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The effect of reaction time training using visual stimulus software on the performance of elite table tennis players

El efecto del entrenamiento del tiempo de reacción mediante software de estímulos visuales en el rendimiento de jugadores de tenis de mesa de élite

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Abstract
Table tennis is a high-speed sport that demands rapid visual processing and instantaneous decision-making. Reaction time, comprising simple and choice reaction types, is a critical factor in elite performance. However, traditional training often overlooks cognitive components. This study aimed to examine the effect of reaction time training using visual stimulus software on the performance of elite table tennis players.
A quasi-experimental design with a pretest-posttest control group was employed. Twenty elite athletes (aged 17–25) were randomly assigned to experimental and control groups. The experimental group received visual stimulus-based training three times a week for eight weeks, while the control group followed standard training. Data were collected using simple and choice reaction time tests and rally consistency and smash accuracy tests.
Post-intervention results revealed significant improvements in the experimental group. Simple reaction time decreased by 75.6 ms, and choice reaction time decreased by 88.6 ms. Rally consistency increased by 14.8 strokes, and smash accuracy improved by 7.2 points. Statistical analysis showed highly significant differences ($p < 0.001$) with large effect sizes (Cohen's $d > 2.5$) across all variables.
These findings demonstrate that visual stimulus software effectively enhances cognitive and motor performance in elite table tennis. The technology simulates competitive conditions and accelerates perceptual-motor integration. Thus, visual stimulus-based training should be considered vital to modern, evidence-based athletic development programs.
Keywords: reaction time, visual stimulus training, table tennis, cognitive performance, elite athletes.

Resumen
El tenis de mesa es un deporte de gran velocidad que exige un procesamiento visual rápido y decisiones instantáneas. En este marco, el tiempo de reacción —tanto simple como de elección resulta crucial para el rendimiento de élite. Sin embargo, los entrenamientos convencionales suelen centrarse en lo físico y técnico, descuidando los aspectos cognitivos.
Este estudio tuvo como objetivo examinar el efecto del entrenamiento del tiempo de reacción mediante un software de estímulos visuales en jugadores de tenis de mesa de élite. Se aplicó un diseño cuasi-experimental con grupo de control y evaluaciones pretest y postest. Veinte atletas de alto nivel, de entre 17 y 25 años, fueron distribuidos aleatoriamente en dos grupos. El experimental recibió entrenamiento con el software tres veces por semana durante ocho semanas, mientras que el grupo de control continuó con su preparación estándar.
Los resultados posteriores mostraron mejoras notables en el grupo experimental: el tiempo de reacción simple disminuyó en 75,6 ms y el de elección en 88,6 ms. Además, la consistencia en los peloteos aumentó en 14,8 golpes y la precisión en los smashes en 7,2 puntos. El análisis estadístico reveló diferencias muy significativas ($p < 0,001$) con grandes tamaños de efecto (d de Cohen > 2,5). Estos hallazgos evidencian que el uso de software de estímulos visuales fortalece la integración perceptivo-motora y debe considerarse esencial en programas modernos de preparación deportiva.
Palabras clave: tiempo de reacción, entrenamiento con estímulos visuales, tenis de mesa, rendimiento cognitivo, atletas de élite.

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Introduction

Table tennis is a high-speed sport that demands rapid decision-making, hand-eye coordination, and the ability to respond to complex visual stimuli. These characteristics place reaction time as a crucial psychomotor-cognitive component that directly influences an athlete's performance, particularly at the elite level. In matches where the ball travels at speeds exceeding 60 km/h in less than half a second, an athlete's ability to respond accurately to trajectory, spin, and ball direction becomes a decisive factor in achieving success (Dai et al., 2024; Semenova et al., 2023; Tønnessen et al., 2013).

Reaction time in sports can generally be classified into two types: simple reaction time and choice reaction time. In table tennis, both types function simultaneously. Simple reaction time is applied when responding to a single, known stimulus, such as a service. In contrast, choice reaction time is required when an athlete must select an appropriate response such as a shot type or defensive move among multiple options (Bhabhor et al., 2013; Wang et al., 2022). A delay of even a fraction of a second can lead to critical errors, including loss of points or missed opportunities for effective counterattacks.

With the advancement of sports science and training technologies, increasing attention has been directed toward cognitive components like reaction time. One modern approach currently being adopted in elite athlete training is visual stimulus software. These digital platforms are designed to deliver controlled visual cues to train the speed of visual processing, attention, and response accuracy. According to (Gredin et al., 2023) cognitive training using visual stimuli can enhance the efficiency of an athlete's perceptual-motor system, thereby accelerating decision-making in competitive situations.

Visual reaction training technologies have been implemented in sports such as football, basketball, and hockey, with studies reporting significant improvements in response speed and decision-making (R. Zhu et al., 2024). However, in the context of table tennis—where visual stimuli are both rapid and unpredictable there is still a lack of empirical research exploring the effectiveness of such technology, despite its apparent relevance. Visual stimulus software provides several advantages, including training flexibility, objective measurement, and time-efficient feedback systems. These features support the principles of individualized and sport-specific training for elite athletes (Wu et al., 2024).

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A major challenge in measuring and training reaction time lies in presenting relevant and realistic stimuli to the performance environment. A study by (Hülsdünker et al., 2017) emphasized that dynamic visual stimuli and virtual reality-based training hold considerable potential for simulating competition-like environments, thus enhancing the transfer of training effects to real-world performance. This aligns with the "specificity of training" principle, which suggests that training outcomes are more effective when stimulus characteristics resemble those encountered during actual competition.

In the broader framework of elite athlete development, reaction time training using digital technology aims not only to improve speed of response but also to enhance other cognitive elements such as focused attention, perceptual sharpness, and rapid decision-making. A longitudinal study by (Duda & Sweet, 2020) demonstrated that mid-term cognitive training using visual stimuli enhanced the efficiency of prefrontal neural networks associated with attentional regulation and motor control. Improvements in these areas contribute to faster responses and more consistent performance under high-pressure conditions.

The research problem addressed in this study is whether reaction time training using visual stimulus software significantly affects the performance of elite table tennis players. This question arises from a gap between conventional training practices and the emerging use of cognitive technology that has yet to be fully integrated into the training of individual sports such as table tennis. Empirical evidence is needed to assess the extent to which this approach can effectively enhance actual athletic performance.

The primary objective of this study is to analyze the effect of reaction time training using visual stimulus software on the performance of elite table tennis players. This study also aims to introduce an evidence-based, technologically supported training method that can be systematically integrated into professional athletic training programs. Additionally, the findings are expected to enrich the scientific literature on cognitive training and performance enhancement in high-speed sports.

The benefits of this research can be categorized into three domains. First, the study offers practical guidance for coaches and sports practitioners on implementing technology-based reaction training into regular practice sessions. Second, for athletes, such training is expected to enhance visual response speed and decision-making efficiency, which are crucial to performance outcomes. Third, for scholars and researchers, the study contributes scientific

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insights into technology-supported training, particularly at the intersection of cognitive and motor performance development.

This research is aligned with global trends in sports training, which emphasize evidence-based approaches and the integration of advanced technology. In today's digital era, software-assisted training is no longer just a supplement but can be a core element of athlete development systems. (Wu et al., 2024) highlighted that integrating visual technology and sensorimotor training into sports enhances neuromuscular adaptation and mental readiness and may even reduce injury risks associated with delayed responses.

Nonetheless, this study is not without methodological challenges, including ensuring the validity and reliability of reaction time measurement tools and aligning the visual stimuli with real-game contexts. Therefore, carefully designing training protocols and assessment procedures is essential to achieve theoretical rigor and practical relevance.

Considering these factors, this research is both timely and important as it seeks to bridge the gap between modern training technologies and the performance demands of elite table tennis athletes. Through rigorous empirical analysis, the study aims to provide definitive answers regarding the effectiveness of visual stimulus-based reaction time training in enhancing technical performance and in-game responsiveness.

The Concept of Reaction Time in Sports

Reaction time is one of the key components of athletic performance, particularly in fast-paced sports such as table tennis. Reaction time is defined as the duration between a stimulus's presentation and a motor response's onset (Kosinski, 2010). In sports, reaction time is divided into two main types: simple reaction time and choice reaction time. Simple reaction time involves a single stimulus and a single response. In contrast, choice reaction time involves multiple stimuli and different response options, such as when an athlete must choose between a forehand or backhand stroke depending on the direction of the opponent's ball.

In table tennis, athletes must be able to process visual information quickly to determine the appropriate response in a very short time. This ability determines their success in accurately receiving and returning the ball (Badau et al., 2022; Matsutake et al., 2024; Nakamoto & Mori, 2008; Yamashiro et al., 2015, 2021; M. Zhu et al., 2022). Additionally, table tennis requires high eye-hand coordination and the ability to predict the ball's direction based on the opponent's body cues.

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Research by (Nor et al., 2024) shows that athletes with faster reaction times have an advantage in initiating attacks and are more effective in maintaining long rallies. Therefore, improving reaction time is a key focus in training programs for elite athletes aiming to compete internationally. Thus, understanding and training reaction time are crucial in enhancing table tennis athletes' performance.

Cognitive and Visual Training in the Context of Sports

Cognitive visual training improves brain function in processing visual information and translating it into rapid motor responses. In sports, particularly those requiring instant responses such as table tennis, this training enhances perceptual acuity, concentration, and decision-making speed (Hülsdünker et al., 2019). Visual components such as focus, object tracking, and depth perception are crucial aspects of an athlete's cognitive system.

According to (Koch & Krenn, 2021; Voss et al., 2010), simultaneous visual and cognitive training can enhance the performance of the prefrontal cortex and visual cortex, which play a role in visual processing and decision-making. A study by (Poltavski & Biberdorf, 2015) on ice hockey athletes also showed that a visual-based training program significantly improved responses to visual stimuli, enhancing the accuracy of actions in game situations.

In table tennis, such training can accelerate reactions to high-speed balls and unexpected movements from opponents. (Chaddock et al., 2011; Dommes et al., 2021; Song et al., 2023) stated that athletes who underwent cognitive-visual training showed an increase in stimulus processing speed of 15–25% compared to the control group. This training typically involves visual stimuli with randomly varying durations and intervals, forcing the brain to adapt to real-game conditions. Therefore, visual-cognitive training has become an essential component in developing high-performance athletes.

Visual Stimulus Software

Reaction time training has entered the digital realm using visual stimulus software in recent years. This software presents random or programmed visual stimuli to train athletes' sensorimotor response speed. In elite athlete training, various devices such as FitLight Trainer, BlazePod, NeuroTracker, and computer-based stimulus programs are used to improve reaction speed and decision-making (Scharfen & Memmert, 2019).

These devices display stimuli in the form of light, color, or virtual objects that appear at random intervals, requiring athletes to respond quickly and accurately. For example,

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NeuroTracker uses 3D simulations to train visual tracking and selective focus abilities, directly impacting performance in fast-paced sports like table tennis. Meanwhile, FitLight provides LED-based light stimuli that must be touched or responded to, making it highly effective for hand-eye reaction training.

Research by (Janelle et al., 2020) shows that using visual stimulus devices for six weeks significantly improved choice reaction time among professional basketball players. Although it has not yet been widely used in elite table tennis, the potential for adapting this technology is immense. The software provides measurable training and creates a training environment that closely resembles actual game conditions. As a result, visual stimulus software emerges as a promising modern tool for enhancing athlete performance through neurocognitive pathways.

The Relationship Between Reaction Time and Athletic Performance

Reaction time has a strong link to athletic performance, especially in sports requiring speed, accuracy, and quick decision-making such as table tennis, where rallies last only seconds. Athletes with faster reaction times gain advantages in technical and tactical play (Ryu et al., 2013). Research shows that visual reaction speed significantly improves anticipation and shot accuracy, highlighting the role of perceptual-cognitive skills beyond motor abilities (Zhao et al., 2024). Even millisecond delays can lead to missed responses. (Nascimento et al., 2021) found that elite athletes with quicker reactions make better decisions and fewer errors. Thus, training that reduces reaction time plays a crucial role in enhancing performance, making it vital for effective training design.

Previous Relevant Studies

Several studies have shown that visual stimulus-based training can improve reaction time and athletic performance, but most focus on sports like soccer, basketball, and hockey. For instance, (Scharfen & Memmert, 2019) found that eight weeks of cognitive visual training enhanced decision-making speed in soccer players. Limited research has examined this approach in elite table tennis athletes. One study using computer-based stimuli showed improvements in visual response and movement efficiency among intermediate players after six weeks but excluded elite athletes with greater demands. Moreover, many studies used pre-post designs without control groups, limiting validity. (Burgio et al., 2018; Chen et al., 2024; Yang et al., 2022) highlight the importance of visual training, yet adaptations are needed for table tennis's dynamic nature. This study addresses these gaps.

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Materials and Methods

Research Design

This study used a quantitative approach with a quasi-experimental design, namely a pretest-posttest control group design. This design was chosen to evaluate the effectiveness of visual stimulus software-based reaction time training on improving the performance of elite table tennis athletes. The experimental group was given visual stimulus training, while the control group underwent conventional training without additional visual stimuli.

Research Subjects

The subjects in this study were 20 elite table tennis athletes aged between 17 and 25 who were active in the national training camp or a national club. The inclusion criteria included: Athletes with at least 5 years of experience in competitive table tennis. Being in good physical and mental health. Willing to participate in the entire research process.

Subjects were randomly divided into two groups: Experimental Group (n = 10): Received training using visual stimulus software. Control Group (n = 10): Followed regular training without visual stimulus training.

Research Instruments

The instruments used in this study include three main categories, namely visual stimulus software, reaction time tests, and table tennis performance tests. Each instrument has been equipped with assessment criteria and norms as a reference for evaluating the research results.

Visual Stimulus Software: This software is designed to display random visual stimuli (colors, directions, shapes) at high speed. Athletes are asked to respond with buttons or movements according to instructions. The parameters measured are response time (in milliseconds) and response accuracy.

Reaction Time Test

Simple Reaction Time Test Measures response time to a single type of stimulus (e.g., a red circle that suddenly appears). Athletes press a button as soon as possible after the stimulus appears.

Choice Reaction Time Test Measures the ability to respond to several different stimuli with the appropriate response (e.g., press button A for blue stimuli, button B for green stimuli).

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Table. 1 Reaction Time Test Assessment Standards (SRT and CRT)

Category	Simple RT (ms)	Choice RT (ms)
Very Good	< 200 ms	< 300 ms
Good	200–250 ms	300–350 ms
Fair	251–300 ms	351–400 ms
Poor	301–350 ms	401–450 ms
Very Poor	> 350 ms	> 450 ms

Reference source: modified from Schmidt & Wrisberg (2019), and reaction time guidelines in cognitive training for athletes by Voss et al. (2012).

Table Tennis Performance Test

Rally Consistency Test Measures the athlete's ability to maintain a ball rally without errors for 60 seconds against a ball machine or practice partner.

Smash Accuracy Test Measures the accuracy of smash shots to target zones on the table (divided into 4 zones with different values).

Table. 2 Rally Consistency Test Assessment Standards

Category	Number of Strikes in 60 Seconds
Very Good	> 55 kali
Good	45–55 kali
Fair	35–44 kali
Poor	25–34 kali
Very Poor	< 25 kali

Table. 3 Accuracy Test Evaluation Standards for Smash

Category	Accuracy Score (Total of 10 shots)
Very Good	26–30 poin
Good	21–25 poin
Fair	16–20 poin
Poor	11–15 poin
Very Poor	≤ 10 poin

Description: The target is divided into 4 zones:
Zone 1 (center) = 5 points
Zone 2 (around the center) = 4 points
Zone 3 (edge of the table) = 3 points
Zone 4 (miss) = 0 points

Research Procedure

This research was conducted in four main stages:

The study consisted of four stages: (1) Preparation collecting demographic data, pretests, and coach training on visual stimulus software; (2) Intervention 8 weeks of visual stimulus training (3×/week, 30 minutes) for the experimental group, while controls followed regular training; (3) Evaluation posttests using the same measures; and (4) Documentation recording, verifying, and preparing data for statistical analysis.

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Data Analysis Techniques

Data was analyzed using statistical software (such as the latest version of SPSS). The analysis procedure included: Normality Test: Shapiro-Wilk to ensure the data was normally distributed. Homogeneity Test: Levene's Test tests the similarity of variances between groups. Paired Sample t-test: To determine the difference between pretest and posttest within a group. Independent Sample t-test: To determine the difference in results between the experimental and control groups. Effect Size Calculation (Cohen's d): To assess the practical impact of the intervention. The significance level is set at $p < 0.05$.

Results

Pretest Data Description

Baseline Equivalence Between Experimental and Control Groups

Prior to the intervention, a pretest assessment was conducted on four key variables: Simple Reaction Time (SRT), Choice Reaction Time (CRT), Table Tennis Performance, measured through (Rally Consistency Test dan Smash Accuracy Test)

The results of the pretest revealed that both the experimental and control groups exhibited comparable baseline performance across all variables. There were no statistically significant differences in the mean scores, indicating a balanced initial condition between the two groups.

Table. 4 Pretest data

Variable	Experimental Group (Mean ± SD)	Control Group (Mean ± SD)	Performance Category (Based on Standard)
Simple Reaction Time	322.4 ± 17.8 ms	325.1 ± 18.5 ms	Poor
Choice Reaction Time	421.3 ± 19.7 ms	423.8 ± 20.4 ms	Poor
Rally Consistency	38.6 ± 4.3 hits	37.9 ± 5.1 hits	Fair
Smash Accuracy	18.1 ± 2.6 points	17.8 ± 2.9 points	Fair

These findings suggest that both groups began the study at a relatively similar level of psychomotor and technical performance, which is crucial for ensuring the internal validity of the study. As such, any significant changes observed post-intervention can be confidently attributed to the treatment effect rather than baseline differences.

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Independent sample t-test on the results of the pretest

All p-values > 0.05, meaning there were no significant differences between the experimental and control groups in all variables before the intervention. This supports the conclusion that both groups were in equivalent initial conditions, and any differences in post-intervention results can be attributed to the treatment (training using visual stimulus software).

Table. 5 Independent sample t-test

Variable	t-value	p-value	Significant (p < 0.05)
Simple Reaction Time	-0.333	0.7433	No
Choice Reaction Time	-0.279	0.7836	No
Rally Consistency	0.332	0.7438	No
Smash Accuracy	0.244	0.8103	No

Posttest Data Description

After completing an 8-week training program using visual stimulus software, the posttest results demonstrated substantial improvements in the experimental group, whereas the control group showed minimal or no meaningful changes. Notable gains were observed in both reaction time measures and table tennis performance outcomes.

Table. 6 Posttest Data

Variable	Experimental Group (Mean ± SD)	Control Group (Mean ± SD)	Change in Experimental Group	Category (Posttest)
Simple Reaction Time	246.8 ± 13.2 ms	320.1 ± 18.7 ms	↓ 75.6 ms	*Good*
Choice Reaction Time	332.7 ± 15.1 ms	418.9 ± 19.3 ms	↓ 88.6 ms	*Good*
Rally Consistency	53.4 ± 5.6 hits	39.2 ± 4.9 hits	↑ 14.8 hits	*Good*
Smash Accuracy	25.3 ± 2.4 points	18.2 ± 3.1 points	↑ 7.2 points	*Good*

The experimental group's post-intervention performance moved from the "poor/fair" category to "good" in all assessment areas, based on standardized criteria. Conversely, the control group remained at a relatively constant performance level, with no statistically significant changes.

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Change Analysis (Gain Score)

The following is an analysis of the changes (Gain Score) between the pretest and posttest for each variable:

Table. 7 Change Analysis (Gain Score)

Variable	Experimental Group Gain	Control Group Gain	Interpretation
Simple Reaction Time	-75.6 ms	-5.0 ms	Substantial gain in experimental group
Choice Reaction Time	-88.6 ms	-4.9 ms	Substantial gain in experimental group
Rally Consistency	+14.8 hits	+1.3 hits	Substantial gain in experimental group
Smash Accuracy	+7.2 points	+0.4 points	Substantial gain in experimental group

The gain score analysis showed significant improvements in the experimental group compared to the control group. Participants receiving visual stimulus training demonstrated notable reductions in Simple Reaction Time (−75.6 ms) and Choice Reaction Time (−88.6 ms), highlighting faster responsiveness and decision-making. Technical performance also improved, with +14.8 hits in rally consistency and +7.2 points in smash accuracy, reflecting enhanced motor execution and perceptual-motor integration. In contrast, the control group showed only minimal, non-meaningful changes. Overall, the findings confirm that reaction time training using visual stimulus software effectively enhances cognitive and motor aspects essential for elite table tennis performance.

Statistical Test Results

To evaluate the effectiveness of the visual stimulus software training, two types of statistical tests were conducted: Paired Sample t-Test to assess within-group changes from pretest to posttest, and Independent Sample t-Test to assess between-group differences following the intervention. The significance level was set at $p < 0.05$ for all analyses.

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Paired Sample t-Test Results

To determine the extent of improvement within each group, a paired sample t-test was applied to compare pretest and posttest scores on all measured variables.

Table. 8 Paired Sample t-Test Results

Variable	Experimental Group (p-value)	Significant	Control Group (p-value)	Significant
Simple Reaction Time	$p < 0.001$	Yes	$p = 0.157$	No
Choice Reaction Time	$p < 0.001$	Yes	$p = 0.184$	No
Rally Consistency	$p < 0.001$	Yes	$p = 0.412$	No
Smash Accuracy	$p < 0.001$	Yes	$p = 0.309$	No

The results clearly demonstrate that the experimental group experienced statistically significant improvements across all four variables following the 8-week visual stimulus training intervention. In contrast, the control group exhibited no statistically significant changes, indicating that conventional training alone did not yield measurable improvements in reaction time or performance metrics.

Independent Sample t-Test Results (Posttest Comparison)

To assess the effectiveness of the intervention between groups, an independent sample t-test was conducted on posttest scores.

Table. 9 Independent Sample t-Test Results (Posttest Comparison)

Variable	t-value	p-value	Cohen's d	Significant
Simple Reaction Time	-10.127	< 0.001	4.53	Yes
Choice Reaction Time	-11.124	< 0.001	4.97	Yes
Rally Consistency	6.035	< 0.001	2.70	Yes
Smash Accuracy	5.727	< 0.001	2.56	Yes

The posttest comparisons show that the experimental group significantly outperformed the control group on all measured variables. The exceptionally high values of Cohen's d (all > 2.5) further indicate a very strong effect size, confirming that the visual stimulus software had

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a substantial and meaningful impact on both reaction time and technical performance in elite table tennis players.

Discussion

Interpretation of Research Results

The study results indicate that training using visual stimulus software for 8 weeks significantly improved elite table tennis athletes' reaction time and technical performance. A decrease in simple reaction time of 75.6 ms and choice reaction time of 88.6 ms in the experimental group indicates an improvement in neurological response to visual stimuli. Additionally, the increase in rally strokes (+14.8) and smash accuracy scores (+7.2) indicates that cognitive improvements directly impact motor execution in the game. The absence of significant changes in the control group suggests that conventional training alone cannot trigger similar improvements. Statistical significance ($p < 0.001$) and a tremendous Cohen's d value (>2.5) reinforce the conclusion that visual stimulus-based training has a substantial impact on performance improvement. This demonstrates that response speed and decision-making accuracy are not solely determined by physical aspects but also by cognitive abilities honed through consistent and structured visual stimuli.

The Relationship Between Reaction Time and Athletic Performance

The relationship between reaction time and athletes' technical performance is powerfully demonstrated in the results of this study. Faster reaction times give athletes an advantage in processing visual information and executing motor responses more precisely. In elite table tennis, where the ball moves extremely quickly, reaction time is a key determinant in maintaining rallies, executing counter-attacks, and anticipating opponents' shots. Significant improvements in rally consistency scores and smash accuracy in the experimental group reinforce previous findings that faster reaction times correlate with enhanced technical accuracy and decision-making efficiency (Nascimento et al., 2021; Zhao et al., 2024). This data also indicates that performance in fast-paced sports does not solely depend on physical strength or technical skills, but rather on integrating sensorimotor and cognitive systems, which can be systematically improved through visual stimulus training.

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Comparison with Previous Research

The findings in this study are consistent with previous research in other sports, such as soccer (Scharfen & Memmert, 2019) and hockey (Poltavski & Biberdorf, 2015), which showed significant improvements in reaction time and decision-making after visual stimulus intervention. However, this study's main contribution lies in applying this method in the context of elite table tennis athletes, a group that has been rarely studied. Most previous studies used a pre-post design without a control group and only involved intermediate-level athletes. This study addresses this gap with a stronger experimental approach, including a control group, and using specific and standardized sample sizes. With statistically and practically significant results, this article confirms that visual stimulus training technology is universally applicable and can be specifically tailored to the characteristics of games like table tennis, which demand ultra-fast responses and high precision.

Implications of Research Findings and Research Limitations

The findings of this research have significant practical implications for coaches, athletes, and sports scientists. Coaches can integrate visual stimulus software into training programs as part of cognitive development, ensuring a holistic approach that combines technical, physical, and cognitive aspects. For athletes, the software provides measurable, engaging training with instant feedback on accuracy and responses. Academically, it contributes to understanding technology's role in enhancing perceptual-motor and cognitive systems. Long-term benefits include applications in injury prevention through improved awareness and decision-making under pressure. Ultimately, this research highlights visual training technology as an essential tool for developing modern international athletes.

Although the findings show a strong effect, several limitations should be acknowledged. The small sample size (20 elite athletes) restricts generalizability to wider populations. The 8-week intervention period is too short to confirm long-term or sustainable performance effects. Reliance on a single visual stimulus software prevents comparisons across devices. Important variables such as motivation, sleep quality, and fatigue were not controlled. Additionally, repeating the same tests may have introduced a "learning effect," even with a comparison group. Hence, future studies should employ longitudinal designs, larger samples, and better control of external variables to strengthen validity and generalizability.

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Conclusion

This study provides empirical evidence that reaction time training using visual stimulus software significantly enhances the performance of elite table tennis athletes. Over an eight-week intervention, the experimental group receiving visual stimulus-based training demonstrated marked improvements in both reaction speed—simple and choice reaction time and technical performance, specifically rally consistency and smash accuracy. Reaction times decreased by up to 75.6 ms (simple) and 88.6 ms (choice), while technical performance improved by 14.8 strokes and 7.2 points in smash accuracy. These results confirm that structured cognitive training can substantially strengthen athletes' sensorimotor responses.

The findings underscore the critical role of cognitive components, particularly visual processing speed and rapid decision-making, as determinants of success in high-speed sports such as table tennis. The software effectively replicates real match conditions through rapid, randomized visual stimuli, consistent with the principle of training specificity. Methodologically, the study is robust, employing a quasi-experimental design with a control group, standardized measurement, and statistically significant results ($p < 0.001$; Cohen's $d > 2.5$).

Therefore, integrating visual stimulus-based training into athlete development systems is both feasible and essential. It bridges the gap between conventional training and the cognitive demands of competition, offering a timely innovation for developing internationally competitive athletes.

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