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The Relationship between Brain Executive Functions and Sports Decision-Making among University Tennis Players in Nanchang, China

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Abstract

This study explores the intricate relationship between brain executive functions and sports decision-making among university tennis players in Nanchang, China. Adopting a cross-sectional correlational and experimental design, the research aimed to determine how executive cognitive processes—specifically inhibitory control, shifting, and updating—affect athletes' decision-making accuracy and reaction time in competitive tennis contexts. A total of 84 participants from Jiangxi Normal University, Jiangxi Science and Technology Normal University, and Nanchang Institute of Technology were assessed using E-prime 3.0 software to measure motor decision-making and executive function. The experimental group underwent multitask cognitive training designed to enhance executive functions, while the control group followed regular training routines. Results showed that, after intervention, the experimental group exhibited significantly higher accuracy in inhibitory control and cognitive decision-making compared to the control group, although no substantial differences were observed in intuitive decision-making or reaction times. These findings confirm that executive functions play a vital role in optimizing performance under pressure, influencing the accuracy and adaptability of decision-making processes. The study contributes valuable insights to sports science and psychology, suggesting that integrating cognitive training into tennis instruction can improve athletes' mental flexibility, inhibitory control, and decision-making performance. Future research should examine long-term intervention effects and expand the sample to different sports to generalize findings across athletic disciplines.

Keywords: Executive Functions, Sports Decision-Making, Tennis Athletes, Cognitive Training, Reaction Time

Introduction

Research into the complex interplay between collegiate tennis players' brain executive functions and their decision-making processes in athletic competition is an intriguing prospect, especially from the perspectives of cognitive psychology and sports science. The significance of this association lies in the fact that it highlights the mental operations that enable athletes to respond strategically and quickly in the face of the intense pressures that characterise competitive sports (Šimeček, 2023). Because of the need of making split-second judgements in fast-paced sports like tennis, athletes rely heavily on their brain executive functions, which include problem-solving, working memory, inhibitory control, and cognitive flexibility. Investigating these mental processes in athletes, especially tennis players, can shed light on how they affect performance on the court and, maybe, lead to training methods that improve both physical and mental agility.

The intricate web of relationships between cognitive processes and athletic performance is only now starting to be untangled, but preliminary evidence suggests that better sports decision-making is linked to stronger brain executive functions (Williams et al., 2022). Athletes that are more adept at inhibitory control and cognitive flexibility are better able to make split-second decisions under pressure, as shown, for example, by Wang et al. (2021). In a similar vein, Santos et al. (2022) discovered a strong link between tennis players' working memory capacity and their decision-making accuracy, suggesting that smarter players are better able to retain information and manipulate it to their advantage. Decisions in sports, like tennis, necessitate quick evaluation and response to changing circumstances, and these results show that the brain's executive processes are crucial for this.

Beyond its theoretical significance, the practical consequences for training regimens of comprehending the connection between executive processes and sports decision-making are substantial (Heisler et al., 2023). Research studying the role of specific brain executive functions in tennis decision-making has the potential to inform the incorporation of cognitive training into practise for the purpose of improving these abilities. A study conducted by Chen et al. (2021) lends credence to this method. The researchers discovered that badminton players, who face comparable decision-making challenges as tennis players, benefited from targeted cognitive training programmes that increased their speed and accuracy in making decisions. In addition, Gomez-Pinilla and Hillman's (2020) research brought attention to the neuroplasticity of the athlete's brain, indicating that specific cognitive exercises may strengthen the neural connections linked to brain executive functions, ultimately leading to better performance in sports.

The connection between brain executive functions and decision-making in sports, however, is complex and goes both ways (Kilger & Blomberg, 2020). When it comes to the effective use of cognitive abilities during competition, factors like stress, exhaustion, and emotional management also matter greatly. According to studies conducted by Lee and Kim (2021), athletes may have impaired decision-making due to stress and anxiety affecting their brain executive functioning. This is in line with the research of Patel and Davidson (2020), who found that athletes' capacity to control their emotions has a direct impact on their decision-making skills while playing. Emotion regulation is a part of brain executive function that is essential for keeping cognitive performance up when the pressure is on.

Because of the complex relationship between mental and physical performance in sports, it is essential to train athletes in a comprehensive manner that takes into account both the mental and physical components of their game. Incorporating cognitive training into sports training has the potential to improve performance by increasing athletes' ability to handle stress and emotions, which in turn improves their decision-making skills (Mayer et al., 2023). Research by Thompson and Voss (2021) lends credence to this all-encompassing method; the authors propose cognitive training as an integral part of sports science programmes, citing its ability to boost athletes' mental toughness and adaptability on the field.

Literature Review

Athletes' ability to integrate their physical abilities with their cognitive processes has recently received a lot of attention, highlighting the interconnected nature of these two domains. Working memory, inhibitory control, and cognitive flexibility are components of executive functions in the brain. These functions allow for planning, decision-making, error correction, and adaptation to new conditions. These cognitive talents are essential for making split-second decisions, devising long-term strategies, and adapting to changing situations; they are also significantly relied upon in everyday life and athletic performance. Athletes with higher levels of cerebral executive functioning performed better in sports requiring quick decision-making and strategic planning, according to a study by Verburgh, L., et al. (2021) performed in the Netherlands. This correlation emphasizes the value of cognitive training for improving athletic performance on all fronts.

Extensive research points to a reciprocal relationship between exercise and enhanced executive functioning in the brain. Staying active on a daily basis can help you perform better in sports. Cognitive capacities, especially executive function, and brain health will both improve as a result of this. Aerobic exercise has a favorable effect on brain executive functions, particularly inhibitory and attentional control, according to a meta-analysis carried out in Switzerland by Ludyga, et al. (2020). Incorporating aerobic exercise into training programs may be beneficial for athletes' physical health and the cognitive components necessary for their performance on the field, according to this study's results.

Sports are distinct from other activities and place special demands on executive functions; this highlights the complicated relationship between cognitive capacities and athletic performance. Sports requiring continual decision-making, tactical thinking, and on-the-fly strategy adjustments, such as soccer, basketball, and tennis, place a premium on the executive functions of the brain. According to a study carried out in Sweden by Vestberg, T., et al. (2022), elite soccer players had superior executive function abilities compared to the general population. This was particularly true for tasks requiring inhibitory control and cognitive flexibility. Not only do these activities tend to attract individuals with stronger executive functions, but there is mounting evidence that they may also improve cognitive capacities through sport-specific training and experiences.

Sports for youth and the development of physical and mental abilities are as crucial to the proper functioning of the brain's executive processes as professional sports for adults. A study carried out in China by Guo, Z., et al. (2021) found that kids and teens whose brains were involved in organized sports had better executive functioning. This link is particularly interesting because the brain is still changing and developing during adolescence, namely during the development of executive functions. Cognitive development, which may lead to better health and academic performance, can be facilitated by engaging in sports that call for strategy, coordination, and teamwork. Incorporating sports into current educational and developmental programs is, thus, a fantastic approach to aid in the mental and physical growth of young people.

Emerging from the field of neuroscience, new technological approaches have been developed for testing and training the executive functions of the brain in relation to athletic performance. Athletes can learn to focus and regulate their thoughts with the help of neurofeedback training, which provides real-time feedback on brain activity. The Italian study by Staiano, W., et al. (2020) indicated that athletes' field performance was enhanced after receiving neurofeedback training for their attention and brain executive functions. This technique shows the potential of technology-assisted training methods for improving the mental aspects of athletic performance as an alternative to traditional physical training.

Lastly, there are numerous intricacies to the intricate network of connections between the brain's executive functions and performance on the field of athletics. These include the following: the benefits of exercise on cognitive abilities; the unique cognitive demands of different sports; and the long-term effects of youth sports participation on brain executive functions. If it turns out that the brain's executive functions are really important for sports performance, that could change training programs, how athletes grow, and how sports science deals with cognitive training. A fascinating new field of research has emerged for sports scientists, coaches, and players: cognitive training and its potential to enhance athletic performance in conjunction with physical training. By including cognitive components into athletic growth and training programs, individuals can reach their full performance potential in all aspects of life.

Theoretical Framework of the Study

Two theories were used for this study: the Unity and Diversity Framework in regard to brain executive functions and the Dual-Process Theory in Sports Decision-Making. Each of these hypotheses adds something new to our understanding of the brain mechanisms that underpin brain executive functions and the way cognition works in athletic settings.

Two separate systems, System 1 and System 2, are involved in decision-making, according to the Dual-Analyze Theory, a well-known theory in cognitive psychology. System 1 acts intuitively and instinctively, whereas System 2 requires conscious effort to process information. Athletes, according to this notion, use a combination of intuitive and analytical thinking when making decisions on the field. System 2 permits more methodical preparation and strategy creation, whereas System 1 permits quick, instinctive reactions to urgent inputs. Recent studies that have applied the Dual-Process Theory to tennis and other sports have shown how both systems work together to maximise the quality of decisions and the results of performances.

Extensive practise and experience allow elite athletes to develop extremely efficient intuitive decision-making skills, according to studies that examined the application of the Dual-Process Theory in sports. As an example, Smith and Wilson (2021) studied the decision-making skills of both seasoned tennis players and those who had never played the sport before. The researchers concluded that top athletes' superior intuitive decision-making skills were a result of their years of training and competition experience, as opposed to those of amateurs. This discovery provides more evidence that athletes are able to make quick and correct decisions under duress because their intuitive decision-making abilities are refined during time via frequent exposure to complicated gameplay scenarios.

In addition, there is encouraging evidence that therapies targeting athletes' intuitive decision-making abilities can improve performance outcomes. Training methods that aim to improve athletes' intuitive decision-making abilities were the subject of a study by Jones and Harwood (2020). Athletes whose performance was drastically enhanced after receiving focused training treatments demonstrated the adaptability of intuitive decision-making abilities with intentional training and practise. These results highlight the significance of training programmes that take into account athletes' analytical and intuitive thinking processes in order to maximise their decision-making abilities during games.

Brain executive functions are critical for good decision-making in sports and other cognitive tasks. The Unity and Diversity Framework offers insights into the underlying brain mechanisms underpinning these functions. This model posits that cognitive processes are complex and diverse, with a common set of brain executive functions shared across tasks and modifications that are task-specific. Supporting this paradigm, new empirical research has illuminated the brain bases of inhibitory control, working memory, and cognitive flexibility.

Neuroimaging methods were used by Nguyen and Zelazo (2021) to study the brain bases of inhibitory control, working memory, and cognitive flexibility tests. Although they did discover that these tasks engaged a shared network of prefrontal areas linked to brain executive functions, they also discovered that different types of brain executive functions elicited different patterns of activation. This discovery lends credence to the idea that brain executive functions display task-specific changes and share overlapping neuronal pathways, underscoring the brain's intricate cognitive processing.

Conceptual Framework of the Study

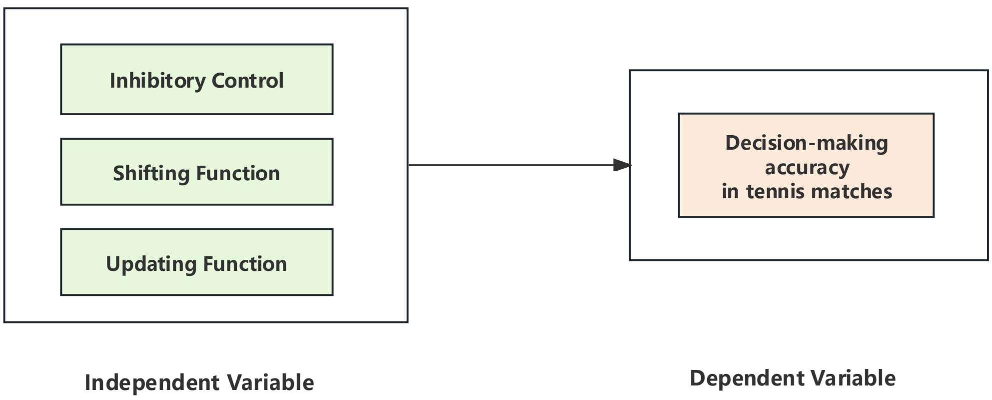

Figure 1 Conceptual Framework

Methodology

This study adopted a cross-sectional correlational design to explore the relationship between athletic decision-making and brain executive functions among university tennis players in Nanchang, China. Using *E-prime 3.0* software, researchers designed measurement systems to assess both motor decision-making and executive functions, ensuring scientific reliability and validity. The study aimed to capture a snapshot of the interaction between cognitive and motor abilities, examining variations across gender and athletic experience. Additionally, an experimental intervention using a multi-task training approach was conducted to further analyze whether cognitive training could enhance executive functions and improve sports decision-making among tennis players.

The research was conducted across three major universities—Jiangxi Normal University, Jiangxi Science and Technology Normal University, and Nanchang Institute of Technology—with a total of 84 participants, including both male and female athletes around 21 years old. Stratified random sampling was used to ensure balanced representation across skill levels, gender, and institutions. The participants were divided into experimental and control groups to test the effects of multitask training interventions. Ethical considerations such as informed consent, confidentiality, and equal opportunity in selection were strictly followed to maintain methodological rigor. Pilot testing further refined the instruments and procedures before full-scale data collection.

Data collection incorporated quantitative assessments and qualitative observations, combining standardized psychological tests, motor performance measures, and field observations. Descriptive and inferential statistical analyses, including correlation, T-tests, and ANOVA, were performed using SPSS to determine the relationships and differences among variables. Qualitative data were analyzed through thematic analysis to complement numerical findings. To safeguard internal validity, techniques such as randomization, counterbalancing, and ANCOVA were employed. Overall, the study provided a comprehensive examination of how executive brain functions influence athletic decision-making in collegiate tennis, contributing valuable insights to sports psychology and performance training.

Research Findings and Analysis

Statistical results of accurate response rates (ACC) in brain executive function tests between the Before the experiment experimental group and the Control Group

To examine the Before the experiment differences in executive function accuracy rates (ACC) between the Experimental group and the Control Group, descriptive statistics were employed. The results are presented in Table 51 below.

Table 1
Before the experiment statistical results for executive function (ACC) between the Experimental group and the Control Group (N=42)

Dimension	Group	N（人数）	M	SD
Inhibitory Control	Experimental	21	0.7114	.13599
(ACC)	Control	21	0.7043	.12828
Shifting	Experimental	21	0.6657	.09108
(ACC)	Control	21	0.6876	.14321
Updating	Experimental	21	0.6576	.06395
(ACC)	Control	21	0.6752	.08920

As shown in Table 1, there was little difference in the accuracy rate of brain executive function (ACC) between the experimental group and the control group before the experiment. An independent samples t-test was further conducted on the ACC data of both groups to assess pre-experimental differences. The specific results are presented in Figure 3.

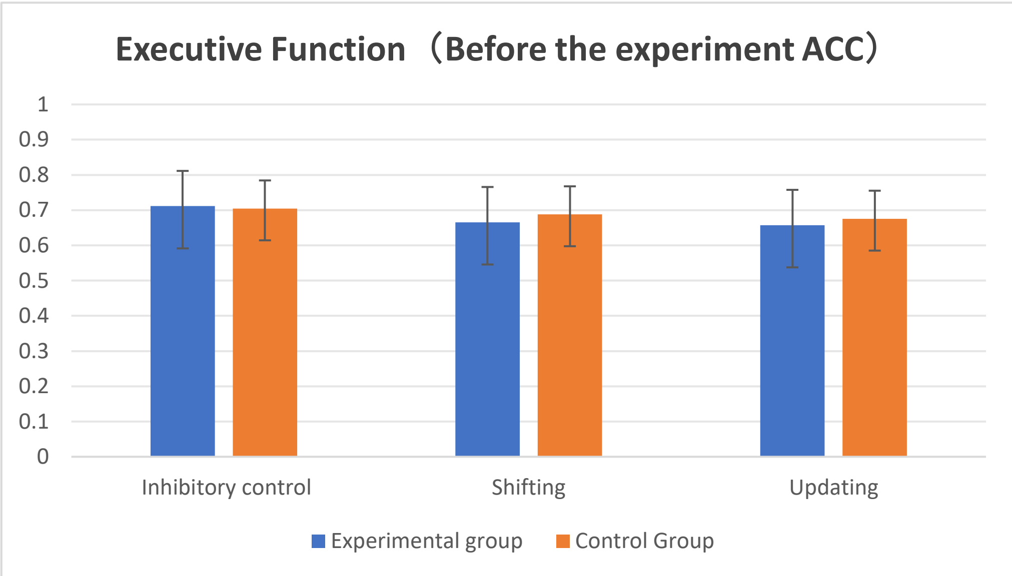

Figure 3: Before the experiment statistical results for executive function (ACC) between the Experimental group and the Control Group

As shown in Figure 3, there was no significant difference in the accuracy rate of brain executive function (ACC) between the Experimental group and the Control Group before the experiment ($P > 0.05$), meeting the experimental requirements.

After the experimen statistical results of accurate response rates (ACC) in brain executive function tests between the Experimental group and the Control Group.

To examine the difference in the accuracy rate of brain executive function (ACC) between the Experimental group and the Control Group after the experiment descriptive statistics were employed. The results are presented in Table 2 below.

Table 2
After the experiment statistical results for executive function (ACC) between the Experimental group and the Control Group

Dimension	Group	N（人数）	M	SD
Inhibitory Control	Experimental	21	0.8662	.07625
(ACC)	Control	21	0.7524	.13946
Shifting	Experimental	21	0.7405	.08255
(ACC)	Control	21	0.7086	.13256
Updating	Experimental	21	0.7276	.06395
(ACC)	Control	21	0.7124	.07127

As shown in Table 2, both the experimental group and the Control Group demonstrated improvements in brain executive function accuracy (ACC) after the experiment. An independent samples t-test was subsequently conducted to assess the difference in brain executive function accuracy (ACC) between the experimental group and the Control Group. The specific results are presented in Figure 4.

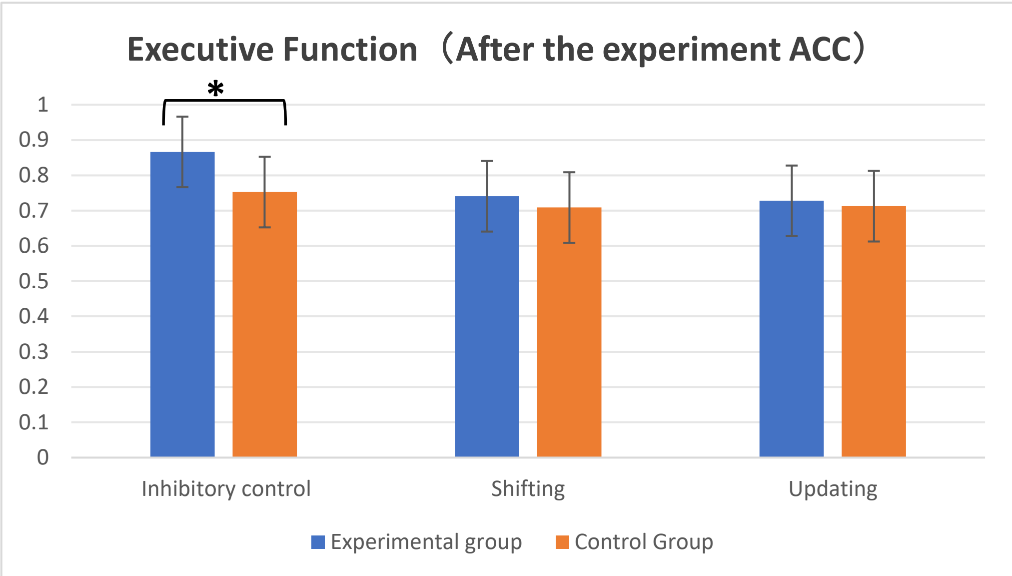

Figure 4: After the experiment statistical results for executive function (ACC) between the Experimental group and the Control Group

As shown in Figure 4, after the experiment, the accuracy rate (ACC) of inhibitory function in the Experimental group was significantly higher than that in the Control Group ($P < 0.05$). The inhibitory function (ACC) of the Experimental group was higher than that of the Control Group. Both the conversion function (ACC) and the refresh function (ACC) showed improvement compared to Before the experiment levels, though no significant differences were observed.

Statistical Results of Reaction Time (RT) in Brain Executive Function Tests for the Experimental group and Control Group Before the experiment

To examine differences in brain executive function reaction time (RT) levels between the Experimental group and the Control Group before the experiment, descriptive statistics were employed. The results are presented in Table 53 below.

Table 33
Before the experiment, statistical results of the RT test for the Experimental group and the Control Group (N=42)

Dimension	Group	N（人数）	M	SD
Inhibitory Control	Experimental	21	836.7143	133.26633
(RT)	Control	21	868.8571	90.36885
Shifting	Experimental	21	860.6190	84.54376
(RT)	Control	21	854.3333	82.49747
Updating	Experimental	21	534.2857	105.25927
(RT)	Control	21	501.2381	50.70099

As shown in Table 3, there was little difference in the brain executive function reaction time (RT) data between the Before the experiment experimental group and the Control Group. An independent samples t-test was further conducted on the Before the experiment brain executive function reaction time (RT) data of the experimental group and the Control Group to statistically evaluate the difference in RT between the two groups. The specific results are presented in Figure 5.

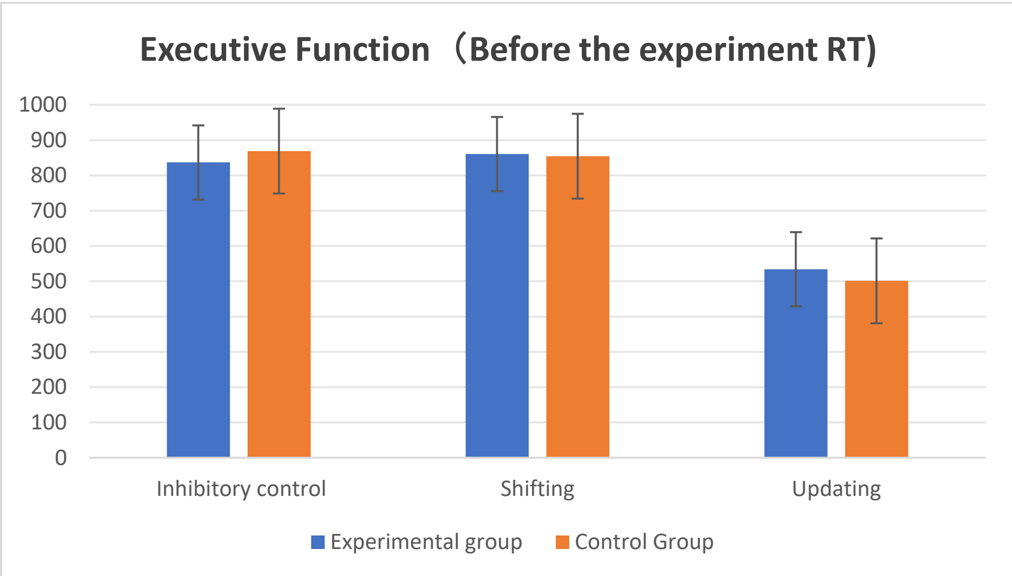

Figure 5: Before the experiment, statistical results of the RT test for the Experimental group and the Control Group

As shown in Figure 5, no significant difference was observed in the reaction times (RT) of brain executive function between the Experimental group and the Control Group before the experiment ($P > 0.05$), meeting the experimental requirements.

Statistical Results of Reaction Time (RT) in Brain Executive Function Tests Between Experimental Group and Control Group After the experimen

To examine the differences in brain executive function reaction time (RT) levels between the Experimental group and the Control Group after the experimen, descriptive statistics were employed. The results are presented in Table 3 below.

Table 3
After the experimen results of the Experimental group and Control Group on the executive function test (RT)(N=42)

Dimension	Group	N（人数）	M	SD
Inhibitory Control	Experimental	21	840.5238	101.68511
(RT)	Control	21	869.8571	72.93441
Shifting	Experimental	21	869.5714	84.58934
(RT)	Control	21	856.3810	73.91311
Updating	Experimental	21	544.17143	55.40861
(RT)	Control	21	532.4286	140.14941

Both the experimental group and the Control Group exhibited improved reaction times (RT) for brain executive function after the experimen compared to Before the experiment levels. An independent samples t-test was subsequently conducted to assess the difference in reaction times (RT) for brain executive function between the experimental group and the Control Group after the experimen. The specific results are presented in Figure 6.

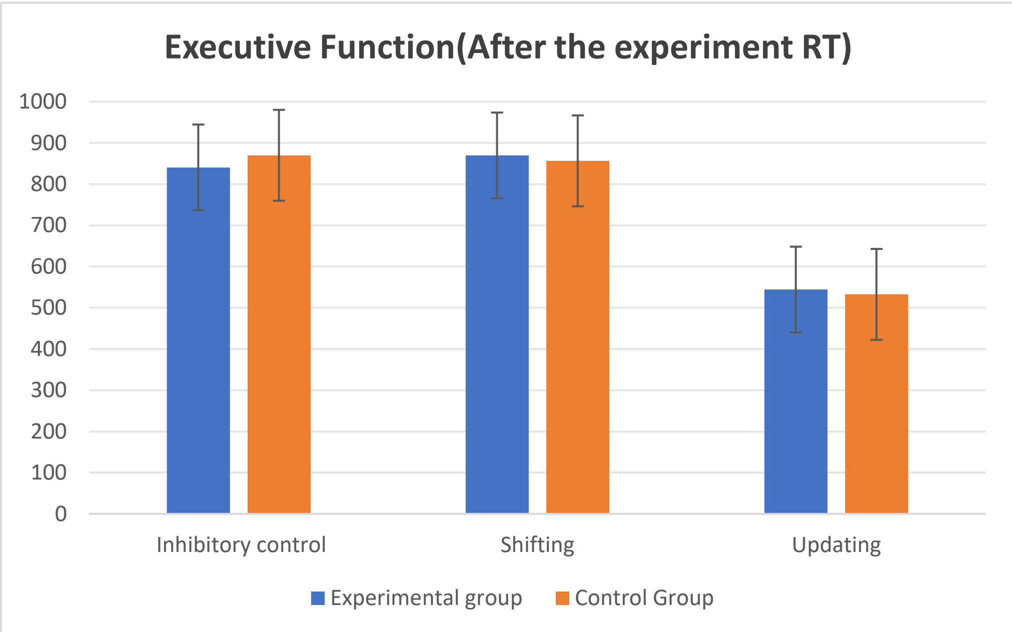

Figure 6: After the experimen results of the Experimental group and Control Group on the executive function test (RT)

After the experimen results indicate that the Experimental group demonstrated superior brain executive function reaction times (RT) compared to the Control Group, though the difference was not statistically significant ($P > 0.05$).

Before the experiment statistical results for decision accuracy (ACC) in tennis activities between the Experimental group and Control Group

To understand the baseline levels of tennis tactical decision accuracy (ACC) between the experimental group and the Control Group before the experiment, descriptive statistics were applied to the ACC levels of both groups. The results are presented in Table 5 below.

Table 4
Before the experiment, tennis decision-making test (ACC) results for the Experimental group and Control Group(N=42)

Dimension	Group	N（人数）	M	SD
Cognitive	Experimental	21	0.5981	0.12524
(ACC)	Control	21	0.5857	0.10166
Intuitive	Experimental	21	0.6771	0.11190
(ACC)	Control	21	0.6548	0.11378

As shown in Table 55, the mean percentage of the Experimental group's tennis tactical decision accuracy (ACC) was higher than that of the Control Group's tennis tactical decision accuracy (ACC). An independent samples t-test was further conducted to examine whether there was a difference in the level of tennis tactical decision-making accuracy (ACC) between the Experimental group and the Control Group before the test. The specific results are shown in Figure 7.

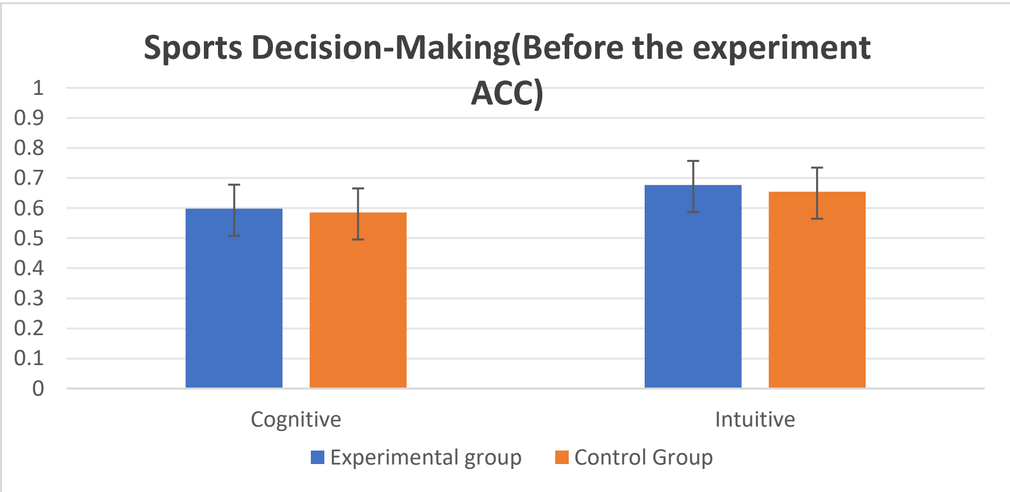

Figure 7: Before the experiment, tennis decision-making test (ACC) results for the Experimental group and Control Group

As shown in Figure 7, there was no significant difference in the accuracy of tennis tactical decision-making (ACC) between the Experimental group and the Control Group before the experiment ($P > 0.05$), meeting the experimental conditions.

After the experiment statistical results for tennis decision-making accuracy (ACC) between the Experimental group and the Control Group

To assess the levels of tennis tactical decision-making accuracy (ACC) between the Experimental group and the Control Group after the experiment, descriptive statistics were applied to the ACC levels of both groups. The results are presented in Table 6 below.

Table 5
After the experiment tennis decision-making test (ACC) results for the Experimental group and Control Group(N=42)

Dimension	Group	N（人数）	M	SD
Cognitive	Experimental	21	0.7076	0.07569
(ACC)	Control	21	0.6381	0.12816
Intuitive	Experimental	21	0.7152	0.07366
(ACC)	Control	21	0.6690	0.11870

As shown in Table 6, the mean percentage of the Experimental group's tennis tactical decision accuracy (ACC) level was higher than that of the Control Group's tennis tactical decision accuracy (ACC) level. An independent samples t-test was further conducted to compare the pre-experiment ACC levels between the Experimental group and the Control Group, assessing whether statistically significant differences existed. The specific results are presented in Figure 8.

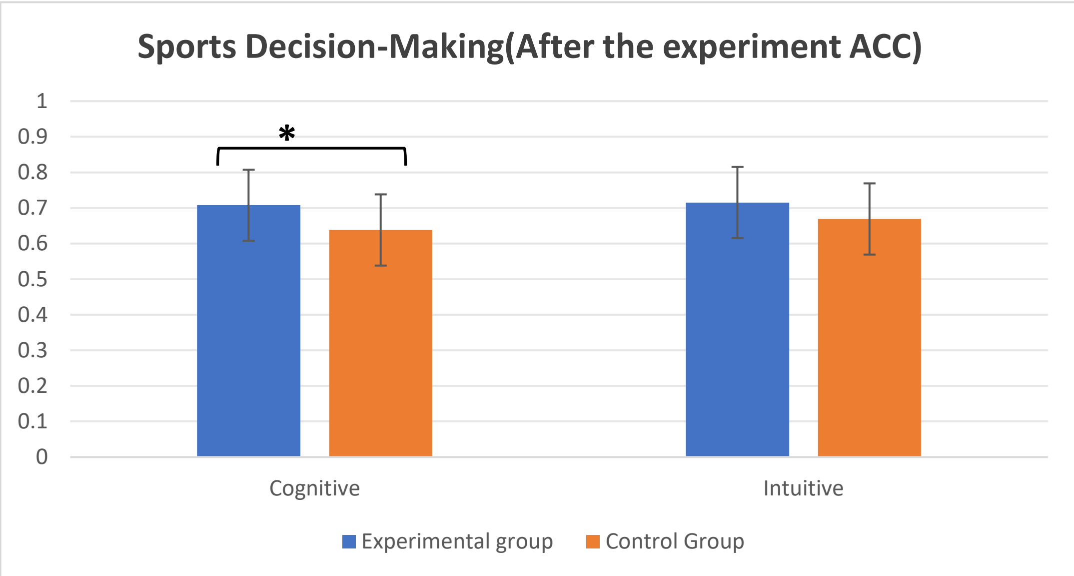

Figure 8: After the experiment tennis decision-making test (ACC) results for the Experimental group and Control Group

The Experimental group outperformed the Control Group in the accuracy of tennis tactical decision-making (ACC) after the experimen. Specifically, the Experimental group demonstrated a significant difference in the accuracy of cognitive dimension decision-making (ACC) compared to the Control Group ($P < 0.05$). However, no significant difference was observed between the Experimental and Control Groups in the accuracy of Intuitive Decision-Making (ACC) at the $P > 0.05$ level.

Statistical Results of Reaction Time (RT) for Tennis Decision-Making between the Experimental Group and the Control Group Before the Experiment

To understand the baseline levels of reaction time (RT) for tennis tactical decision-making between the experimental group and the Control Group before the experiment, descriptive statistics were applied to the pre-experiment RT levels for tennis decision-making in both groups. The results are presented in the table below. To understand the baseline levels of tennis tactical decision-making reaction time (RT) between the experimental and control groups prior to the experiment, descriptive statistics were applied to their respective pre-experiment RT data. The results are presented in the table 7 below.

Table 6
Before the experiment results of the tennis decision-making test (RT) for the Experimental group and the Control Group (N=42)

Dimension	Group	N（人数）	M	SD
Cognitive	Experimental	21	2496.38	267.838
(RT)	Control	21	2523.90	458.827
Intuitive	Experimental	21	2203.57	155.048
(RT)	Control	21	2321.90	261.767

As shown in Table 7, the mean reaction time (RT) for tennis tactical decision-making in the Experimental group was 1.0% faster than that in the Control Group. An independent samples t-test was further conducted to examine whether there was a difference in the pre-test reaction times (RT) for tennis tactical decision-making between the Experimental group and the Control Group. The specific results are shown in Figure 9.

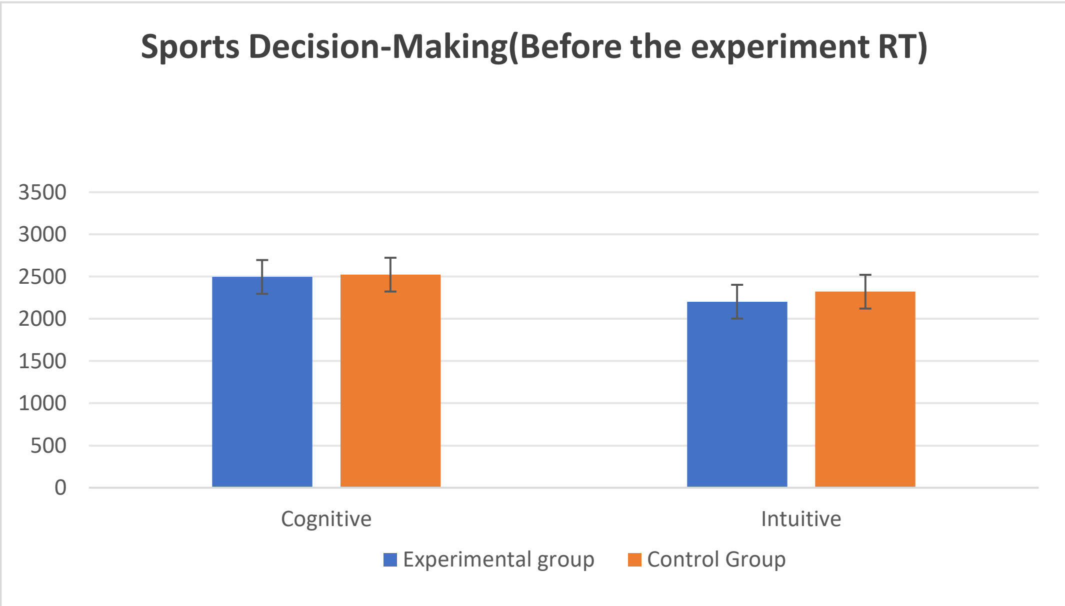

Figure 9: Before the experiment results of the tennis decision-making test (RT) for the Experimental group and the Control Group

As shown in Figure 9, there was no significant difference in reaction time (RT) for tennis tactical decision-making between the Experimental group and the Control Group before the experiment ($P > 0.05$), meeting the experimental conditions.

After the experimen statistical results for reaction time (RT) in tennis decision-making between the Experimental group and the Control Group

To understand the levels of reaction time (RT) for tennis tactical decision-making between the Experimental group and the Control Group after the experimen, descriptive statistics were applied to the RT levels for tennis decision-making in both groups. The results are presented in Table 8.

Table 7
After the experiment statistical results for tennis decision-making reaction time (RT) between the Experimental group and Control Group (N=42)

Dimension	Group	N（人数）	M	SD
Cognitive	Experimental	21	2410.67	228.673
(RT)	Control	21	2490.57	450.276
Intuitive	Experimental	21	2194.05	135.189
(RT)	Control	21	2288.57	222.371

As shown in Table 8, the mean percentage of reaction time (RT) for tennis tactical decision-making in the Experimental group after the experimen was higher than that in the Control Group. An independent samples t-test was further conducted to examine whether there was a difference in the pre-experimental reaction time (RT) levels for tennis tactical decision-making between the Experimental group and the Control Group. The specific results are shown in Figure 10.

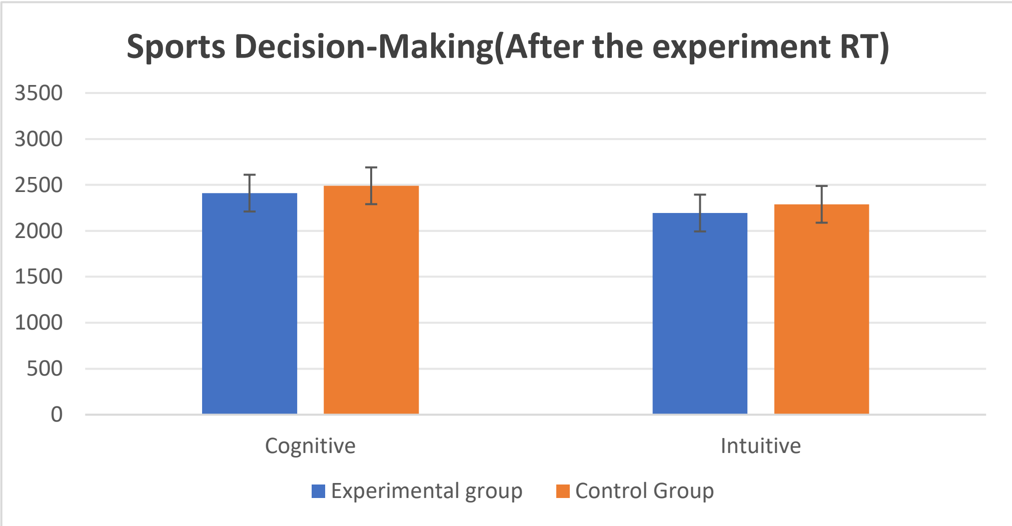

Figure 10: After the experimen statistical results for tennis decision-making reaction time (RT) between the Experimental group and Control Group

As shown in Figure 10, the Experimental group demonstrated superior reaction times (RT) in tennis tactical decision-making compared to the Control Group after the experiment. However, no significant difference was observed between the two groups in reaction times (RT) for the cognitive dimension ($P > 0.05$).

Conclusions

The study concludes that brain executive functions—particularly inhibitory control, cognitive flexibility, and updating—are crucial determinants of effective sports decision-making among collegiate tennis players. The experimental results demonstrated that multitask cognitive training significantly improved athletes' decision-making accuracy and executive control, confirming that targeted mental training can enhance athletic performance beyond physical conditioning alone. While improvements in reaction time were not statistically significant, the overall enhancement in decision-making accuracy underscores the importance of integrating cognitive and motor skill development in sports training programs. These findings highlight the need for a holistic approach to athlete preparation that combines physical practice with cognitive exercises to optimize performance outcomes in competitive environments.

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