from consuming substances that could affect cognitive performance, such as central nervous system-acting drugs, caffeine, and alcohol, for 24 hours before the EEG recording. Additionally, they were asked to wash their hair and refrain from using hair spray or oil. Upon arrival at the lab, participants were seated comfortably and fitted with an EEG cap in a controlled environment (22-24°C, lighting below 150 lux, and controlled noise levels) (3). Standard EEG procedures were followed, with electrodes applied using oneStep Cleargel (Germany) to maintain impedance below 5 kΩ. All electrodes were referenced to an average calculated from the electrodes on both earlobes (A1 + A2/2). The online filters were set at 0.1-60 Hz. Electrooculograms (EOG) were used to monitor eye movements, referenced to the average of both mastoid regions. EEG signals were recorded using the eegosports system (ANT Neuro, Germany) (2).

Visual Oddball Paradigm: The visual oddball paradigm was employed to investigate attention-related ERP components (26). Participants were shown a total of 240 2D images: 200 common targets (far objects) and 40 rare targets (near objects) (22), all presented in a randomized sequence on a single display. Each image appeared for 0.80 seconds, followed by a 0.50-second interval between stimuli. The entire task lasted 5 minutes. Participants were instructed to press a button as quickly as possible with their right hand whenever a rare target (near object) appeared, and both response speed and accuracy were recorded as behavioral performance metrics (6).

P300 Event-Related Potential (ERPs) Analysis: The P300 peak amplitude and latency were analyzed from midline electrodes located at Fz, Cz, and Pz. The peak amplitude was defined as the voltage difference between the baseline and the highest positive peak within the 180-600 ms window following stimulus presentation (30). The peak latency (ms) was defined as the time from stimulus onset to the point of the maximum positive amplitude of the P300 wave. The latency and amplitude of the P300 peak were measured using eego software and analyzed using Cognitech software. Any EEG artifacts were automatically corrected using the asa software (erp version) by its artifact correction function (asa™). The analog-to-digital rate was set to 512 Hz. The offline filters for ERP analysis were set as low-cutoff and high-cutoff at 0.3 and 30 Hz, respectively. The notch filter was set at 50 Hz (3).

Statistical Analysis

Participant characteristics were presented as mean ± standard deviations. The normal distribution of dependent measures from the visual oddball paradigm was assessed using the Shapiro-Wilk test. One-way ANOVA was used to determine the demographic characteristics of the participants and the P300 ERP data. When significant differences were detected, the Bonferroni post-hoc test was applied to identify which groups differed. In addition to the test statistic (F value), the effect size eta-squared (η^2), and the p-value were calculated. An $\eta^2 < 0.01$ indicates a small effect, between 0.01 and 0.06, a moderate effect, and greater than 0.14, a large effect. Furthermore, Cohen's D effect sizes (*d*) were calculated for the pairwise comparisons to assess the magnitude of differences between specific groups, where $d = 0.2$ indicates a small effect, $d = 0.5$ indicates a medium effect, and $d = 0.8$ indicates a large effect (5). The significance level was set at $p < 0.05$. Statistical analyses were performed using GraphPad Prism 9 software version 9.5.1.

RESULTS

The demographic characteristics of the participants, including age, height, body weight, and body mass index (BMI), did not significantly differ among the three athlete groups. The mean age of gymnasts, soccer players, and esports athletes was 20 ± 1, 21 ± 1, and 21 ± 2 years, respectively. Similarly, there were no significant differences in height among the groups, with mean values of 1.62 ± 0.02 meters for gymnasts, 1.60 ± 0.06 meters for soccer, and 1.62 ± 0.06 meters for esports. Body weight also showed no significant variation, with mean values of 57.6 ± 4.0 kg for gymnasts, 53.4 ± 7.3 kg for soccer, and 56.8 ± 10.6 kg for esports. The BMI was consistent across groups, with mean values of 22.0 ± 1.5 kg/m^2 for gymnasts, 20.8 ± 2.5 kg/m^2 for soccer, and 21.5 ± 3.3 kg/m^2 for esports.

For visual ERPs, a significant difference was found between athlete groups in the latency of P300 at Fz ($F_{(2,39)} = 5.141$, $p = 0.01$, $\eta^2 = 0.2153$). Post hoc tests revealed that the P300 latency at Fz was longer in esports athletes compared to gymnasts ($p < 0.01$ d=1.10). However, there were no significant differences in the P300 amplitude at Fz, Cz, and Pz, as well as the P300 latency at Cz and Pz among the three groups (Table 1 and Figure 1).

Behavioral performance, including accuracy rate and mean reaction time of responses, differed significantly among groups ($F_{(2,39)} = 4.328$, $p = 0.02$, $\eta^2 = 0.1676$). Post hoc tests revealed that soccer players' correct percentage was lower than esports athletes ($p = 0.03$, d=0.83) and gymnasts ($p = 0.049$, d=0.77). Mean reaction time showed significant differences between groups ($F_{(2,39)} = 44.87$, $p < 0.01$, $\eta^2 = 0.6761$). Post hoc tests indicated that the mean reaction time of esports athletes was longer than that of soccer players ($p < 0.01$, d=1.96) and gymnasts ($p < 0.01$, d=3.24). Additionally, the mean reaction time of soccer players was longer than that of gymnasts ($p < 0.01$, d=1.67) (Table 1).

Table 1. Peak amplitudes and peak latencies of the P300 components in visual oddball paradigm and the behavioral outcomes, including visual reaction time (VRT) and the accuracy rate (AR) in Gymnasts, Soccer, and Esports.

Electrode position of P300		**Visual oddball paradigm**			
		Gymnasts	**Soccer**	**Esports**	**p-value**
Fz					
Amplitude	(μV)	12.9±0.9	16.2±2.2	14.6±1.6	0.38
Latency	(ms)	411.4±9.6	431.4±5.2	444.2±5.8[c]	<0.01 [c]
Cz					
Amplitude	(μV)	15.8±1.0	18.6±2.2	15.7±1.7	0.43
Latency	(ms)	407.8±7.4	419.1±7.5	426.8±8.0	0.22
Pz					
Amplitude	(μV)	15.5±0.8	17.1±1.3	17.5±1.3	0.49
Latency	(ms)	408.9±6.9	402.5±6.3	425.3±7.6	0.07
Behavioral outcomes	AR (%)	97.5±0.7	93.8±1.6 [a,b]	97.7±0.5	0.03 [a,b]
	RT (ms)	454.5±6.0	483.8±3.7[a]	507.2±2.1[b, c]	<0.01[a,b,c]

Note: Fz= the midline frontal, Cz = the midline central, and Pz = the midline parietal. [a] significant difference between gymnasts and soccer; [b] significant difference between soccer and Esports; [c] significant difference between Gymnasts and Esports. Data are presented as means ± SEM, with n = 14 for each group. Significance was accepted at p-value < 0.05.

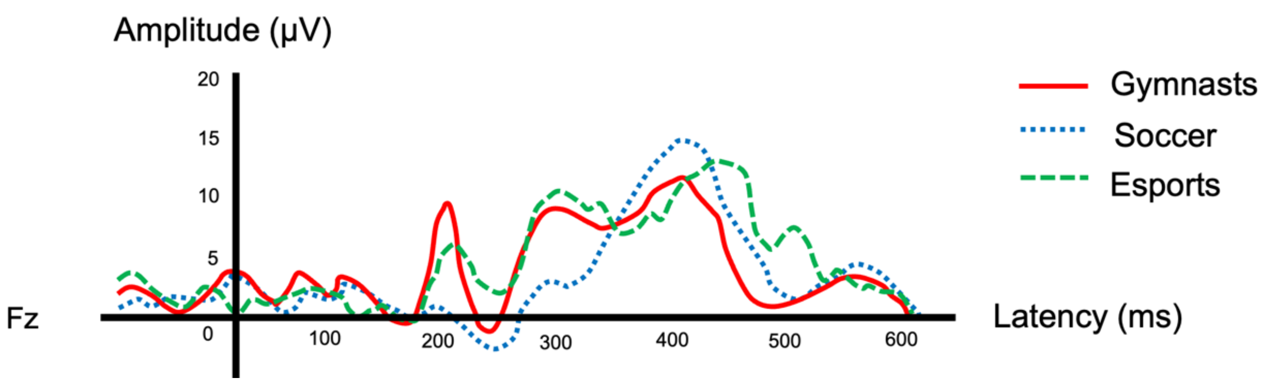

Figure 1. Grand average P300 event-related potential (ERP) response in the Gymnasts (Red- solid line), the Soccer (Blue-dotted line), and the Esports (Green-dashed line) at sample electrodes of the midline frontal (Fz) for visual stimuli in response to targets and non-targets. Note: The latency of the P300 ERP component was longer in the Esports compared to the Gymnasts.

DISCUSSION

This study aimed to investigate visual processing in the brain by measuring event-related P300 brain waves, as well as accuracy and response speed, comparing female elite athletes from gymnastics, soccer, and esports. The findings revealed several notable results that highlight the distinct visual skills associated with each sport. Specifically, esports athletes displayed longer P300 latencies at the mid-frontal cortex compared to gymnasts, soccer players exhibited the lowest accuracy rates (AR) in response to visual stimuli, and gymnasts had the shortest visual response times (RT) among the three types of athletes.

Visual ERPs provide valuable insights into the neural mechanisms underlying visual processing in athletes. Notably, esports athletes exhibited longer P300 latencies at the mid-frontal brain region compared to gymnasts, indicating differences in cognitive processing and attention allocation between the two groups. The competitive gaming environment requires esports athletes to rapidly process and interpret visual information, coordinating cues from screen movements to detect and counter opponents (4, 19). Although longer P300 latencies in esports athletes may imply slower processing times, it is crucial to recognize that they engage in complex cognitive tasks requiring sustained attention and strategic planning. This additional cognitive load may contribute to extended latencies as they rapidly assess and integrate multiple visual stimuli. Conversely, gymnastics relies less on immediate visual feedback from teammates or opponents, with skills such as visual acuity, field of vision, and visual imagery essential for executing movements gracefully and with balance (23). As a result, the frontal cortex may be less involved in visual object discrimination in gymnasts than in esports athletes. Thus, longer P300 latencies in esports athletes reflect the unique cognitive demands of their sport rather than inferior processing capabilities.

Behavioral performance measures of visual skills, such as accuracy and speed in response to visual stimuli, revealed that gymnasts had the shortest visual RT, while soccer players exhibited the lowest AR in response to visual stimuli, compared to esports athletes and gymnasts. For AR, soccer requires a variety of visual skills during matches and training, such as visual acuity, visual adjustment, field of vision, and visual memory (15, 25). Although previous studies have reported that professional soccer players tend to display superior visual skills compared to non-athletes (24, 29), this study found lower AR in soccer players when compared with athletes from other sports. This could be due to the complexity and diversity of visual attention and decision-making challenges that soccer players face during matches. The lower AR observed in soccer players may reflect the visual and cognitive demands of the sport, which require constant adjustment and tracking of fast-moving objects and dynamic play. Previous research has reported that complex decision-making in competitive situations can lead to delayed physical responses (8), potentially contributing to the accuracy deficits observed in soccer players.

For RT, esports and soccer had longer visual RT compared to gymnasts, whereas gymnasts had the shortest visual RT. These results could be explained by the fact that, as team-based sports, esports, and soccer athletes must process not only their actions but also the positions and movements of teammates, opponents, and fast-moving game dynamics (4, 15). This additional cognitive load could contribute to the longer RT observed in esports and soccer players, as they must integrate a larger volume of visual and contextual information to make decisions (11). For individual sports like gymnastics, athletes emphasize internal coordination, which may lead to shorter RT. Thus, our findings suggest that the specific visual and cognitive demands of individual sports like gymnastics, which emphasize internal coordination, could lead to shorter response times. In contrast, the more complex and dynamic decision-making required in team sports, where athletes must constantly adjust to external variables, may contribute to longer response times.

This study has several limitations that should be addressed. First, the cross-sectional design limits our ability to draw conclusions about long-term changes in visual processing patterns or causality between the observed neural responses and sports-specific skills. Future longitudinal studies would be beneficial to track how these patterns evolve over time with training and competition. Second, although efforts were made to control for potential confounding factors such as age, cognitive abilities, and training intensity, other variables, such as attention levels, competition schedules, or arousal states, may have influenced the results. Incorporating a broader range of cognitive and physiological measures in future studies would help clarify the underlying mechanisms. Lastly, while our study was conducted in a controlled laboratory setting, which allowed us to isolate specific variables, this may have limited the ecological validity of the findings. Future research could benefit from using more dynamic, sport-specific testing environments that better simulate athletes' real-world visual demands in competition.

This study demonstrates that visual processing in the brain is uniquely patterned among female elite athletes from gymnastics, soccer, and esports. The distinct cognitive demands and visual processing patterns observed across these sports highlight the influence of sport-specific factors on neural activity and behavioral performance. Esports athletes displayed longer P300 latencies, indicating increased cognitive load during complex decision-making tasks, while gymnasts exhibited the shortest RT, likely due to the need for precise internal coordination. Soccer players, however, had the lowest AR, potentially reflecting the complex visual and cognitive demands of their dynamic, fast-paced sport. These findings suggest that training programs aimed at enhancing athletes' visual performance should be tailored to the specific visual and cognitive demands of each sport. For example, esports athletes may benefit from training programs that enhance speed in decision-making, while gymnasts may require exercises focusing on quick visual-motor coordination, and soccer players could benefit from training that enhances both accuracy and decision-making under pressure. Future research should investigate sport-specific visual training interventions, which could enhance performance by targeting the unique visual processing and cognitive skills required in each sport. Longitudinal studies would also be valuable to explore how these visual processing patterns evolve with continued training and competition.

ACKNOWLEDGEMENTS

The researchers would like to thank all participants for participating in this study and the College of Sports Science and Technology, Mahidol University, for supporting equipment for data collection. This research is part of a doctoral dissertation supported by the National Research Council of Thailand (NRCT): NRCT5-RGJ63012-129.

REFERENCES

1. Abernethy B. Visual search in sport and ergonomics: Its relationship to selective attention and performer expertise. Hum Perform 1(4):205-235, 1988. https://doi.org/10.1207/s15327043hup0104_1

2. Ajjimaporn A, Noppongsakit P, Ramyarangsi P, Siripornpanich V, Chaunchaiyakul R. A low-dose of caffeine suppresses eeg alpha power and improves working memory in healthy university males. Physiol Behav 256:113955, 2022. https://doi.org/10.1016/j.physbeh.2022.113955

3. Ajjimaporn A, Ramyarangsi P, Siripornpanich V. Effects of a 20-min nap after sleep deprivation on brain activity and soccer performance. Int J Sports Med 41(14):1009-1016, 2020. https://doi.org/10.1055/a-1192-6187

4. Bonny JW, Castaneda LM, Swanson T. Using an international gaming tournament to study individual differences in moba expertise and cognitive skills. In Proceedings of the Proceedings of the 2016 CHI conference on human factors in computing systems. 2016. p. 3473-3484. https://doi.org/10.1145/2858036.2858190

5. Cohen J. Statistical power analysis for the behavioral sciences. 2nd ed. Hillsdale, NJ: Lawrence Erlbaum Associates; 1988.

6. Covington JW, Polich J. P300, stimulus intensity, and modality. Electroencephalogr Clin Neurophysiol /Evoked Potentials Section 100(6):579-584, 1996. https://doi.org/10.1016/S0168-5597(96)96013-X

7. Dickson DS, Wicha NYY. P300 amplitude and latency reflect arithmetic skill: An erp study of the problem size effect. Biol Psychol 148:107745, 2019. https://doi.org/10.1016/j.biopsycho.2019.107745

8. Erickson GB. Review: Visual performance assessments for sport. Optom Vis Sci 98(7):672-680, 2021. https://doi.org/10.1097/OPX.0000000000001731

9. Gilbert CD, Li W. Top-down influences on visual processing. Nat Rev Neurosci 14(5):350-363, 2013. https://doi.org/10.1038/nrn3476

10. Gostilovich S, Kotliar Shapirov A, Znobishchev A, Phan AH, Cichocki A. Biomarkers of professional cybersportsmen: Event related potentials and cognitive tests study. PLoS One 18(8):e0289293, 2023. https://doi.org/10.1371/journal.pone.0289293

11. Grushko A, Morozova O, Ostapchuk M, Korobeynikova E. Perceptual-cognitive demands of esports and team sports: A comparative study. In Proceedings of the Advances in Cognitive Research, Artificial Intelligence and Neuroinformatics: Proceedings of the 9th International Conference on Cognitive Sciences, Intercognsci-2020, October 10-16, 2020, Moscow, Russia 9. 2021. p. 36-43. https://doi.org/10.1007/978-3-030-71637-0_4

12. Hack J, Rupp A, Memmert D. Attentional mechanisms in sports via brain-electrical event-related potentials. Res Q Exerc Sport 80(4):727-738, 2009. https://doi.org/10.5641/027013609X13088509982487

13. Ji Q, Zhou C, Wang Y. Influence of conflicting prior information on action anticipation in soccer players: An erp study. Front Behav Neurosci 17:1320900, 2023. https://doi.org/10.3389/fnbeh.2023.1320900

14. Ketelhut S, Martin-Niedecken AL, Zimmermann P, Nigg CR. Physical activity and health promotion in esports and gaming-discussing unique opportunities for an unprecedented cultural phenomenon. Front Sports Act Living 3:693700, 2021. https://doi.org/10.3389/fspor.2021.693700

15. Lazarus R. Vision for soccer. In: Optometrists Network 2020.

16. Matsutake T, Nakata H, Matsuo G, Natsuhara T, Zippo K, Watanabe K, Sugo T. Fast and stable responses during decision making require strong inhibitory processes in soccer players. Brain Sci 14(3): 199, 2024. https://doi.org/10.3390/brainsci14030199

17. McMains S, Kastner S. Interactions of top-down and bottom-up mechanisms in human visual cortex. J Neurosci 31(2):587-597, 2011. https://doi.org/10.1523/JNEUROSCI.3766-10.2011

18. McMains SA, Kastner S. Defining the units of competition: Influences of perceptual organization on competitive interactions in human visual cortex. J Cogn Neurosci 22(11):2417-2426, 2010. https://doi.org/10.1162/jocn.2009.21391

19. Memmert D. Pay attention! A review of visual attentional expertise in sport. Int Rev Sport Exerc Psychol 2(2):119-138, 2009. https://doi.org/10.1080/17509840802641372

20. Nagorsky E, Wiemeyer J. The structure of performance and training in esports. PLoS One 15(8):e0237584, 2020. https://doi.org/10.1371/journal.pone.0237584

21. Navalta JW, Stone WJ, Lyons TS. Ethical issues relating to scientific discovery in exercise science. Int J Exerc Sci 12(1):1-8, 2019. https://doi.org/10.70252/EYCD6235

22. Pollatos O, Matthias E, Schandry R. Heartbeat perception and p300 amplitude in a visual oddball paradigm. Clin Neurophysiol 118(10):2248-2253, 2007. https://doi.org/10.1016/j.clinph.2007.06.057

23. Potgieter K, Ferreira J. The effects of visual skills on rhythmic gymnastics. Afr Vis Eye Health 68(3):137-154, 2009. https://doi.org/10.4102/aveh.v68i3.159

24. Roberts JW, Strudwick AJ, Bennett SJ. Visual function of English premier league soccer players. Sci Med Footb 1(2):178-182, 2017. https://doi.org/10.1080/24733938.2017.1330552

25. Rostami R, Mohammadi H, Alborzi M. Assessment and comparison of visual skills among footballers. Ann Appl Sport Sci 3(4):49-58, 2015. https://doi.org/10.18869/acadpub.aassjournal.3.4.49

26. Sur S, Sinha VK. Event-related potential: An overview. Ind Psychiatry J 18(1):70-73, 2009. https://doi.org/10.4103/0972-6748.57865

27. Wang C-H, Lin C-C, Moreau D, Yang C-T, Liang W-K. Neural correlates of cognitive processing capacity in elite soccer players. Biol Psychol 157:107971, 2020. https://doi.org/10.1016/j.biopsycho.2020.107971

28. Wang Y, Ji Q, Fu R, Zhang G, Lu Y, Zhou C. Hand-related action words impair action anticipation in expert table tennis players: Behavioral and neural evidence. Psychophysiol 59(1):e13942, 2022. https://doi.org/10.1111/psyp.13942

29. Williams AM, Davids K. Visual search strategy, selective attention, and expertise in soccer. Res Q Exerc Sport 69(2):111-128, 1998. https://doi.org/10.1080/02701367.1998.10607677

30. Yagi Y, Coburn KL, Estes KM, Arruda JE. Effects of aerobic exercise and gender on visual and auditory p300, reaction time, and accuracy. Eur J Appl Physiol Occup Physiol 80:402-408, 1999. https://doi.org/10.1007/s004210050611