A BALANCING ACT IN SPORTS: HOW COGNITIVE SKILLS CONTRIBUTE TO BETTER GYMNASTIC PERFORMANCE

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Abstract
Professional trainers and athletes often neglect the importance of cognitive skills yet they are arguably among the keys to improving athletes' performance. This study aims to investigate the role of cognitive skills in gymnasts' performance using the correlational method. The research study included thirty-seven young gymnasts (average age of 18.64 ± 0.83 years old) who regularly participated in and were preparing for competitions. Research data were collected from cognitive skills tests and gymnastic performance reviewed by a professional jury. The findings of this study show that better cognitive abilities led to better gymnastic performance, emphasizing the importance of attention, concentration, memory, visuospatial, language, and executive functions. Further research could longitudinally examine the development of athletes' cognitive skills and focus on implementing cognitive training to enhance gymnastic performance.

Keywords: *cognitive skills, gymnastic performance, young gymnasts.*

INTRODUCTION

Optimal performance in sports, specifically at the elite level, requires a balance between physical aspects and cognitive skills. Although we could argue that strength, flexibility, and endurance are highly important (Höög & Andersson, 2021; Marefat et al., 2021; Mkaouer et al., 2018; Russo et al., 2021), the deficiency in cognitive skills could prevent an athlete from reaching their full potential. (Walton et al., 2018). Professional trainers and athletes oftentimes only prioritize physical development without taking into account the fact that cognitive abilities play an important role in improving overall performance (Kilger & Blomberg, 2020). Cognitive abilities such as creativity, mental sharpness, focus, memory, multitasking, and inhibition, have been identified as important factors in predicting athlete's success at the elite level. Especially for athletes who have specialized in sports early on, such as gymnastics, the early development of cognitive abilities can play an important role in helping to deal with the stress and challenges that arise when transitioning to the next stage (Hofer & Clouston, 2014). For instance, in women's artistic gymnastics, athletes must synchronize their movements with music.

Their cognitive capacity to memorize intricate routines and adjust to fluctuations in musical tempo distinguishes between impressive and less satisfactory performances.

Cognitive skills, also known as cognitive abilities or functions, consist of mental processes performed consciously such as thinking, remembering, learning, and using language in communication (Leisman et al., 2016). Cognitive processes are caused by the gradual psychological changes in the brain constructed from interactions with the environment (Cocchi et al., 2017; Grossberg, 2021). Such processes directly affect knowledge acquisition (Cherukunnath & Singh, 2022; Molenaar et al., 2011), and according to Jean Piaget's views on cognitive development, they are also interconnected with maturity, brain development, and environmental adaptation (Barrouillet, 2015; Daskalakis et al., 2013). During one's development, cognitive abilities transform as one gets older and obtains experiences (Hopkins et al., 2016; Park & Bischof, 2013; Riva et al., 2016). The transformation affects one's view in making sense of the world and in responding to the acquired information (Modabbernia et al., 2021). In the early stages of development, children learn through sensory experiences and physical activity, but over time, they begin to use symbols and language to describe their reality. This stage not only includes the ability to think logically and abstractly, but also introduces increasingly complex concepts of problem-solving, creativity and reasoning. This transformation continues into adulthood, where individuals develop the ability to process information, evaluate situations and make complex decisions (Lourenço, 2016).

In recent years, there has been significant attention directed towards the role of cognitive skills and neuroscience in comprehending, predicting, and enhancing the performance of elite athletes (Chuang et al., 2013; García-Monge et al., 2020; Jacobson & Matthaeus, 2014; Negara et al., 2021). This trend is evident from previous studies that have investigated the cognitive performance of athletes (Logan et al., 2023; Stasielowicz, 2020). Other researchers even concluded that basic cognitive abilities could potentially become indicators of athletic achievements in the future (Cona et al., 2015; Montuori et al., 2019; Vestberg et al., 2017). Another study similarly investigated the functions of five primary cognitive abilities: attention and concentration, memory, visuospatial, language, and executive functions (Hendrayana et al., 2020). Those aforementioned studies prove to be highly significant element in understanding how cognitive abilities affect athletes' performance in various sports.

Gymnastics is a branch of sports requiring complex technical skills (Hendrianto & Firmansyah, 2023). It requires coordination of precise movements and the ability to adapt to unexpected situational changes (Diaz-artiles & Karmali, 2021; Hiley et al., 2019; G. K. R. Williams et al., 2016). In gymnastics, several skills are gradually taught in phases (Irwin et al., 2005), in which every phase is aimed at fundamentally preparing one's skills for the next phase, for instance: posture adjustment, balance, flexibility, and muscle strength.

In this context, cognitive skills take center stage. The complex characteristics of gymnastics call for quick decision-making, proper spatial awareness, and quick information processing (Heppe et al., 2016;

Hötting et al., 2021; Von Lassberg et al., 2012). Additionally, attention, concentration, and memory are required to perform certain movements accurately and to coordinate step patterns with the music or choreography (Abdollahipour et al., 2015; Bisagno et al., 2022; de Paula Ferreira et al., 2021; Seidler et al., 2012). Executive functions involving planning, self-regulation, and impulse control (Miyake & Friedman, 2012) are also vital in gymnastics. Gymnasts must be able to plan every movement with precision, manage time efficiently, and control impulses to avoid mistakes. Language ability also enables gymnasts to comprehend creative nuances and movement interpretations and their relevance when interacting with their trainers and teammates (Ivanova, 2022). Those aforementioned cognitive abilities enable athletes to perform under pressure and at high stakes.

Despite the significance of previously explained elements, the precise contribution of cognitive skills in gymnastics is yet to be fully understood. Therefore, this study aims to provide a comprehensive description of the impact of cognitive skills on gymnasts' performance. The study focuses on the question of whether cognitive abilities contribute to gymnasts' performance, since previous studies focused on one cognitive aspect only such as attention, concentration (Nassib et al., 2014), memory (Zisi et al., 2009), or executive functions (Bisagno et al., 2022). Ultimately, this research seeks to investigate the most important cognitive skills in gymnastic performance.

This study anticipates to provide empirical evidence supporting the significance of cognitive abilities in gymnastics, potentially facilitating the development of more effective training programs in the sport. In essence, this study aims to bridge the gap by comprehensively identifying the relationship between cognitive aspects and gymnastics, which has not been fully explored.

One of the important issues in this research is the fact that there is insufficient empirical evidence to support the contribution of cognitive aspects to gymnastic exercise performance. The main objective of this study was to find more empirical evidence that could support the role played by the cognitive components in gymnastic training. It is hoped that this study will not only provide empirical confirmation but also provide a solid foundation for the development of more effective training programs, as the main problem it seeks to address is the lack of a deep and detailed understanding of the causal relationship between cognitive processes and gymnasts' performance enhancement. This study aims to expand our scientific knowledge on how cognitive processes such as concentration, memory, language, executive and visuospatial functions correlate with gymnastics to achieve the best performance.

METHODS

This study employed the correlational method, involving thirty-seven male artistic gymnasts who regularly participated in competitions or undergoing preparations for them. Participants were randomly selected and provided their consent prior to data collection. Data were gathered while participants were in peak physical condition. Detailed physical characteristics are presented in Table 1.

Table 1

Physical characteristics of the research participants

Data	$\bar{x}$ ± Sd	Min	Max	N
Age	19.03 ± 3.88	10	25	37
Height (cm)	155.14 ± 8.07	135	171	
Weight (kg)	50.51 ± 8.56	28	67	
Body Mass Index	20.78 ± 2.18	15	25	

We employed various instruments to collect data, including cognitive tests designed to measure attention and concentration, memory, language, and executive functions.

Attention and concentration were assessed using the Concentration Grid Test (CGT), as described by Weinberg and Gould (2018). The CGT has been validated in multiple studies (Greenlees et al., 2006; Hendrayana et al., 2020; Komarudin et al., 2021; Negara et al., 2021). This test consists of a 10x10 grid marked with two-digit numbers ranging from 00 to 99. To conduct the test, participants require several tools and facilities, including a comfortable indoor room, a concentration test grid drawing sheet, stationery (such as pens or pencils), and a stopwatch. The test procedure involves participants sitting comfortably and relaxed in the designated area, with a minimum distance of 2 meters between each participant. Participants are then asked to complete their provided biodata before commencing the test. Each participant is instructed to connect the numbers in ascending order, from the smallest (00) to the largest (99), using horizontal, vertical, or diagonal lines.

Memory ability was assessed using the Digit Span test, as outlined by Ridsdale (2011) and validated in multiple studies (Alloway et al., 2008; Hendrayana et al., 2020; Woods et al., 2011). The test involved sheets of paper with sequentially arranged rows of numbers, ranging from 3 to 10 digits, for both forward and backward tests. Participants were tasked with repeating back the series of numbers presented by the researcher, either in the same order (forward test) or in reverse order (backward test). The difficulty level increased gradually, with rows of numbers starting from a lower difficulty level and increasing by one digit each time. Participants had two attempts within each difficulty level, with different number sequences, before being considered to have failed that level after making two errors. Each correct repetition earned the participant a check mark (√), while errors were marked with a cross (X).

Language, visuospatial, and executive function skills were evaluated using academic potential tests (Hendrayana et al., 2020). These tests are commonly regarded as measures of an individual's intelligence (Coyle & Greiff, 2021). Academic potential tests typically include verbal or language tests, numerical or mathematical tests, logical reasoning tests, and spatial or visual reasoning tests. As part of cognitive assessment, academic potential tests aim to assess an individual's maximum performance and are utilized to predict their potential achievement.

To evaluate performance in gymnastics, we engage judges who have experience in judging gymnastics or specialized knowledge of the scoring guidelines referring to the Code of Points (Fédération International de Gymnastique, 2022). In gymnastics, there are two judges whose job

is to assess the athlete's performance, namely D Jury *(Difficulty Jury)* and E Jury *(Execution Jury)* (Dallas & Kirialanis, 2010). D Jury is responsible for assessing the level of difficulty, group elements and connections between movements performed by the athlete as well as providing additional marks for successful connections. E jury is responsible for assessing the athlete's overall performance, including technical and artistic aspects. E Jury also grades the quality of the movements performed by the athlete, including body position, speed, and smoothness of movement. After D Jury and E Jury have completed their tasks, the difficulty and performance scores of the athletes are combined to determine the final score of each athlete's performance.

We employed the Statistical Package for the Social Sciences - Version 25.0 (SPSS 25.0) for analyzing statistical data. Descriptive statistical processes included using the average score as the central indicator, standard deviation to assess data distribution, and identifying the minimum and maximum scores to determine the data range. The normality of the data was assessed using the Shapiro-Wilk test, which confirmed that the data were normally distributed. Subsequently, the Linear Regression Test was utilized to examine the correlation between the independent and dependent variables. Statistical significance was set at $p < 0.05$ to determine whether the relationship between the independent and dependent variables was significant.

RESULTS

Table 3

The collected data consisted of cognitive function scores (attention and concentration, memory, visuospatial skills, language, and executive functions) and the gymnasts' performance, as presented in Table 2. Specifically, attention and concentration had an average score of 7.86, with a standard deviation of 2.85, a maximum score of 14, and a minimum score of 3. Memory had an average score of 65.86, with a standard deviation of 5.61, a maximum score of 79, and a minimum score of 55. Visuospatial, language, and executive functions (assessed via academic potential test) had an average score of 440.64, with a standard deviation of 82.55, a maximum score of 588, and a minimum score of 440. Overall, the cognitive skills had an average score of 150, with a standard deviation of 26.51, a maximum score of 212.68, and a minimum score of 110.55.

Table 2 *The descriptive data of cognitive skills and athletes' performance*

Variable	$\bar{x}$ ± Sd	Min	Max
A&C	7.86 ± 2.85	3	14
M	65.86 ± 5.61	55	79
VLEF	440.64 ± 82.55	440	588
CF	150 ± 26.51	212.68	110.55

(A&C) attention & concentration, (M) memory, (VLEF) visuospatial, language & executive function), (CF) cognitive function.

The correlation of cognitive skills with gymnastic scores is presented in Table 3. The correlation significance reached ($r = .727$, $p = .000$) with determination coefficient of ($r^2 = .529$) (see Figure 1). This means that cognitive functions contribute 2.9% to gymnastic performance.

The linear regression test on gymnastic performance

Variable	Correlation r	Correlation r^2	Contribution (%)	*p*
Attention & Concentration	.592	.351	35.1%	.000
Memory	.671	.451	45.1%	.000
Visuospatial, Language, Executive Function	.664	.441	44.1%	.000
Cognitive Function	.727	.529	52.9%	.000

All cognitive aspects, including attention and concentration, memory, visuospatial skills, language, and executive function, were thoroughly evaluated. Results indicate that memory emerged as the primary predictor of gymnastic performance, as illustrated in Figure 2. The correlation significance reached (r = .671, p = .000) with a contribution score of 45.1%. Additionally, attention and concentration had a correlation score of (r = .592, p = .000) and a contribution score of 35.1%. Moreover, the academic potential test had a significant correlation score of (r = .664, p = .000) with a contribution score of 44.1%.

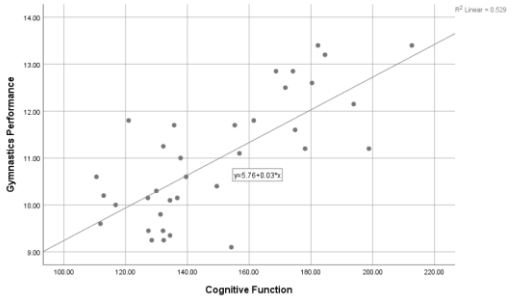

Figure 1. The scatter plot of cognitive functions' contribution to gymnastic performance R= .529; *p* = .000

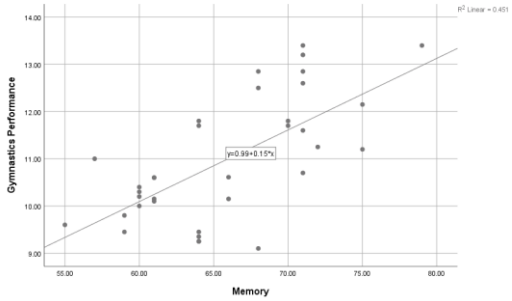

Figure 2. The scatter plot of memory's contribution to gymnastic performance R= .451; *p* = .000

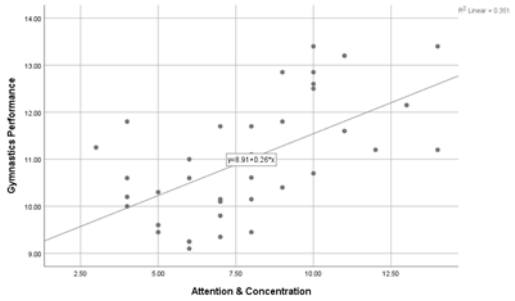

Figure 3. The scatter plot of the contribution of attention and concentration to gymnastic performance R= .351; *p* = .000

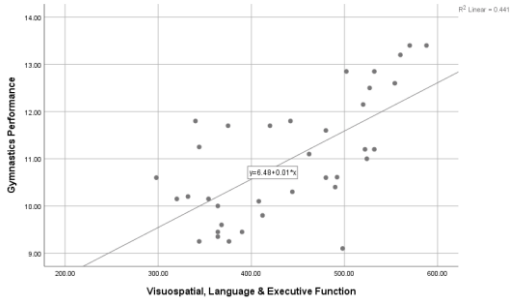

Figure 4. The scatter plot of the contribution of visuospatial, language and executive functions to gymnastic performance R= .441; *p* = .000

DISCUSSION

This study addresses two key objectives. Firstly, we aimed to investigate the role of cognitive skills in the performance of young gymnasts. Additionally, we sought to identify the primary predictor among five cognitive aspects: attention and concentration, memory, visuospatial skills, language, and executive functions. As hypothesized, we initially posited that cognitive skills could serve as predictors of young gymnasts' performance. The results conclusively demonstrate that cognitive skills can indeed

predict the quality of gymnastic performance. These findings build upon previous studies' conclusions, which have highlighted the relationships between attention and concentration and gymnastic performance (Nassib et al., 2014), memory and gymnastic performance (Zisi et al., 2009), and the impact of executive functions on gymnastic performance (Bisagno et al., 2022).

Optimal cognitive skills are undeniably crucial for sports performance, especially at the elite level. There is a complex relationship between cognitive skills and sports activities. While the relationship between cognitive skills and sports activities may not be fully elucidated (Brimmell et al., 2022; Hernández-Mendo et al., 2019; Vaughan & Laborde, 2021), several studies suggest that athletes outperform non-athletes in tasks requiring rapid processing and attention (Isoglu-Alkac et al., 2018), executive functions (De Waelle et al., 2021; Sharma et al., 2019), and spatial memory (Cynthia et al., 2016; Verburgh et al., 2016). It's important to recognize that each sport demands distinct cognitive skills, emphasizing the specificity of cognitive abilities required for performance (Koch & Krenn, 2021; Pačesová, 2021).

In the realm of sports, each type presents athletes with unique cognitive demands. From strategy and tactics to coordination and responses to dynamic situations, the characteristics of each sport vary widely. This perspective aligns with Jean Piaget’s insights into cognitive development, emphasizing the complexity of cognitive growth influenced by neural changes and experiences (Barrouillet, 2015; Choi et al., 2014). Through structured, intentional, focused, and consistent training (Chiappe & Vu, 2019; Eccles et al., 2022; Ericsson, 2020; Moratal et al., 2020), athletes' brain neurons form stronger and more efficient connections (Hosang et al., 2022; Kapilevich et al., 2019; Ludyga et al., 2016; Nakata et al., 2010). This concept aligns with cognitive adaptation, which underscores the brain's ability to adapt to increased physical activity levels. Moreover, environmental experiences, such as engaging in matches, interacting with peers, and learning from professional trainers, are integral to athletes' cognitive development. These experiences enable athletes to develop effective cognitive strategies that enhance their performance.

The results of this study underscore the significant contribution of memory compared to other cognitive aspects. Here, memory refers to the brain's capacity to store, retain, and access information garnered from past experiences (Ofen et al., 2016). The dual process theory (Furley et al., 2015; Imbir, 2016; Shea & Frith, 2016) reinforces the notion that memory plays a pivotal role in predicting the performance of young gymnasts. This theory delineates two primary systems in information processing: automatic and controlled. The automatic system operates unconsciously and efficiently during familiar or routine activities. Conversely, the controlled system involves conscious thought, deep analysis, and planning.

In the context of young gymnasts, memory functions akin to the automatic processing system, enabling athletes to recall and replicate gymnastic movements automatically after rigorous training. However, when executing complex choreographies, the controlled processing system becomes paramount. A robust memory assists athletes in recollecting movement patterns, technical intricacies, and choreographic sequences (Enghauser, 2003; Fukuo et al., 2020), while also aiding

in sustaining mental focus during performances (Furley & Wood, 2016; Unsworth & Robison, 2017).

In this context, concentration refers to athletes' capacity to focus on relevant environmental cues during practice or competition (Oliver et al., 2021). This entails the ability to filter out external and internal distractions that may impede performance. Concentration is sometimes referred to as executive attention in literature (Posner et al., 2019; Rueda et al., 2015; Uus et al., 2020), encompassing mental processes responsible for athletes' stimulus awareness. It activates athletes' perception of stimuli, including visuospatial abilities. During competition, gymnasts must rapidly process visual and kinesthetic information, such as recognizing movements, assessing spatial dimensions, and adjusting body positioning (Barreto et al., 2021). Optimal performance necessitates high concentration, enabling athletes to maintain focus despite external disruptions like audience cheers or internal distractions such as anxiety.

Furthermore, language ability plays a pivotal role in facilitating effective communication between athletes and their gymnastics trainers. Effective communication not only enhances learning but also improves performance in practice and competition (Kim & Park, 2020; A. Williams et al., 2023). Clear communication enables athletes to better receive feedback, leading to accelerated improvements in performance. Communication with trainers, comprehension of instructions and feedback, involve robust executive skills comprising inhibition control, memory, and cognitive flexibility (Diamond & Lee, 2011; Miyake et al., 2000). Athletes must cultivate these skills to regulate impulses, retain pertinent information, and adapt to changing strategies or situations. Additionally, they must actively listen, seek clarification when necessary, and communicate clearly to ensure comprehension of feedback from their trainers. These elements collectively contribute to effective communication between athletes and trainers, fostering optimal gymnastics performance.

In conclusion, all cognitive skills are interconnected and contribute to gymnastic performance. Developing these skills not only enhances gymnasts' cognitive capabilities but also leads to significant improvements in their performance, which necessitates precision in choreography execution.

CONCLUSIONS

Based on the findings and discussions outlined in this study, there is potential for further research to delve deeper into the role of cognitive skills in gymnastic performance. Future studies could longitudinally investigate the development of athletes' cognitive skills by incorporating brain imaging techniques and cognitive training into gymnastic training regimens, particularly among young gymnasts. This approach may enhance their potential, ultimately leading to greater achievements at competitive levels. Additionally, expanding the scope of research to include regional variations (across different countries) and international competitions could provide new valuable insights.

REFERENCES

Abdollahipour, R., Wulf, G., Psotta, R., & Palomo Nieto, M. (2015). Performance of gymnastics skill benefits from an external focus of attention. *Journal of Sports Sciences*, *33*(17), 1807–1813. https://doi.org/10.1080/02640414.2015.101

2102

Alloway, T., Gathercole, S. E., Kirkwood, H., & Elliott, J. (2008). Evaluating the validity of the automated working memory assessment. *Educational Psychology*, *28*(7), 725–734. https://doi.org/10.1080/01443410802243828

Barreto, J., Casanova, F., Peixoto, C., Fawver, B., & Williams, A. M. (2021). How task constraints influence the gaze and motor behaviours of elite-level Gymnasts. *International Journal of Environmental Research and Public Health*, *18*(13), 6941. https://doi.org/10.3390/ijerph18136941

Barrouillet, P. (2015). Theories of cognitive development: From Piaget to today. *Developmental Review*, *38*, 1–12. https://doi.org/10.1016/j.dr.2015.07.004

Bisagno, E., Cadamuro, A., Rubichi, S., Robazza, C., & Vitali, F. (2022). A developmental outlook on the role of cognition and emotions in youth volleyball and artistic gymnastics. *Frontiers in Psychology*, *13*, 954820. https://doi.org/10.3389/fpsyg.2022.954820

Brimmell, J., Edwards, E. J., & Vaughan, R. S. (2022). Executive function and visual attention in sport: a systematic review. *International Review of Sport and Exercise Psychology*, *0*(0), 1–34. https://doi.org/10.1080/1750984X.2022.2145574

Cherukunnath, D., & Singh, A. P. (2022). Exploring Cognitive Processes of Knowledge Acquisition to Upgrade Academic Practices. *Frontiers in Psychology*, *13*, 682628. https://doi.org/10.3389/fpsyg.2022.682628

Chiappe, D., & Vu, K. P. L. (2019). The motor intentional core of situation awareness. *Theoretical Issues in Ergonomics Science*, *20*(2), 129–152. https://doi.org/10.1080/1463922X.2018.1488299

Choi, H. S., Johnson, B., & Kim, Y. K. (2014). Children's Development Through Sports Competition: Derivative, Adjustive, Generative, and Maladaptive Approaches. *Quest*, *66*(2), 191–202. https://doi.org/10.1080/00336297.2013.861757

Chuang, L. Y., Huang, C. J., & Hung, T. M. (2013). The differences in frontal midline theta power between successful and unsuccessful basketball free throws of elite basketball players. *International Journal of Psychophysiology*, *90*(3), 321–328. https://doi.org/10.1016/j.ijpsycho.2013.10.002

Cocchi, L., Gollo, L. L., Zalesky, A., & Breakspear, M. (2017). Criticality in the brain: A synthesis of neurobiology, models and cognition. *Progress in Neurobiology*, *158*, 132–152. https://doi.org/10.1016/j.pneurobio.2017.07.002

Cona, G., Cavazzana, A., Paoli, A., Marcolin, G., Grainer, A., Bisiacchi, P. S., & Di Pellegrino, G. (2015). It's a matter of mind! Cognitive functioning predicts the athletic performance in ultra-marathon runners. *PLoS ONE*, *10*(7), 1–12. https://doi.org/10.1371/journal.pone.0132943

Coyle, T. R., & Greiff, S. (2021). The future of intelligence: The role of specific abilities. *Intelligence*, *88*(May), 101549. https://doi.org/10.1016/j.intell.2021.101549

Cynthia, J., Lubis, L., & Vitriana. (2016). Spatial Ability Differences in Athletes and Non-Athletes. *Althea Medical Journal*, *3*(4), 533–537. https://doi.org/10.15850/amj.v3n4.935

Dallas, G., & Kirialanis, P. (2010). Judges' evaluation of routines in men artistic gymnastics. *Science of Gymnastics Journal*, *2*(2), 49–57.

Daskalakis, N. P., Bagot, R. C., Parker, K. J., Vinkers, C. H., & de Kloet, E. R. (2013). The three-hit concept of vulnerability and resilience: Toward understanding adaptation to early-life adversity outcome. *Psychoneuroendocrinology*, *38*(9), 1858–1873. https://doi.org/10.1016/j.psyneuen.2013.06.008

de Paula Ferreira, B., Nogueira, N. G. de H. M., Lage, G. M., de Oliveira, J. R. V.,

& Apolinário-Souza, T. (2021). The role of mental practice in decreasing forgetting after practicing a gymnastics motor skill. *Science of Gymnastics Journal*, *13*(1), 119–126. https://doi.org/10.52165/sgj.13.1.119-126

De Waelle, S., Laureys, F., Lenoir, M., Bennett, S. J., & Deconinck, F. J. A. (2021). Children involved in team sports show superior executive function compared to their peers involved in self-paced sports. *Children*, *8*(4), 264. https://doi.org/10.3390/children8040264

Diamond, A., & Lee, K. (2011). Interventions shown to aid executive function development in children 4 to 12 years old. *Science*, *333*(6045), 959–964. https://doi.org/10.1126/science.1204529

Diaz-artiles, A., & Karmali, F. (2021). Vestibular Precision at the Level of Perception, Eye Movements, Posture, and Neurons. *Neuroscience*, *468*, 282–320. https://doi.org/10.1016/j.neuroscience.2021.05.028

Eccles, D. W., Leone, E. J., & Williams, A. M. (2022). Deliberate Practice: What Is It and How Can I Use It? *Journal of Sport Psychology in Action*, *13*(1), 16–26. https://doi.org/10.1080/21520704.2020.1850577

Enghauser, R. (2003). Motor Learning and the Dance Technique Class: Science, Tradition, and Pedagogy. *Journal of Dance Education*, *3*(3), 87–95. https://doi.org/10.1080/15290824.2003.10387235

Ericsson, K. A. (2020). Towards a science of the acquisition of expert performance in sports: Clarifying the differences between deliberate practice and other types of practice. *Journal of Sports Sciences*, *38*(2), 159–176. https://doi.org/10.1080/02640414.2019.1688618

FIG [Fédération International de Gymnastique]. (2022). *The Code of Points - Men ' s Artistic Gymnastics (2022-2024)*.

Fukuo, M., Kamagata, K., Kuramochi, M., Andica, C., Tomita, H., Waki, H., Sugano, H., Tange, Y., Mitsuhashi, T., Uchida, W., Takenaka, Y., Hagiwara, A., Harada, M., Goto, M., Hori, M., Aoki, S., & Naito, H. (2020). Regional brain gray matter volume in world-class artistic gymnasts. *Journal of Physiological Sciences*, *70*, 1–8. https://doi.org/10.1186/s12576-020-00767-w

Furley, P., Schweizer, G., & Bertrams, A. (2015). The two modes of an athlete: Dual-process theories in the field of sport. *International Review of Sport and Exercise Psychology*, *8*(1), 106–124. https://doi.org/10.1080/1750984X.2015.1022203

Furley, P., & Wood, G. (2016). Working Memory, Attentional Control, and Expertise in Sports: A Review of Current Literature and Directions for Future Research. *Journal of Applied Research in Memory and Cognition*, *5*(4), 415–425. https://doi.org/10.1016/j.jarmac.2016.05.001

García-Monge, A., Rodríguez-Navarro, H., González-Calvo, G., & Bores-García, D. (2020). Brain activity during different throwing games: Eeg exploratory study. *International Journal of Environmental Research and Public Health*, *17*(18), 1–18. https://doi.org/10.3390/ijerph17186796

Greenlees, I., Thelwell, R., & Holder, T. (2006). Examining the efficacy of the concentration grid exercise as a concentration enhancement exercise. *Psychology of Sport and Exercise*, *7*(1), 29–39. https://doi.org/10.1016/j.psychsport.2005.02.001

Grossberg, S. (2021). Attention: Multiple types, brain resonances, psychological functions, and conscious states. *Journal of Integrative Neuroscience*, *20*(1), 197–232. https://doi.org/10.31083/J.JIN.2021.01.406

Hendrayana, Y., Negara, J. D. K., Nuryadi, Gumilar, A., & Lesyiana, M. (2020). The impact of beta brain waves in improving cognitive function through brain jogging applications. *International Journal of Human Movement and Sports Sciences*, *8*(6), 73–77. https://doi.org/10.13189/saj.2020.080713

Hendrianto, R., & Firmansyah, H. (2023). Correlation between Physical Fitness and Concentration of Gymnastics Athletes Article Info. *Jurnal Pendidikan Jasmani Dan Olahraga*, *8*(1), 1–8. https://ejournal.upi.edu/index.php/penjas/article/view/53566DOI:https://doi.org/10.17509/jpjo.v8i1.53566https://ejournal.upi.edu/index.php/penjas/index

Heppe, H., Kohler, A., Fleddermann, M. T., & Zentgraf, K. (2016). The relationship between expertise in sports, visuospatial, and basic cognitive skills. *Frontiers in Psychology*, *7*, 904. https://doi.org/10.3389/fpsyg.2016.00904

Hernández-Mendo, A., Reigal, R. E., López-Walle, J. M., Serpa, S., Samdal, O., Morales-Sánchez, V., Juárez-Ruiz de Mier, R., Tristán-Rodríguez, J. L., Rosado, A. F., & Falco, C. (2019). Physical Activity, Sports Practice, and Cognitive Functioning: The Current Research Status. *Frontiers in Psychology*, *10*, 1–7. https://doi.org/10.3389/fpsyg.2019.02658

Hiley, M. J., Schmid, N., & Yeadon, M. R. (2019). How do technique and coordination change during learning of a whole-body task: Application to the upstart in gymnastics. *Journal of Sports Sciences*, *37*(20), 2374–2380. https://doi.org/10.1080/02640414.2019.1634413

Hofer, S. M., & Clouston, S. (2014). On the Importance of Early-Life Cognitive Abilities in Shaping Later-Life Outcomes. *Research in Human Development*, *11*(3), 241–246. https://doi.org/10.1080/15427609.2014.936173

Höög, S., & Andersson, E. P. (2021). Sex and Age-Group Differences in Strength, Jump, Speed, Flexibility, and Endurance Performances of Swedish Elite Gymnasts Competing in TeamGym. *Frontiers in Sports and Active Living*, *3*, 1–12. https://doi.org/10.3389/fspor.2021.653503

Hopkins, N., Reicher, S. D., Khan, S. S., Tewari, S., Srinivasan, N., & Stevenson, C. (2016). Explaining effervescence: Investigating the relationship between shared social identity and positive experience in crowds. *Cognition and Emotion*, *30*(1), 20–32. https://doi.org/10.1080/02699931.2015.1015969

Hosang, L., Mouchlianitis, E., Guérin, S. M. R., & Karageorghis, C. I. (2022). Effects of exercise on electroencephalography-recorded neural oscillations: a systematic review. *International Review of Sport and Exercise Psychology*, 1–54. https://doi.org/10.1080/1750984X.2022.2103841

Hötting, K., Rogge, A. K., Kuhne, L. A., & Röder, B. (2021). Balance expertise is associated with superior spatial perspective-taking skills. *Brain Sciences*, *11*(11). https://doi.org/10.3390/brainsci11111401

Imbir, K. K. (2016). From heart to mind and back again. A duality of emotion overview on emotion-cognition interactions. *New Ideas in Psychology*, *43*, 39–49. https://doi.org/10.1016/j.newideapsych.2016.04.001

Irwin, G., Hanton, S., & Kerwin, D. G. (2005). The conceptual process of skill progression development in artistic gymnastics. *Journal of Sports Sciences*, *23*(10), 1089–1099. https://doi.org/10.1080/02640410500130763

Isoglu-Alkac, U., Ermutlu, M. N., Eskikurt, G., Yücesir, İ., Demirel Temel, S., & Temel, T. (2018). Dancers and fastball sports athletes have different spatial visual attention styles. *Cognitive Neurodynamics*, *12*(2), 201–209. https://doi.org/10.1007/s11571-017-9469-6

Ivanova, I. V. (2022). Sports Profile of Elite Athletes in Rhythmic Gymnastics. *Science of Gymnastics Journal*, *14*(1), 73–88. https://doi.org/10.52165/sgj.14.1.73-83

Jacobson, J., & Matthaeus, L. (2014). Athletics and executive functioning: How athletic participation and sport type correlate with cognitive performance. *Psychology of Sport and Exercise*, *15*(5), 521–527. https://doi.org/10.1016/j.psychsport.2014.05.005

Kapilevich, L. V., Yezhova, G. S., Zakharova, A. N., Kabachkova, A. V., & Krivoshchekov, S. G. (2019). Brain Bioelectrical Activity and Cerebral Hemodynamics in Athletes under Combined Cognitive and Physical Loading. *Human Physiology*, *45*(2), 164–173. https://doi.org/10.1134/S0362119719010080

Kilger, M., & Blomberg, H. (2020). Governing Talent Selection through the Brain: Constructing Cognitive Executive Function as a Way of Predicting Sporting Success. *Sport, Ethics and Philosophy*, *14*(2), 206–225. https://doi.org/10.1080/17511321.2019.1631880

Kim, Y., & Park, I. (2020). "Coach really knew what i needed and understood me well as a person": Effective communication acts in coach–athlete interactions among Korean olympic archers. *International Journal of Environmental Research and Public Health*, *17*(9), 3101. https://doi.org/10.3390/ijerph17093101

Koch, P., & Krenn, B. (2021). Executive functions in elite athletes – Comparing open-skill and closed-skill sports and considering the role of athletes' past involvement in both sport categories. *Psychology of Sport and Exercise*, *55*, 101925. https://doi.org/10.1016/j.psychsport.2021.101925

Komarudin, K., Mulyana, M., Berliana, B., & Purnamasari, I. (2021). NeuroTracker Three-Dimensional Multiple Object Tracking (3DMOT):A Tool to Improve Concentration and Game Performance among Basketball Athletes. *Annals of Applied Sport Science*, *9*(1), 1–9. https://doi.org/10.29252/aassjournal.946

Leisman, G., Moustafa, A. A., & Shafir, T. (2016). Thinking, Walking, Talking: Integratory Motor and Cognitive Brain Function. *Frontiers in Public Health*, *4*, 1–19. https://doi.org/10.3389/fpubh.2016.00094

Logan, N. E., Henry, D. A., Hillman, C. H., & Kramer, A. F. (2023). Trained athletes and cognitive function: a systematic review and meta-analysis. *International Journal of Sport and Exercise Psychology*, *21*(4), 725–749. https://doi.org/10.1080/1612197X.2022.2084764

Lourenço, O. M. (2016). Developmental stages, Piagetian stages in particular: A critical review. *New Ideas in Psychology*, *40*, 123–137. https://doi.org/10.1016/j.newideapsych.2015.08.002

Ludyga, S., Gronwald, T., & Hottenrott, K. (2016). The athlete's brain: Cross-sectional evidence for neural efficiency during cycling exercise. *Neural Plasticity*, *2016*, 4583674. https://doi.org/10.1155/2016/4583674

Marefat, S., Ebrahim, B. M., & Mehdi, M. (2021). Muscle flexibility and explosive power in young artistic gymnast boys at different performance level. *Science of Gymnastics Journal*, *13*(2), 253–262. https://doi.org/10.52165/sgj.13.2.253-262

Miyake, A., & Friedman, N. P. (2012). The Nature and Organization of Individual Differences in Executive Functions: Four General Conclusions. *Current Directions in Psychological Science*, *21*(1), 8–14. https://doi.org/10.1177/0963721411429458

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The Unity and Diversity of Executive Functions and Their Contributions to Complex "' Frontal Lobe "' Tasks : A Latent Variable Analysis and. *Cognitive Psychology*, *41*(1), 49–100. https://doi.org/10.1006/cogp.1999.0734

Mkaouer, B., Hammoudi-Nassib, S., Amara, S., & Chaabène, H. (2018). Evaluating the physical and basic gymnastics skills assessment for talent identification in men's artistic gymnastics proposed by the International Gymnastics Federation. *Biology of Sport*, *35*(4), 383–392. https://doi.org/10.5114/biolsport.2018.78059

Modabbernia, A., Janiri, D., Doucet, G. E., Reichenberg, A., & Frangou, S. (2021).

Multivariate Patterns of Brain-Behavior-Environment Associations in the Adolescent Brain and Cognitive Development Study. *Biological Psychiatry*, *89*(5), 510–520. https://doi.org/10.1016/j.biopsych.2020.08.014

Molenaar, I., van Boxtel, C. A. M., & Sleegers, P. J. C. (2011). Metacognitive scaffolding in an innovative learning arrangement. *Instructional Science*, *39*(6), 785–803. https://doi.org/10.1007/s11251-010-9154-1

Montuori, S., D'Aurizio, G., Foti, F., Liparoti, M., Lardone, A., Pesoli, M., Sorrentino, G., Mandolesi, L., Curcio, G., & Sorrentino, P. (2019). Executive functioning profiles in elite volleyball athletes: Preliminary results by a sport-specific task switching protocol. *Human Movement Science*, *63*(November 2018), 73–81. https://doi.org/10.1016/j.humov.2018.11.011

Moratal, C., Lupiáñez, J., Ballester, R., & Huertas, F. (2020). Deliberate Soccer Practice Modulates Attentional Functioning in Children. *Frontiers in Psychology*, *11*, 761. https://doi.org/10.3389/fpsyg.2020.00761

Nakata, H., Yoshie, M., Miura, A., & Kudo, K. (2010). Characteristics of the athletes' brain: Evidence from neurophysiology and neuroimaging. *Brain Research Reviews*, *62*(2), 197–211. https://doi.org/10.1016/j.brainresrev.2009.11.006

Nassib, S. H., Mkaouer, B., Nassib, S., Riahi, S. H., & Arfa, Y. (2014). Precompetitive anxiety effect on concentration and performance on elite rhythmic gymnasts. *Science of Gymnastics Journal*, *6*(1), 23–32.

Negara, J. D. K., Mudjianto, S., Budikayanti, A., & Adhitya Nugraha, P. P. (2021). The effect of gamma wave optimization and attention on hitting skills in softball. *International Journal of Human Movement and Sports Sciences*, *9*(1), 103–109. https://doi.org/10.13189/saj.2021.090114

Ofen, N., Yu, Q., & Chen, Z. (2016). Memory and the developing brain: Are insights from cognitive neuroscience applicable to education? *Current Opinion in Behavioral Sciences*, *10*, 81–88. https://doi.org/10.1016/j.cobeha.2016.05.010

Oliver, A., McCarthy, P. J., & Burns, L. (2021). Teaching Athletes to Understand Their Attention Is Teaching Them to Concentrate. *Journal of Sport Psychology in Action*, *12*(3), 196–210. https://doi.org/10.1080/21520704.2020.1838980

Pačesová, P. (2021). Cognitive and executive functions of young men regarding sport activity and personality traits. *Sustainability*, *13*(21), 11752. https://doi.org/10.3390/su132111752

Park, D. C., & Bischof, G. N. (2013). The aging mind: Neuroplasticity in response to cognitive training. *Dialogues in Clinical Neuroscience*, *15*(1), 109–119. https://doi.org/10.31887/dcns.2013.15.1/dpark

Posner, M. I., Rothbart, M. K., & Ghassemzadeh, H. (2019). Restoring attention networks. *Yale Journal of Biology and Medicine*, *92*(1), 139–143.

Ridsdale, J. (2011). Digit Memory Test. *Encyclopedia of Clinical Neuropsychology*, 844–844. https://doi.org/10.1007/978-0-387-79948-3_5282

Riva, G., Baños, R. M., Botella, C., Mantovani, F., & Gaggioli, A. (2016). Transforming experience: The potential of augmented reality and virtual reality for enhancing personal and clinical change. *Frontiers in Psychiatry*, *7*, 164. https://doi.org/10.3389/fpsyt.2016.00164

Rosso, E. G. F., & Mcgrath, R. (2017). Community engagement and sport ? Building capacity to increase opportunities for community- based sport and physical activity. *Annals of Leisure Research*, *0*(0), 1–19. https://doi.org/10.1080/11745398.2017.1317604

Rueda, M. R., Pozuelos, J. P., & Cómbita, L. M. (2015). Cognitive neuroscience of attention. *AIMS*

Neuroscience, *2*(4), 183–202. https://doi.org/10.3934/Neuroscience.2015.4.183

Russo, L., Palermi, S., Dhahbi, W., Kalinski, S. D., Bragazzi, N. L., & Padulo, J. (2021). Selected components of physical fitness in rhythmic and artistic youth gymnast. *Sport Sciences for Health*, *17*(2), 415–421. https://doi.org/10.1007/s11332-020-00713-8

Seidler, R. D., Bo, J., & Anguera, J. A. (2012). Neurocognitive contributions to motor skill learning: The role of working memory. *Journal of Motor Behavior*, *44*(6), 445–453. https://doi.org/10.1080/00222895.2012.672348

Sharma, V. K., Subramanian, S. K., & Rajendran, R. (2019). Comparison of cognitive auditory event related potentials and executive functions in adolescent athletes and non-athletes - A cross sectional study. *International Journal of Physiology, Pathophysiology and Pharmacology*, *11*(6), 274–282. http://www.ncbi.nlm.nih.gov/pubmed/31993102%0Ahttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC6971495

Shea, N., & Frith, C. D. (2016). Dual-process theories and consciousness: the case for 'Type Zero' cognition. *Neuroscience of Consciousness*, *1*, niw005. https://doi.org/10.1093/nc/niw005

Stasielowicz, L. (2020). How important is cognitive ability when adapting to changes? A meta-analysis of the performance adaptation literature. *Personality and Individual Differences*, *166*, 110178. https://doi.org/10.1016/j.paid.2020.110178

Unsworth, N., & Robison, M. K. (2017). A locus coeruleus-norepinephrine account of individual differences in working memory capacity and attention control. *Psychonomic Bulletin and Review*, *24*(4), 1282–1311. https://doi.org/10.3758/s13423-016-1220-5

Uus, Õ., Seitlinger, P. C., & Ley, T. T. (2020). Cognitive capacity in self-directed learning: Evidence of middle school students' executive attention to resist distraction. *Acta Psychologica*, *209*(May), 103089. https://doi.org/10.1016/j.actpsy.2020.103089

Vaughan, R. S., & Laborde, S. (2021). Attention, working-memory control, working-memory capacity, and sport performance: The moderating role of athletic expertise. *European Journal of Sport Science*, *21*(2), 240–249. https://doi.org/10.1080/17461391.2020.1739143

Verburgh, L., Scherder, E. J. A., Van Lange, P. A. M., & Oosterlaan, J. (2016). Do elite and amateur soccer players outperform non-athletes on neurocognitive functioning? A study among 8-12 year old children. *PLoS ONE*, *11*(12), 1–12. https://doi.org/10.1371/journal.pone.0165741

Vestberg, T., Reinebo, G., Maurex, L., Ingvar, M., & Petrovic, P. (2017). Core executive functions are associated with success in young elite soccer players. *PLoS ONE*, *12*(2), 1–13. https://doi.org/10.1371/journal.pone.0170845

Von Lassberg, C., Beykirch, K., Campos, J. L., & Krug, J. (2012). Smooth pursuit eye movement adaptation in high level gymnasts. *Motor Control*, *16*(2), 176–194. https://doi.org/10.1123/mcj.16.2.176

Walton, C. C., Keegan, R. J., Martin, M., & Hallock, H. (2018). The potential role for cognitive training in sport: More research needed. *Frontiers in Psychology*, *9*, 1–7. https://doi.org/10.3389/fpsyg.2018.01121

Weinberg, R. S., & Gould, D. (2018). *Foundations of Sport and Exercise Psychology* (7th ed.). Human Kinetics.

Williams, A., Butt, J., & Kavanagh, E. (2023). An exploration of coaches' and sport psychologists' experiences of managing performance blocks. *Journal of Applied Sport Psychology*, 1–19. https://doi.org/10.1080/10413200.2023.2214745

Williams, G. K. R., Irwin, G., Kerwin, D. G., Hamill, J., Van Emmerik, R. E. A., &

Newell, K. M. (2016). Coordination as a function of skill level in the gymnastics longswing. *Journal of Sports Sciences*, *34*(5), 429–439. https://doi.org/10.1080/02640414.2015.1057209

Woods, D. L., Kishiyama, M. M., Yund, E. W., Herron, T. J., Edwards, B., Poliva, O., Hink, R. F., & Reed, B. (2011). Improving digit span assessment of short-term verbal memory. *Journal of Clinical and Experimental Neuropsychology*, *33*(1), 101–111. https://doi.org/10.1080/13803395.2010.493149

Zisi, V., Giannitsopoulou, E., Vassiliadou, O., Pollatou, E., & Kioumourtzoglou, E. (2009). Performance level, abilities and psychological characteristics in young junior rhythmic gymnasts: The role of sport experience. *International Quarterly of Sport Science*, *4*, 1–13.

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