



Developing an Integrated Cognitive Training Program to Improve Volleyball Skills for High School Students

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Abstract

Background and Aims: Traditional high school volleyball training methods often focus on repetitive technical drills without adequately addressing cognitive development, potentially limiting students' ability to perform effectively in dynamic competitive environments. This study aimed to develop and evaluate an integrated cognitive training program that simultaneously enhances volleyball technical skills and cognitive abilities in high school students aged 16-18 years.

Methodology: The experimental group received an 8-week integrated cognitive training program combining traditional volleyball skills (passing, serving, spiking, receiving) with cognitive components (perception, attention, reaction, decision-making). The control group underwent conventional training. Assessment tools included four validated volleyball skill tests (Static Jump. Spiking Test, Basic Serve Accuracy Test, Static Passing Test, Dynamic Serve-and-Receive Test; IOC $\geq$ 0.95) and three cognitive ability measures (Visual-Spatial Perception Test, Selective Attention Test, Tactical Decision Simulation Test; IOC $\geq$ 0.90). Pre-test, mid-test (4 weeks), and post-test (8 weeks) Assessments were conducted. Data analysis utilized independent samples t-tests, repeated measures ANOVA, and Bonferroni post hoc tests, with statistical significance set at $p < 0.05$.

Results: The experimental group demonstrated significantly superior performance compared to the control group in spike hit accuracy ($63.00 \pm 6.76\%$ vs $42.70 \pm 12.66\%$, $p < 0.001$), tactical decision-making reaction time ($662.5 \pm 93.620\text{ms}$ vs $820.30 \pm 47.41\text{ms}$, $p < 0.001$), and visual perception accuracy ($85.10 \pm 8.89\%$ vs $74.30 \pm 9.58\%$, $p < 0.001$). Within-group analysis revealed progressive improvements across all measured variables with effect sizes ranging from moderate to large ($\eta^2 G = 0.11-0.50$).



Conclusion: The integrated cognitive training program effectively improved both volleyball technical skills and cognitive performance in high school students, supporting holistic youth sport development approaches.

Keywords: Cognitive Training; Volleyball Skills; High School Students

Introduction

In high schools, volleyball is a universally competitive game that requires athletes to perform various difficult technical skills along with rapid tactical information processing under high time pressure (Zwierko et al., 2024). On the contrary, most of the present volleyball training in high schools was limited to repetitive training of technical skills without integration of cognitive skills, which seems to be a serious lack of gap between training methodologies and the high cognitive load required in volleyball match play (Fleddermann et al., 2019). This training gap, especially, might be a great issue in the high school setting when players undergo the period of the growth spurt (between 16 to 18 years old) that is characterized by high neuroplasticity (Saito & Hatakenaka, 2024).

Previous sport science research found that not only physical and technical skills but also cognitive functions such as perceptual speed, attention and selective attention, decision-making, and reaction time are important factors that can significantly influence athletes' performance in team sports (Masseti et al., 2021). It is even possible to find a meta-analysis that suggests a large effect size for cognitive training interventions on the tactical decision-making performance of adolescent volleyball players with a standardized mean difference (Hedge's g) equal to 0.94 (Aguiar et al., 2020). Moreover, there are multiple studies reporting strong positive relationships between basic cognitive functions and sport-specific skill performance, especially between working memory capacity and motor learning of volleyball players (Bisagno & Morra, 2018). These and other findings provide a rationale for training integration and more emphasis on cognitive skills to enhance overall athletic development.

As previously mentioned, the period between the ages of 16 to 18 might be an ideal time for cognitive-motor integration training, given high levels of neuroplasticity and ongoing development of the executive function system (Aktaş & Yılmaz, 2025). In spite of the potential that this scientific evidence provides, the practical implementation of integrated cognitive training programs in high school volleyball, in general, and especially in Asian school volleyball, in particular, remains relatively low. This is, to a large extent, due to a prevailing traditional coach-centered, repetition-based training approach.

This study was performed to fill this research gap and to create a unique integrated cognitive training program for high school volleyball players by combining the components of traditional





volleyball technical skills and specific volleyball cognitive skills in one holistic training program and implementing it across eight weeks. In doing so, this study will not only provide evidence for training innovation but also guidance for physical education teachers, volleyball coaches, sport development administrators, and others interested in volleyball to best support student athletes in their development towards not only immediate success but also long-term athletic potential.

Objectives

The objectives of this study were as follows:

1. To develop an integrated cognitive training program combining volleyball technical skills (passing, serving, spiking, receiving) with cognitive components (perception, attention, reaction, decision-making) for high school volleyball players aged 16-18 years.
2. To examine the effectiveness of the integrated cognitive training program on volleyball skill performance and cognitive abilities in high school students by comparing results between the experimental group receiving integrated cognitive training and the control group receiving conventional training methods.
3. To compare volleyball skill performance and cognitive ability changes across three measurement periods (pre-test, mid-test at 4 weeks, and post-test at 8 weeks) within the experimental group receiving the integrated cognitive training program.

Literature Review

Sport science has advanced the understanding that successful volleyball performance relies on both technical execution and cognitive skills. However, a gap remains in traditional volleyball training programs, which tend to focus primarily on repetitive skill drills lacking in cognitive challenges (Fleddermann et al., 2019). The purpose of this literature review is to provide empirical evidence for the benefits of integrated cognitive-motor training methods in volleyball and to highlight the existing gaps to be addressed with this study.

Meta-analyses offer strong evidence for the value of cognitive training in volleyball. Aguiar et al. (2020) conducted a systematic review and meta-analysis on the impact of tactical decision-making training in volleyball. The results showed a large effect size (standardized mean difference = 0.94, 95% CI [0.61, 1.27]) for cognitive training methods with adolescent volleyball players. This meta-analysis confirms that well-designed cognitive training leads to significant performance enhancements in volleyball. Conejero-Suárez et al. (2020) also found that a Tactical Games Approach to volleyball significantly affected decision-making performance as well as technical skill execution with moderate to large effect sizes across different measured performance outcomes.





Several studies have identified the link between specific cognitive abilities and volleyball performance. Massetti et al. (2021) found strong positive correlations ($r = 0.68-0.74$) between reaction time, executive control, visual search speed, and volleyball-specific technical skills in adolescent players. Bisagno and Morra (2018) also showed that working memory capacity is a strong predictor of motor learning outcomes (explaining 34% of the variance) in volleyball players. These studies provide evidence that cognitive skills are important for technical volleyball performance, suggesting that training these skills can lead to better overall performance.

Several studies have shown that perceptual-cognitive training can be effective for enhancing volleyball performance. Wang et al. (2022) conducted a study where they implemented an 8-week perceptual decision-making training program and found that their training group significantly improved in anticipatory skills and judgment compared to a control group. Zwierko et al. (2024) found that stroboscopic training resulted in faster reaction times and improved decision-making speed in adolescent volleyball players. Systematic reviews have also found that perceptual-cognitive training in off-court settings can lead to performance improvements in volleyball when well-designed (Fleddermann et al., 2019; Saito & Hatakenaka, 2024).

However, there are important gaps in the literature that are not yet addressed. While several studies have explored the impact of tactical decision-making training or specific cognitive functions on volleyball performance, existing literature is currently limited in training programs that address multiple cognitive functions in an integrated manner, especially in the high school population. In addition, existing studies have examined either elite adult players or specific cognitive components rather than a comprehensive integrated training program for development, and the existing literature provides limited information on the optimal dosage or progression of training or long-term retention of performance improvements.

The current study aims to fill these gaps by developing an 8-week integrated cognitive training program and conducting a pre-post intervention evaluation with a group of high school volleyball players. The findings of this study will provide evidence for the systematic and comprehensive integration of cognitive and motor training for the high school population, where such an approach is currently underutilized despite a strong theoretical and empirical basis.



Conceptual Framework

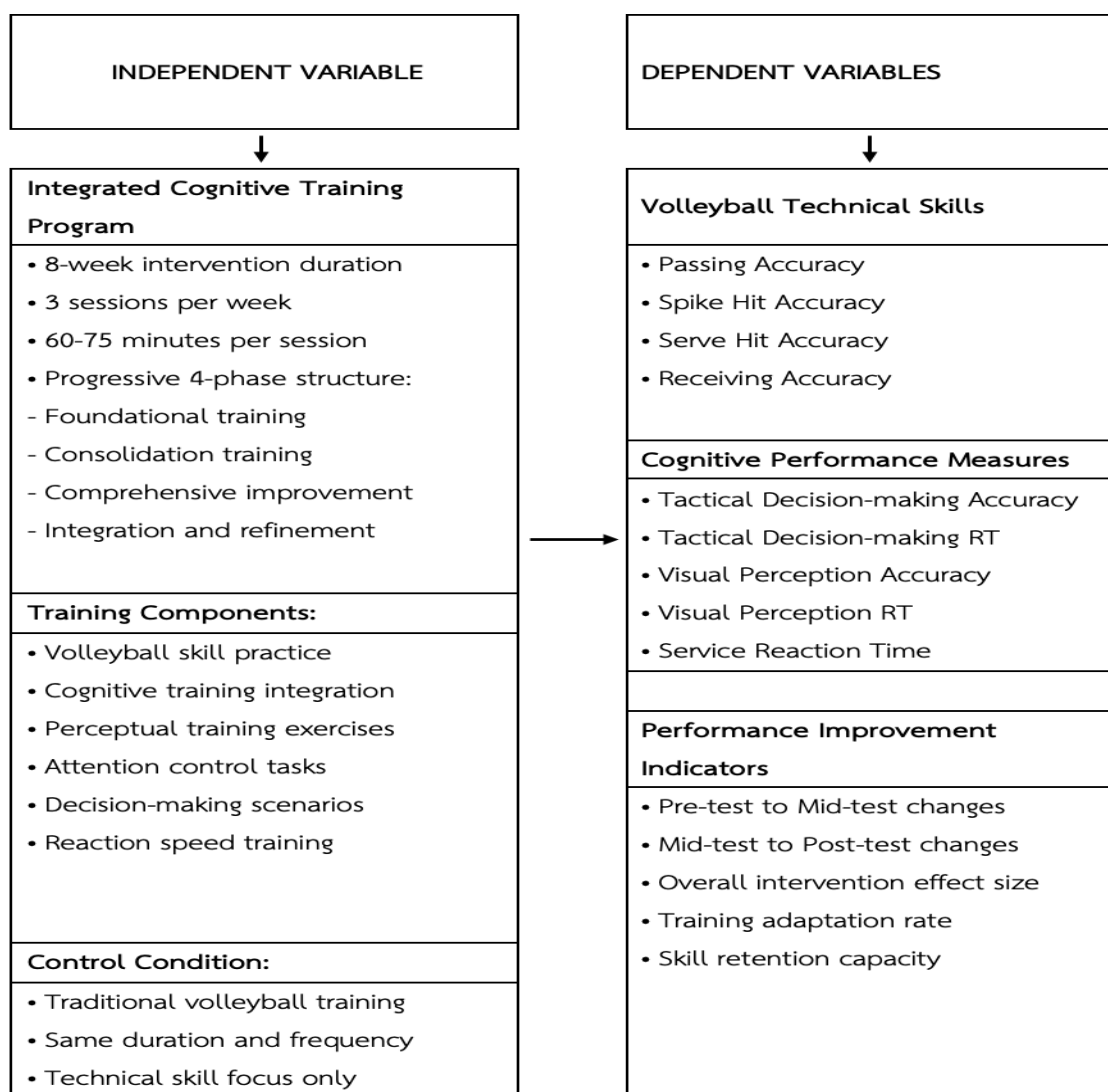


Figure 1 Conceptual Framework

Methodology

Research Design and Ethical Approval

This quasi-experimental study employed a pre-test, mid-test, post-test control group design, approved by the Human Research Ethics Committee of Bangkokthonburi University (Project ID: 2568/204(4)) before data collection. The intervention was conducted over 8 weeks from September to November 2024 at Yangfushan Gaofu Middle School and Wenzhou No. 3 Middle School, Wenzhou City, Zhejiang Province, China.

Population and Sample Selection



The target population comprised 250 male high school students aged 16-18 years enrolled in school volleyball clubs. Using purposive sampling with specific eligibility criteria, 30 participants were selected based on: (1) current school enrollment with active volleyball club membership, (2) medical clearance certification from qualified physicians confirming fitness for physical activity, (3) signed informed consent from both participants and legal guardians, and (4) absence of prior structured cognitive training experience. Following baseline volleyball skills assessment using standardized tests, participants were ranked by performance scores and randomly assigned via lottery method into experimental group (n=15) and control group (n=15), ensuring comparable baseline abilities (Portney & Watkins, 2015). Exclusion criteria included training attendance below 80%, injury occurrence during intervention, or voluntary withdrawal.

Research Instruments

Independent Variable - Integrated Cognitive Training Program: The experimental intervention consisted of an 8-week program (IOC=0.90-1.00) validated by five expert panel members through focus group methodology (Lynn, 1986). The program systematically integrated volleyball technical skills with four cognitive components: (1) Visual-Spatial Perception Training, (2) Selective Attention Control Training, (3) Reaction Speed Enhancement Training, and (4) Tactical Decision-Making Training. Training sessions occurred three times weekly for 60-75 minutes, progressing through four phases: foundational (weeks 1-2), consolidation (weeks 3-4), intensive improvement (weeks 5-6), and integration (weeks 7-8).

Dependent Variables - Performance Assessment Battery: Volleyball Skills Assessment included four validated tests (IOC $\geq$ 0.95): Static Jump Spiking Test, Basic Serve Accuracy Test, Static Passing Test (wall-pass technique), and Dynamic Serve-and-Receive Test. Cognitive Ability Assessment comprised three instruments (IOC $\geq$ 0.90): Visual-Spatial Perception Test measuring accuracy and reaction time, Selective Attention Test evaluating focus maintenance, and Tactical Decision Simulation Test assessing decision-making speed and accuracy under time-constrained conditions.

Data Collection and Analysis

Data collection occurred at three time points: Week 0 (pre-test), Week 4 (mid-test), and Week 8 (post-test). Each 90-minute assessment session was administered by trained assessors blinded to group assignment. The control group received conventional volleyball training, maintaining equivalent frequency and duration, emphasizing traditional technical drill repetition without cognitive integration. Data analysis utilized a statistical computer software package with descriptive statistics (means, standard deviations), independent samples t-tests for between-group comparisons, repeated measures ANOVA for within-group temporal changes, and Bonferroni post





hoc tests for pairwise comparisons. Statistical significance was established at $\alpha=0.05$, with effect sizes calculated using Cohen's d and generalized eta-squared (η^2G) (Cohen, 1988).

Results

Table 1 Pre-test Performance Comparison Between Experimental and Control Groups

Variable	Control Group (n=15)	Experimental Group (n=15)	t	p
Volleyball Skills				
Passing Accuracy (%)	63.3±8.38	62.0±9.60	0.39	0.70
Spike Hit Accuracy (%)	46.0±13.52	46.7±8.80	-0.16	0.87
Serve Hit Accuracy (%)	55.3±9.72	52.3±12.08	0.73	0.47
Receiving Accuracy (%)	56.7±13.05	58.3±13.45	-0.32	0.75
Cognitive Abilities				
TDS Reaction Time (ms)	853.8±89.27	869.1±89.73	-0.47	0.64
TDS Accuracy (%)	63.3±14.02	63.3±9.35	0.00	1.00
VPD Accuracy (%)	72.7±8.37	71.6±10.98	0.29	0.77
VPD RT (ms)	320.8±44.62	337.0±54.34	-0.86	0.40
Service RT (ms)	347.9±38.74	350.8±45.25	-0.18	0.86

Note: No significant differences between groups at baseline (all $p > 0.05$)

Table 2 Post-test Performance Comparison Between Experimental and Control Groups

Variable	Control Group (n=15)	Experimental Group (n=15)	t	p	Cohen's d
Volleyball Skills					
Passing Accuracy (%)	60.00±13.23	72.3±14.25	-2.46	0.02*	-0.90
Spike Hit Accuracy (%)	42.70±12.66	63.0±6.76	-5.49	0.01*	-2.00
Serve Hit Accuracy (%)	54.70±9.90	62.0±8.19	-2.21	0.04*	-0.81
Receiving Accuracy (%)	53.70±16.63	65.3±11.72	-2.22	0.03*	-0.81
Cognitive Abilities					
TDS Reaction Time (ms)	820.30±47.41	662.5±93.62	5.83	0.01*	2.13
TDS Accuracy (%)	67.20±15.26	73.9±16.02	-1.17	0.25	-0.43
VPD Accuracy (%)	74.30±9.58	85.1±8.89	-3.21	0.03*	-1.17
VPD RT (ms)	304.50±38.75	292.6±32.54	0.91	0.37	0.33



Variable	Control Group (n=15)	Experimental Group (n=15)	t	p	Cohen's d
Service RT (ms)	324.10±44.91	303.6±38.22	1.34	0.19	0.49

*Note: $p < 0.05$; TDS = Tactical Decision-making Skill; VPD = Visual Perception and Decision-making; RT = Reaction Time

Table 3 Within Experimental Group Analysis - Repeated Measures ANOVA

Variable	Pre-test (M±SD)	Mid-test (M±SD)	Post-test (M±SD)	F	p	η^2G
Volleyball Skills						
Passing Accuracy (%)	62.00±9.60	72.30±3.30	72.30±14.25	3.63	0.04*	0.14
Spike Hit Accuracy (%)	46.70±8.80	54.70±3.22	63.00±6.76	9.04	0.01*	0.34
Serve Hit Accuracy (%)	52.30±12.08	63.70±2.46	62.00±8.19	5.91	0.01*	0.21
Receiving Accuracy (%)	58.30±13.45	61.00±2.40	65.30±11.72	1.56	0.23	0.06
Cognitive Abilities						
TDS Reaction Time (ms)	869.10±89.73	804.00±22.3	662.50±93.62	21.40	0.01*	0.50
TDS Accuracy (%)	63.30±9.35	68.80±2.99	73.90±16.02	4.19	0.03*	0.11
VPD Accuracy (%)	71.60±10.98	75.70±2.90	85.10±8.89	8.39	0.01*	0.24
VPD RT (ms)	337.00±54.34	305.00±12.52	292.60±32.54	4.17	0.03*	0.15
Service RT (ms)	350.80±45.25	325.00±8.98	303.60±38.22	7.12	0.03*	0.20

*Note: η^2G = Generalized eta-squared effect size; $p < 0.05$

Table 4 Bonferroni Post Hoc Pairwise Comparisons for Experimental Group

Variable	Mean Difference	p-value	95% CI
Spike Hit Accuracy (%)			
Pre vs Mid	-8.00	0.33	[-25.14, 9.14]
Pre vs Post	-16.33	0.01*	[-23.87, -8.79]
Mid vs Post	-8.33	0.16	[-20.45, 3.79]
TDS Reaction Time (ms)			
Pre vs Mid	65.30	0.19	[-35.82, 166.42]
Pre vs Post	206.60	0.01*	[129.34, 283.86]
Mid vs Post	141.30	0.01*	[78.56, 204.04]
VPD Accuracy (%)			





Variable	Mean Difference	p-value	95% CI
Pre vs Mid	-4.11	0.98	[-15.23, 7.01]
Pre vs Post	-13.56	0.01*	[-20.89, -6.23]
Mid vs Post	-9.45	0.06	[-19.24, 0.34]
Passing Accuracy (%)			
Pre vs Mid	-10.30	0.01*	[-18.45, -2.15]
Pre vs Post	-10.30	0.10	[-22.67, 2.07]
Mid vs Post	0.00	1.00	[-12.37, 12.37]

*Note: $p < 0.05$; CI = Confidence Interval

Table 5 Progressive Improvement Data for Key Variables in Experimental Group

Variable	Pre-test	Mid-test	Post-test	Total Change	% Improvement	Change Rate (per week)
Volleyball Skills						
Spike Hit Accuracy (%)	46.70±8.80	54.70±3.22	63.00±6.76	+16.30	+34.90	+2.04 per week
Passing Accuracy (%)	62.0±9.60	72.3±3.30	72.3±14.25	+10.30	+16.60	+1.29 per week
Serve Hit Accuracy (%)	52.3±12.08	63.7±2.46	62.0±8.19	+9.70	+18.50	+1.21 per week
Receiving Accuracy (%)	58.3±13.45	61.0±2.40	65.3±11.72	+7.00	+12.00	+0.88 per week
Cognitive Abilities						
TDS RT (ms)	869.1±89.73	804.0±22.3	662.5±93.62	-206.6	-23.80	-25.80 ms per week
VPD Accuracy (%)	71.6±10.98	75.7±2.90	85.1±8.89	+13.5	+18.90	+1.69 per week
TDS Accuracy (%)	63.3±9.35	68.8±2.99	73.9±16.02	+10.6	+16.70	+1.33 per week
VPD RT (ms)	337.0±54.34	305.0±12.52	292.6±32.54	-44.4	-13.20	-5.55 ms per week
Service RT (ms)	350.8±45.25	325.0±8.98	303.6±38.22	-47.2	-13.50	-5.90 ms per week

Note: Change Rate calculated over 8-week intervention period





Discussion

The purpose of this study was to integrate cognitive training with volleyball technical training and to observe the effect on the cognitive abilities and volleyball technical performance of male high school volleyball players. This study successfully verified that an 8-week integrated cognitive training program can significantly improve the volleyball technical abilities and cognitive abilities of 16-18-year-old male high school volleyball players. The integrated cognitive training group was significantly better than the control group in all performance indices, and the effect size of spike hit accuracy, tactical decision-making reaction time, and visual perception accuracy was the largest (Cohen's $d=2.00$, $d=2.13$, $d=1.17$, respectively). In-group comparison, from pre-test to post-test, the performance of all indices in both groups was significantly improved. The effect size is medium to large ($\eta^2G=0.11-0.50$). In summary, the integrated cognitive training is effective for volleyball technical and cognitive training.

Interpretation: The significant improvement in tactical decision-making reaction time (206.60ms decrease, $p<0.001$) can be explained by Wang et al. (2022), who found that perceptual decision-making training can improve the game judgment ability of young athletes. By combining cognitive training with volleyball technical training, athletes were able to build faster neural pathways, which allowed them to quickly extract and process necessary information to make decisions under time pressure during competitions. In the same way, spike accuracy improved the most. Aguiar et al. (2020) conducted a meta-analysis, which found that the effect size of decision-making intervention on the performance of adolescent volleyball players is $SMD=0.94$. The cognitive training content of visual perception and attention control may allow athletes to anticipate the ball's flight path and hitting angle. The ability to quickly and accurately perceive visual information and control attention was transformed into spike hit accuracy through physical training.

The change trend of most performance indices, from pre-test to mid-test, and the largest improvement was from pre-test to post-test. This was in agreement with the study conducted by Massetti et al. (2021), who found that cognitive functions are highly correlated with volleyball-specific motor skills in adolescent athletes. The changes observed at 4 weeks post-intervention could be explained by early adaptation to fundamental skills, while the full program period (8 weeks) was required to complete the integration of cognitive-motor skills. This finding is in agreement with Saito and Hatakenaka (2024), who conducted a systematic review and found that cognitive-motor dual-task training in adolescents requires an appropriate period of sustained exposure to produce significant effects on reducing interference and increasing efficiency.

Study limitations: First, the sample size in this study was relatively small ($n=30$), and the participants were all from Wenzhou City. This may affect the representativeness of the results





and their applicability to a wider range of adolescent male volleyball athletes with different cultural backgrounds or training experiences. Second, while this study showed significant improvement in a relatively short period of 8 weeks, it did not explore the long-term retention of the training effect or the transfer of the effect to match performance. Third, this study only investigated the training effect on male participants and did not compare the differences in training response between the two genders. Fourth, this study did not conduct follow-up assessments to determine whether the training effect was sustained after the end of the intervention. Fifth, due to limited resources, this study only recruited participants from two schools. Although random assignment was used to form groups, there may be some selection bias. Future studies can overcome these limitations by using larger and more diverse samples, including different genders, and conducting long-term follow-up to better understand the training effect of integrated cognitive training on youth volleyball players.

Recommendations

Recommendations for Practice

1. Physical education teachers and volleyball coaches should implement integrated cognitive training approaches combining technical skills with perception, attention, and decision-making exercises during regular training sessions.
2. Training programs should follow progressive periodization models, beginning with foundational cognitive-motor connections (weeks 1-3) and advancing to complex game-like scenarios (weeks 7-8).
3. Schools should allocate three training sessions weekly (60-75 minutes each) to achieve meaningful cognitive-motor adaptations, balancing academic schedules with athletic development needs.
4. Coaches should incorporate validated assessment tools ($IOC \geq 0.90$) to monitor both technical skill progression and cognitive performance improvements systematically.

Recommendations for Future Research

1. Investigate long-term retention effects beyond 8 weeks and transfer to competitive match performance through longitudinal designs with 6-month and 12-month follow-up assessments.
2. Examine gender-specific responses by including female participants to determine whether integrated cognitive training produces differential effects across sexes.
3. Expand research to larger, multi-regional samples encompassing diverse cultural backgrounds and training histories to enhance the generalizability of findings.





4. Explore optimal training dosage by comparing different intervention durations (4-week, 8-week, 12-week) and session frequencies (2x, 3x, 4x weekly) to identify the minimal effective dose.

5. Investigate individual difference factors (baseline cognitive ability, motor skill proficiency, training history) as potential moderators of training response to inform personalized program development.

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