Journal of Multidisciplinary Healthcare

Dovepress
Taylor & Francis Group

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ORIGINAL RESEARCH

The Effect of Task Cognitive Difficulty on Perceptual-Cognitive Indicators: Evidence on the Relationship Between Challenge Point Framework (CPF) and Cognitive Development in Table Tennis Beginners

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Introduction: Motor learning, in addition to influencing the practice of physical activity, affects cognitive skills related to prediction and decision. One key principle in sports training is designing exercise programs that optimize cognitive-motor performance, based on the Challenge Point Framework (CPF). The aim of this study is to investigate the effect of different levels of work difficulty on cognitive-perceptual indicators in table tennis beginners.

Methods: Forty-two female beginners in table tennis (ages 20–35) were divided into high, moderate, low task difficulty, and control groups based on pre-test scores of attention networks. The intervention consisted of 8 daily training sessions, each lasting 30 minutes. Pre- and post-test comparisons were made to evaluate changes in cognitive-perceptual performance.

Results: Post-test results showed improvements in executive control of attention and cognitive effort across all groups. But there was no significant difference between the groups.

Discussion: These findings suggest that cognitive task difficulty, much like functional difficulty, aligns with predictions from the CPF, enhancing executive control and cognitive effort, and thereby supporting motor learning.

Conclusion: Cognitive difficulty, like functional difficulty, takes advantage of the challenge point framework and improves cognitive–cognitive indicators.

Keywords: task difficulty, attention networks, cognitive effort, challenge point, table tennis

Introduction

Motor learning is a problem-solving process in which developing an appropriate movement pattern is essential to achieve the desired goal.[1] Motor skill learning refers to the improvement of motor performance through training,[2] which involves the interaction between motor and cognitive systems.[3] However, limited training time and minor improvements in each session emphasize the importance of getting the most out of each training session. The Challenge Point Framework (CPF), developed by Guadagnoli and Lee,[1] is a theoretical model that explains how practice conditions influence motor learning based on the learner's experience level and task difficulty. The CPF categorizes task difficulty into two types: nominal difficulty (the inherent difficulty of the task) and functional difficulty (the difficulty experienced by the learner, which varies with skill level and context).

Received: 4 August 2024
Accepted: 11 January 2025
Published: 25 January 2025

Research has demonstrated that task difficulty plays a critical role in motor learning. For instance, Bootsma et al[2] found that increasing the difficulty of a motor task, such as tracking a mirror star, led to improved learning rates and enhanced neural mechanisms, especially in older adults. Similarly, Sanli and Lee[4] designed a training protocol based on the Challenge Point Hypothesis and concluded that overly challenging tasks hindered learning, while tasks better matched to the learner's current skill level led to more effective learning. Akizuki and Ohashi[5] further investigated task difficulty and found that a moderate level of difficulty during training produced optimal motor learning outcomes, as compared to tasks that were either too easy or too hard.

In contrast, some studies suggest that highly challenging tasks can also benefit motor learning under certain conditions. For example, Raisbeck et al[6] found that an external focus of attention enhances learning and performance more than an internal focus in an accuracy-speed task. Despite inconsistent findings regarding task difficulty, their study showed that participants maintained the accuracy and consistency across targets, regardless of task difficulty. Ong Nicole et al[7] manipulated target size in a dart-throwing task and found that participants who practiced with a larger target reported greater confidence, but these practice effects did not translate to long-term retention.

Elghoul et al[8] suggested that adjusting task difficulty progressively and varying the frequency of feedback (knowledge of results, KR) could create more optimal cognitive demands for learning. Guadagnoli and Lindquist[9] emphasized that the level of challenge during practice should match the learner's skill level, and as the learner becomes more proficient, the challenge should increase. Early in learning, tasks should have little variety, but as proficiency grows, task variability should increase to maintain an appropriate level of challenge.

Motor learning involves a variety of cognitive processes, ranging from low-level mechanisms that keep movements calibrated to high-level cognitive decisions required in novel situations.[10]

According to the CPF, task difficulty also includes cognitive-perceptual indicators,[5] such as anticipatory judgments and decision-making.[3] These indicators are linked to cognitive skills like attention networks and cognitive effort, which vary according to the task's conditions and the learner's skill level.

Meanwhile, focusing plays a critical role in cognitive processes, including memory, perception, and decision-making.[11] Researchers have identified three primary brain networks that govern attention: alerting, orienting, and executive control.[12,13] Alerting involves maintaining a state of readiness for incoming stimuli,[14] while orienting refers to selecting relevant sensory input and aligning attention with it.[15] Executive control helps regulate conflicts during planning, decision-making, and action inhibition.[16]

Wang, Guo and Zhou[17] examined attentional networks in table tennis players and non-athletes, finding that table tennis players demonstrated enhanced executive control of attention networks. Interestingly, no significant differences in the alertness or attention orientation networks were observed between the two groups. Fumagalli et al[18] echoed these findings, noting that both physical activity and executive functions can be developed through regular practice and engagement with challenging tasks. Maurer and Roebers[19] found that more challenging motor tasks relied more heavily on executive functions, underscoring the importance of task difficulty in the relationship between motor skills and cognitive functions.

Cognitive training has also been shown to improve the efficiency of the executive control attention network in table tennis players[20] The CPF aligns with theories on cognitive load and problem-solving in educational contexts, where optimal challenges are critical for learning and memory retention.[21] Additionally, self-controlled practice, where learners adjust task difficulty themselves, has been shown to improve motor accuracy and movement patterns in young athletes.[22]

In another study, Abdollahipour et al[23] found that the type of attentional focus, whether internal or external, did not significantly affect dart throwing performance in young girls.

External focus on dart flight was more beneficial than other attention focus instructions in the transfer test. This suggests that the optimal external focus distance for learning may change when a goal-directed task is performed on a fixed or moving target. The study of Frikha and Alharbi[24] investigated whether a combined educational program, including visual arts activities and motor accuracy exercises, compared to motor accuracy training alone, could improve children's performance in the areas of fine motor coordination, selective attention, and reaction time.

In summary, while the CPF has traditionally focused on motor performance, recent research suggests that cognitive-perceptual indicators, such as attention networks and decision-making, also play a critical role in motor learning. In this study, we aim to extend the CPF by examining how manipulating the attentional network of executive control affects cognitive-perceptual outcomes in table tennis beginners. Based on the aforementioned research, we hypothesize that increasing cognitive task difficulty will improve cognitive-perceptual indicators in novice table tennis players.

Materials and Methods

Participants

In this study, 42 beginner female table tennis players aged 20 to 40 years were selected as participants. The sample size was determined using G*Power software (n=40, power (1-β err prob)=95%, α err prob=0.05, effect size=0.35,[25] based on prior research by Sanli and Lee).[4] Initially, 48 participants were recruited, but 6 individuals withdrew from the study due to personal reasons, leaving a final sample of 42 participants.

The participants were divided into four homogeneous groups (low difficulty, medium difficulty, high difficulty, and control) based on their average scores on attention network tests. Each group consisted of 12 participants.

A self-report questionnaire was used (Box 1) to determine the inclusion/exclusion criteria which are as follows: the participants were right-handed (according to the participants' self-report) and table tennis beginners (they had no experience playing racket sports and did not follow any sport professionally). Participants were selected based on their responses to a questionnaire. This questionnaire assessed criteria such as having regular or corrected vision with glasses, not having a neurological disease, and not taking drugs affecting vision and attention. The exclusion criteria were insufficient sleep the previous night and lack of concentration during the experimental sessions. The participants signed informed consent forms before taking part in the study. This study was approved by the ethics review board at Shahid Beheshti University review board (REC.1400.209).

Implementation of the Exercise Protocol

The training protocol consisted of 8 sessions, each lasting 30 minutes.[20] Each session was divided into three parts: 10 minutes of warm-up exercises (Box 2), 15 minutes of designed training (table tennis forehand) specific to each group (Table 1), and 5 minutes of cool-down exercises (Box 2). The tasks involved different levels of cognitive difficulty. The executive attention mechanism was engaged in various ways, such as resolving conflicts when presented with distracting stimuli, maintaining and manipulating information in working memory,[26] and managing performance across multiple tasks (eg, distributed attention; Memmert).[27] To target these mechanisms, visual-spatial working memory training was incorporated using a ball-throwing device for the experimental groups.

Experimental groups: Participants in the experimental groups practiced sending balls to predetermined areas, with daily variations in ball speed and the number of balls thrown per minute (Figure 1). In fact, the structure of the training sessions was designed to gradually increase their difficulty, began with simple cognitive exercises, and moved towards more challenging homework designed to increase the cognitive task.

Box 1 Administered Self-Report Questionnaire

Name or password
Phone number
Date of birth
Superior hand
Do you practice table tennis regularly?
Do you have normal vision or do you use appropriate glasses if your eyes are weak?
Have you ever had a nervous illness and visited a doctor?
Have you ever used attention control medication?

Box 2 Warm Up and Cool Down Exercises for Table Tennis

Warm up
2 minutes of jogging. 7 minutes of easy mobility drills (Stretching, High knees and butt kicks will prepare your leg muscles and joints, arm circles will warm up your arms and shoulders, doing lateral movement (with your knees bent) and carioca) 1 minute of jogging, then walking.
Cool Down Stretching movements for the whole body

Table 1 Exercise Protocol

Groups Training Session		Low Difficulty	Moderate Difficulty	High Difficulty
1	• Sending the ball to the forehead area and returning • Frequency of balls • Speed of the ball	• 2 distinct numbered areas • 30 balls per minute • 5 meters per second	• 2 distinct numbered areas • 30 balls per minute • 6 meters per second	• 2 distinct numbered areas • 30 balls per minute • 7 meters per second
2		• 3 distinct numbered areas • 30 balls per minute • 5 meters per second	• 3 distinct numbered areas • 30 balls per minute • 7 meters per second	• 3 distinct numbered areas • 40 balls per minute • 8 meters per second
3		• 4 distinct numbered areas • 30 balls per minute • 6 meters per second	• 4 distinct numbered areas • 40 balls per minute • 7 meters per second	• 4 distinct numbered areas • 50 balls per minute • 8 meters per second
4		• 5 distinct numbered areas • 30 balls per minute • 6 meters per second	• 5 distinct numbered areas • 40 balls per minute • 8 meters per second	• 5 distinct numbered areas • 50 balls per minute • 9 meters per second
5		• 6 distinct numbered areas • 30 balls per minute • 7 meters per second	• 6 distinct numbered areas • 50 balls per minute • 8 meters per second	• 6 distinct numbered areas • 60 balls per minute • 9 meters per second
6		• 7 distinct numbered areas • 30 balls per minute • 7 meters per second	• 7 distinct numbered areas • 50 balls per minute • 9 meters per second	• 7 distinct numbered areas • 60 balls per minute • 10 meters per second
7		• 3–7 distinct numbered areas • 40 balls per minute • 7 meters per second	• 3–7 distinct numbered areas • 60 balls per minute • 9 meters per second	• 3–7 distinct numbered areas • 70 balls per minute • 11 meters per second
8		• 3–7 distinct numbered areas • 50 balls per minute • 5 meters per second	• 3–7 distinct numbered areas • 60 balls per minute • 10 meters per second	• 3–7 distinct numbered areas • 70 balls per minute • 12 meters per second

https://doi.org/10.2147/JMDH.S472671

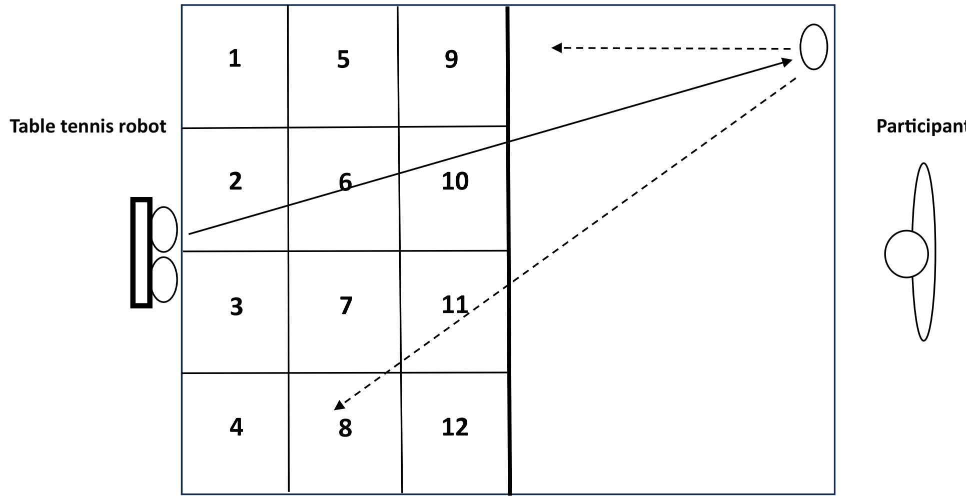

Figure 1 An example of a training plan.

Control Group: The control group performed the same structure of training (10 minutes of warm-up, 15 minutes of routine exercises, and 5 minutes of cool-down) but with a simpler task. They received 30 balls per minute at a speed of 3 $m{\bullet}s^{-1}$ aimed at the forearm area and returned the ball to the forehand area.

Data Collection

Participants were introduced to the research environment, software, and tasks upon arrival at the research site. After signing the informed consent forms, they underwent a familiarisation phase.

Pre-Test

During the pre-test phase, participants sat 50 cm away from a 14-inch monitor in a dark room.[28] They completed the Attention Network Test (ANT) in four blocks over 20 minutes, using the index fingers of both hands to respond. Following a brief rest to eliminate any residual effects of the ANT test, participants completed the cognitive effort test. In this test, participants placed their index finger on the space bar and pressed it when the letter "X" appeared on the screen. Finally, they completed the working memory test.

Based on the average scores from the three attention networks, participants were divided into four homogeneous groups, following the principle of homogenisation, which states that all groups should have comparable attention network scores from the start. The groups were as follows: Executive control group with low difficulty (n=11), Executive control group with medium difficulty (n=10), Executive control group with high difficulty (n=11), and Control group (routine exercise, n=10).

Training Phase

In the acquisition phase, each group performed table tennis forehand exercises for 30 minutes per session, according to the training program, for a total of 8 sessions.

Post-Test

During the post-test phase, participants repeated the ANT test and the cognitive effort assessment, using the same procedures as in the pre-test.

Tasks and Tools

Attentional Network Test

Fan et al[13] were behind the creation of the attentional network test (ANT), and the validity of its re-test was reported to be 0.87 (Figure 2). To take the attention network test, the participants sat in a dimly lit room 80 cm away from a 14-inch

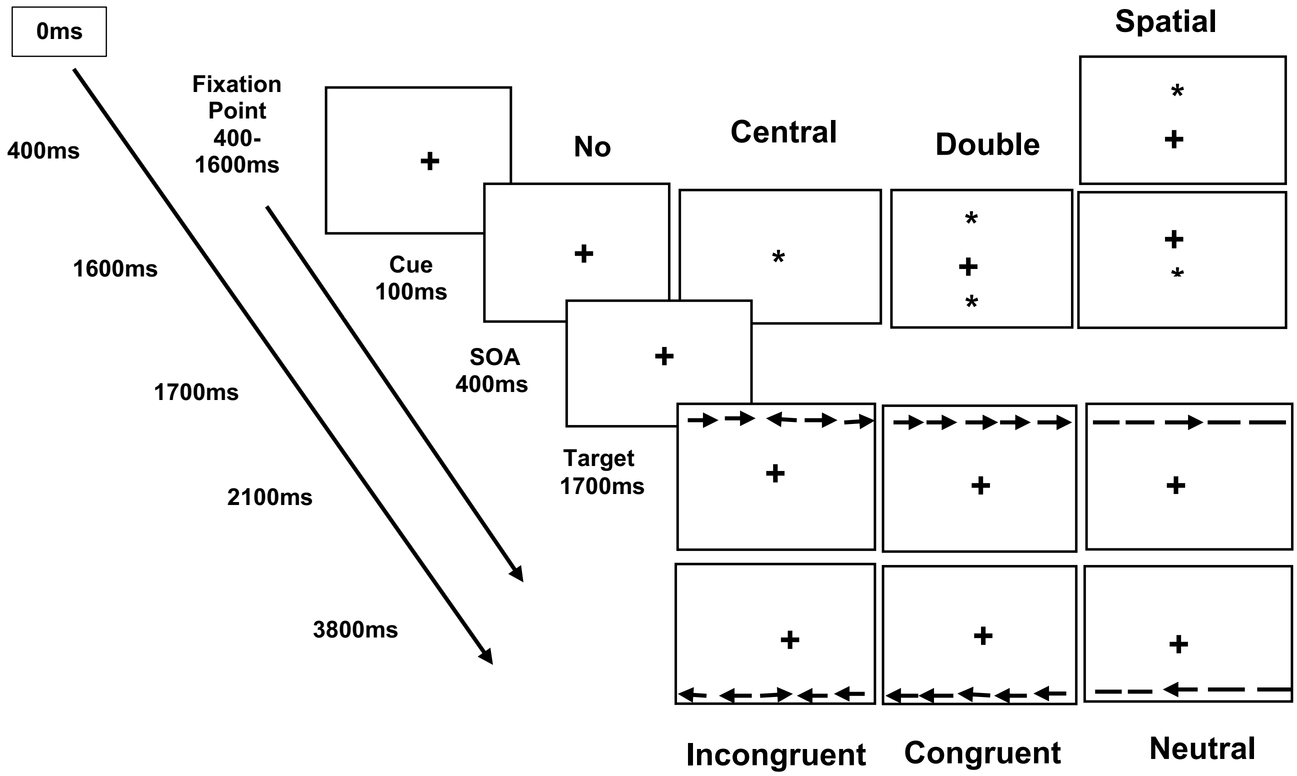

Figure 2 Attention network test plan.
Notes: The * indicates the sign, the + symbol indicates fixation in the center of the screen, and → indicates the direction.

monitor in front of it. Participants were required to focus their eyes on the central crosshair (+) throughout the experiment.

The participant was instructed to observe five arrows displayed on the monitor. Participants were to use the left or right arrow key to indicate the direction shown by the central arrow. A "+" sign was positioned at the centre of the screen, and the arrows would appear only above or below the "+" sign. Participants were directed to look only at the "+" and not shift their eyes to the arrows during the test. Sometimes, one or two asterisks briefly appeared before the arrows. When the * appeared, the arrows would appear half a second later. If only one "*" appears and it is positioned above or below the "+", it indicates the location where the arrows will appear. The task is to press the left or right arrow key to match the direction shown by the middle arrow. This test measures RT. Fast and error-free responses are important to us. There are four blocks of effort, with short rests in between, and the first block is intended for training and lasts for two minutes. During the training block, an error message will appear if you make an error. If it does not appear, you will know that you performed correctly. No feedback is provided on the results during the first two blocks. The results obtained are based on your performance in the last two blocks.

The efficiency of three attention networks is obtained based on the performance of individuals according to the following formula: Alerting = RT on no cue trials − RT on double cue trials, Orienting = RT on central cue trials − RT on spatial cue trials, Conflict = RT on incongruent trials − RT on congruent trial.

In examining the reliability of this test, Ishigami et al[29] showed that all network scores were significantly reliable ($r = 0.29$, 0.70, and 0.68, for alerting, orienting, and executive networks, respectively; p's < 0.05).

Cognitive Effort Test

Continuous performance tests (cognitive effort assessment, CPT tests[30]) require the inhibition of unwanted responses and continuous monitoring of target responses. In this test, the person must move (pressing the key) in front of the target stimulus in a series of provided and non-target stimuli.

The test generates the following data: the right answer to the target, the mean response time for correct answers, the wrong answer to the non-target, and the absence of a response to the target (deletion error). Visual stimuli were presented consecutively with a fixed time interval of 920 ms. Whenever the letter "X" (target) appeared, the subjects had to respond by pressing a lever and refrain from responding if any other letter appeared (CPT type X). In this test, two types of errors (elimination and commission) were measured.[31] In Iran, the validity of this test has been reported between 0.59 and 0.93.[32]

Black Corsi Software

The Black Corsi test[33] was used to check working memory. This software is designed to include blocks with nine cubes that appear regularly on the monitor screen. At first, the person observes the number of cubes and the order of their appearance for a few seconds. The cubes are then hidden from the monitor and reappear. This time, one must remember the location of the cubes according to the order and click on them. All participants must do the first step correctly to get to the next steps. As the number of cubes in each level increases, the task's difficulty also increases, so it becomes more difficult to remember the cubes' location and order.

The validity and reliability of this test has been reported by the Veena Institute to be above 0.83. In Iran, Entezari, Abdoli, and Farsi[34] reported its validity and reliability as 0.86 and 0.81, respectively.

TW2700-S9 Table Tennis Robot

This robot was manufactured in China. It has two machine heads and two spinning structures. The robot has advanced capabilities, including top and bottom spinning, self-programming, single or combined programs, and intelligent control modes. The device can throw 18 points on the table. Nine areas are directed backwards of the table, and 9 areas are directed at the front of the table. The sequence of throwing balls from this device is 30 to 100 throws per minute. The speed of throwing the ball from the device varies from 2 to 40 $m \cdot s^{-1}$. A standard table tennis table, 100 white tournament balls and a suitable racket were used.

Data Analysis

The researchers first used a one-way ANOVA to check for differences in attention network efficiency during the pre-tests. They confirmed that the data were normally distributed using the Shapiro–Wilk test before running a two-way repeated measures ANOVA. This analysis compared the performance of the high, moderate, low, and control groups performed on the assessments at both pre-test and post-test time points.

We used the Bonferroni post-hoc test to elucidate the differences within the groups. Statistical analysis was done using SPSS Statistics 26.0.0 software and drawing tables and graphs using Excel software. The researchers used Cohen's guidelines to interpret the effect sizes. According to these guidelines ($\eta p2<0.06$=small effect, $0.06\leq\eta p2<0.14$ medium effect and $\eta p2\geq0.14$=large effect).[35] They set the significance level at $p \leq 0.05$.

Results

An ANOVA with repeated measures test was used to evaluate ANT. The results of the ANOVA with repeated measures of the warning attention network showed that the main effect of training time (pre-test and post-test, p=0.860) and the main effect of the interaction between groups (control, low difficulty, moderate difficulty, high difficulty, p=0.472) were not significant. The main effect of the group was significant ($F(3,38)=3.393$, $p=0.028$, $\eta p2=0.21$, large effect).

There was a significant difference between the warning attention network in the four groups, in which we used the Bonferroni post-hoc test to clarify the difference between these conditions. These results show that the control group performed better than the moderate difficulty group in responding to the warning sign (Figure 3).

The results of variance analysis with repeated measures test of orientation attention network showed that the main effect of training time (pre-test and post-test, p=0.740), the main effect of group (p=0.710) and the main effect of interaction between groups and time exercise (p=0.504) were not significant. The results of ANOVA with repeated measures test of orientation attention network showed that the main effect of training time (pre-test and post-test), the main effect of group and the main effect of interaction between groups and time exercise (p=0.504) were not significant.

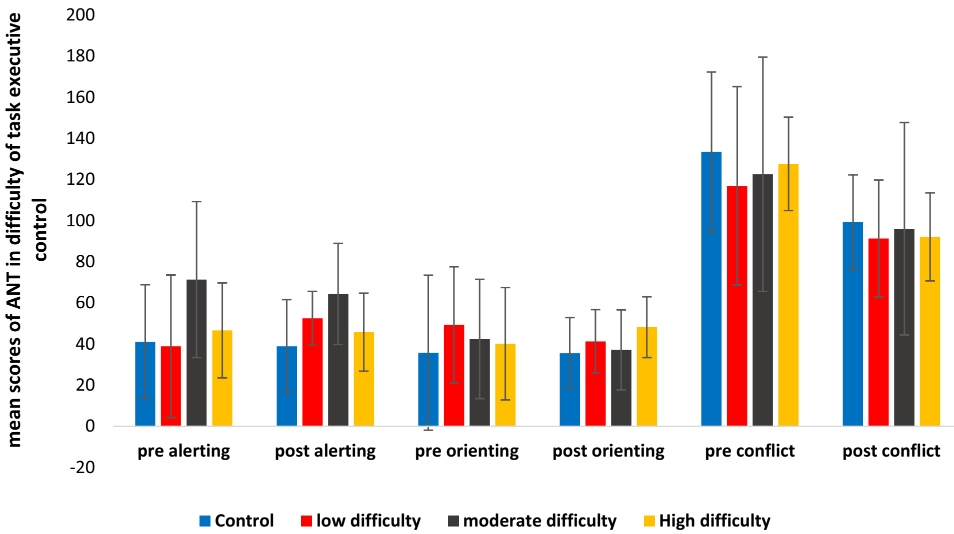

Figure 3 Performance of the four experimental groups based on three networks: attention alert, orientation and executive control.

The results of ANOVA with repeated measures test of the attention network of executive control showed that the main effect of group (p=0.897) and the main effect of interaction between groups and training time (p=0.684) were not significant, the main effect of training time was significant (F(1,38)=70.886, p=0.000, ηp2=0.65, large effect). In other words, there was a significant difference between the pre-test and the post-test of the executive control attention network in the four groups. Regardless of the type of training protocol (task difficulty), the present results showed that only the training effect improved the attentional network of executive control. The groups did not show a significant difference, so an optimal region could not be determined.

Figure 3 shows subjects' performance in the four groups of control, low difficulty, moderate difficulty and high difficulty, on two occasions before and after the test in the three networks of alert attention, orientation and executive control.

Figure 3 shows that according to the average pre- and post-test scores, exercise affects executive control efficiency in all groups.

Cognitive Effort Measurement

ANOVA with repeated measures test was used to evaluate cognitive effort. The results of ANOVA with repeated measures of cognitive effort showed that the main effects of training time (p=0.637), group (p=0.993) and the interaction between groups and training time were not significant (p=0.212). Figure 4 shows subjects' performance in four groups: control, low difficulty, moderate difficulty and high difficulty, two times, before and after the cognitive effort test.

Working Memory Measurement

The main effect of training time (pre-test vs post-test) was statistically significant (F(1,38)=6.818, p=0.013, ηp2=0.15, large effect). There was also a significant difference between the pre-test and post-test performance on the working memory measure across the four groups, in which we used the Bonferroni post hoc test to clarify the difference between these conditions. These results show that the number of correct answers to Black Corsi has improved in the post-test of all groups. Therefore, it can be concluded that the number of training sessions with different difficulty levels has improved working memory performance. These results show that the number of correct answers to Black Corsi has improved in the post-test of all groups. Regardless of the type of training protocol (task difficulty), the present results showed that only the training effect improved working memory. The group differences were not statistically significant, so a optimal region was not found. Additionally, neither the main effect of group (p=0.330) nor the interaction between group and training time (p=0.938) was significant. Figure 5 shows the performance of subjects in four groups of control, simple difficulty, medium difficulty and high difficulty, two times, before and after the test on working memory.

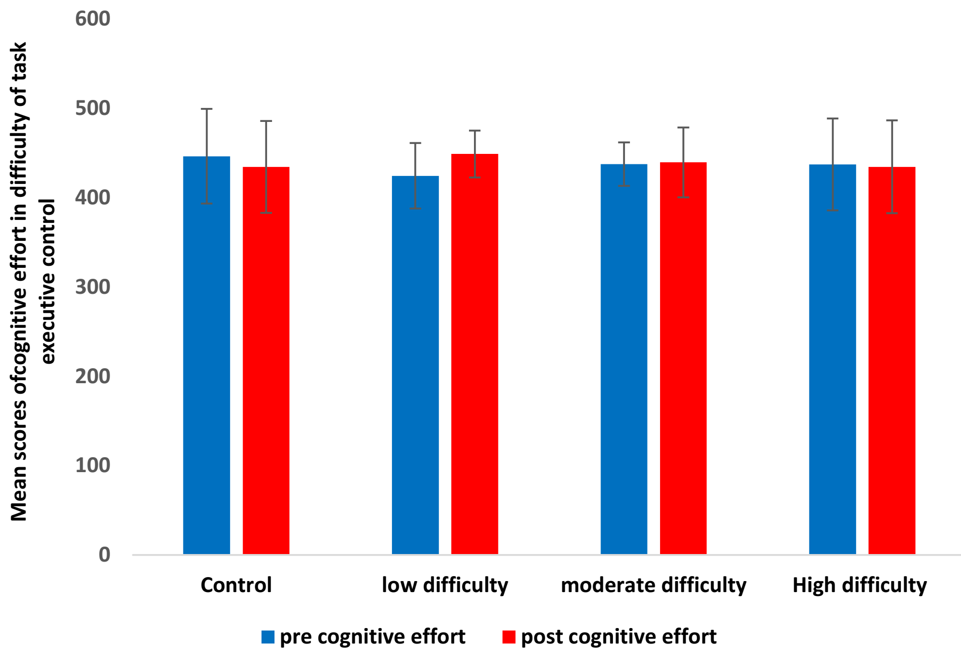

Figure 4 Performance of the four experimental groups based on cognitive effort.

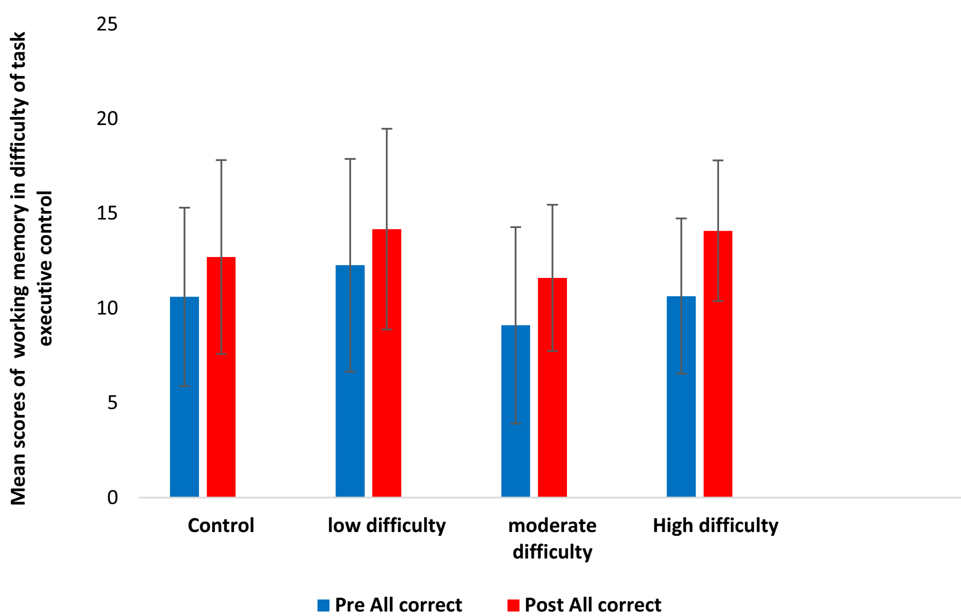

Figure 5 Performance of the four experimental groups based on working memory.

Discussion

To influence the brain networks involved, we need to develop tailored training methods. One of the training methods is to train a particular attention network.[36] Therefore, the present study investigated executive control exercises in groups with difficulty (low, moderate and high) and control over three attention networks (alertness, orientation and executive control) and cognitive effort. The results showed that the control group responded to the warning sign better than the moderate difficulty group. The results of our research supported the hypothesis of the superiority of endogenous attention (alert) over exogenous (orientation).

In the framework of the dual flexibility model, it was hypothesized that endogenous attention is important for task-related visual perceptual learning and exogenous attention is not important for task-related visual perceptual learning.

This suggests that, compared to exogenous attention, endogenous attention is more influenced by task characteristics.[37–39]

In addition, the executive control network of attention improved in the post-test of all groups. In other words, only the exercise effect improved the attention network of executive control.

The training protocol, including task difficulty, did not impact the executive control attention network. The optimal region for this network was not identified. Research by Kleinberg et al[40] and Beck et al[41] has found that practicing working memory tasks can enhance attention networks, particularly the executive control network, in children with ADHD. Fathirezaei et al[20] showed that cognitive training positively impacts the efficiency of the neural network.

This suggests that cognitive training enhances communication within brain networks and increases the brain's flexibility in response to repetition and practice. As a result, cognitive training may have beneficial effects on various cognitive abilities, such as memory, attention, and perception, by engaging brain networks more extensively and facilitating synaptic communication. Also, Hebb's theory of simple synaptic connections states that practice and repetitive activities improve neural networks such as attention.[20] Therefore, it can be said that the findings of this study are consistent with Hebb's theory.

To check the cognitive effort, we used two software: cognitive effort and working memory. The results obtained from the cognitive effort software showed no difference between the training groups in the cognitive effort variable, and no significant progress was seen in the post-test of the training groups. Maybe this version of the cognitive effort tool was not the right choice for this research. However, the results obtained from the working memory software showed that only the effect of training improves working memory. The training protocol (task difficulty) did not affect working memory, and the optimal region was not found.

Kim et al[42] found that participants performed better on working memory tasks with easier difficulty levels, demonstrating higher accuracy and shorter response times compared to more challenging tasks. However, the two stress conditions did not differ in memory accuracy. Soodmand Afshar and Tofighi[43] found that for lower-intermediate language learners, more challenging tasks resulted in lower accuracy, but simpler tasks improved fluency. In contrast, for advanced learners, more complex tasks enhanced accuracy but reduced fluency. Our study did not support the results of studies by Kim et al[42] and Soodmand Afshar and Tofighi.[43] The inconsistency between the present study and Soodmand Afshar and Tofighi research is due to their focus on how task complexity affects intermediate and advanced Iranian language learners. Additionally, Kim et al study looked at how stress and task difficulty interact to impact the accuracy and reaction time of adolescents' working memory performance.

Cognitive effort is an "attention-demanding" characteristic of the mental processes employed during task performance.[44] It relies on working memory resources and is described as "mental work in decision making".[45] The cognitive effort has been linked to theories explaining both typical and atypical behaviors, as well as the physiological responses associated with engaging in challenging tasks.[46] The information stored in this method is stored in "short-term memory" or "working memory". When a high volume of information is required to be used, this process can be quite effortful or need attention.[46]

If a large amount of information is required to perform a task, then the attentional load is high, and the working memory must work hard to process the information. In these conditions, a performer will experience much cognitive effort (tasks with high difficulty). Suppose less information is required to perform the task. In that case, the attentional load is low, and less information is processed by working memory, and the performer will experience low levels of cognitive effort (low-difficulty tasks).[45]

The central idea behind challenge point theory is that the difficulty of a motor task varies depending on the performer's skill level. Learning is related to performance-related information, which should be optimised along with the performance related to task difficulty to the performer's skill level.[1] Let us put it this way. Guadagnoli and Lee[1] defined the concept of a challenge as the difference between performance and learning. Performance is good when the challenge is low (like blocked practice). As task difficulty gradually increases (through random practice), performance may initially decline. However, when considering the learning process, a different relationship emerges. When the task difficulty is very low, there is little learning, which is called the "comfortable" level. As the challenge starts to increase, that is when the learning process begins.

In this research, the main goal is to manipulate the executive control attention network at three different difficulty levels (simple, medium and high) to determine the framework of the challenge point. Although our research supported the concept of the challenge point for learning, no difference was found between the difficulty groups and the control group. This issue can be explained from two points. First, the number of our training sessions has been low. Our goal for this research was to practice (cognitive training), for learning and finding, the optimal point of learning. According to Hodges and Lohse,[21] the difficulty can change in the short term, perhaps due to fatigue or arousal, and in the long term, because of learning. Our impression is that because of the number of short and limited sessions and the lack of great difference between the training designs of the groups in this training, people could not completely use cognitive capabilities such as memory, attention and perception. Second, the difficulty entered needed to be more appropriate. According to Hodges and Lohse,[21] depending on the training goals, training with high functional difficulty may sometimes be beneficial to optimise learning and improvement. In racket sports, in specific training periods, the practice with relatively less difficulty may be useful to reinforce successes, improve competence, and reduce the risk of injuries. In difficult situations, task performance relies mainly on limited inputs (bottom-up factors). As a result, adding more resources does not significantly improve performance, since the problem comes from the low discriminability of the stimuli, not their strength. In easier conditions, participants can complete tasks without needing extra resources, which means there is little room for stopping. Thus, the cognitive system likely allocates more resources to harder tasks, as the investment in these conditions yields better outcomes.[47] In this study, while all intervention groups showed improvements in the executive control network, the difficult groups performed significantly better than the control group. The lack of difference between the difficulty groups could be due to the limited number of sessions, shorter training time, and the minimal differences in task difficulty among the groups. Executive functions are crucial for human behavior, helping us engage with our environment and participate in society. Giustino et al (2024) in a review article pointed out that in padel racket sports, the most common injuries among non-professionals occur in the elbow, followed by the shoulder and back.[48] In contrast, the present study was conducted in the field of table tennis racket sports. This difference may be attributed to the specific movement patterns and technical characteristics of each sport. Padel sports exert significant stress on the upper body joints, particularly the elbows and shoulders, due to frequent and sudden movements. Additionally, twisting and stretching during shots can lead to back injuries. In contrast, while table tennis also requires quick movements and instantaneous reactions, the movement patterns and types of shots differ, potentially influencing the types and locations of injuries. Overall, understanding these differences can assist exercise program designers and coaches in optimizing injury prevention strategies tailored to the specific vulnerabilities of each discipline.

The challenge point framework in various fields, such as clinical,[6,49] developmental[18] and learning,[9,45] was examined from a functional point of view.

The challenge framework is based on the idea that effortful practice and cognitive engagement, such as planning, memory, and information processing, are necessary for learning to occur.[50] As mentioned in the study of Maurer and Roebers,[19] one way to increase cognitive and attentional demands in time-limited team sports is to challenge players' working memory through exercises that require them to quickly process and respond to information. Based on this, the designed program of this study involves attentional networks of executive control by increasing the speed and number of ball throws in table tennis play. In the future research, researchers can examine other skills that need attention and recognition.

Limitations

Many factors affecting perceptual-cognitive indexes, including caffeine and playing computer games, were not investigated in this study.

Conclusions

The current research showed that the challenge point theory includes cognitive needs and performance. We applied different levels of task difficulty in ANT and cognitive effort. The training protocol of cognitive difficulty task difficulty in the present study did not find the optimal learning region.

Institutional Review Board Statement

The study was reviewed and approved by the Ethics Committee for Biological Research at Shahid Beheshti University in Tehran, Iran, in accordance with the principles of the Declaration of Helsinki (Protocol code: REC.1400.209).

Data Sharing Statement

The data from this study are available from the first author upon reasonable request (mahya.mohamadtaghi@yahoo.com).

Informed Consent Statement

All participants provided informed consent to take part in the study.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Funding

This research received no external funding.

Disclosure

The authors declare no conflict of interest.

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