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Research Article

The influence of cognitive training using mobile applications on attentional control and impulsivity among pre-service teachers

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ABSTRACT

The purpose of this study was to investigate the influence of cognitive training (CT) using mobile applications on attentional control and impulsivity among pre-service teachers. Pre-service teachers were divided into two groups: experimental (n=25) and control (n=14) groups, they were selected from a large sample (n=718). Over 28 sessions, the training group engaged in CT tasks (the tower of Hanoi [TOH] and simple reaction time [SRT]), whereas the control group did not participate in training sessions or understand the main goal of the study. In the criterion tasks (matching familiar figures and numerical Stroop), all participants were pre- and post-tested. CT using mobile applications helps us see how the trained group's attentional control and impulsivity had influenced. we also observed the progress of trained group as measured by number of moves or time for TOH, and reaction time (RT) for SRT. Other effects were observed in comparison to a control group that underwent no training. There were changes in impulsivity in post-test in favor of training group according to number of moves, and time component of matching familiar figures test. Corresponding to attentional control, the finding indicated that there were changes in (number and size) RT component in post-test in favor of training group.

Keywords: cognitive training, mobile applications, attentional control, impulsivity, the tower of Hanoi, simple reaction time

INTRODUCTION

Cognitive training (CT) using mobile applications is a method that involves supervised practice of activities that directly improve or preserve cognitive abilities such as memory and attention. It is founded on the premise that the brain may change for the better even as we age (Bahar-Fuchs et al., 2014). It can be carried out on a computer or presented in person, either alone or in small groups, but it often includes employing regular practices aimed at enhancing cognitive ability (Kueider et al., 2014).

Moreover, it needs to be broken down into different categories of cognitive exercise and strategy training (Gates et al., 2011, Mowszowski et al., 2010). It entails practicing a certain cognitive skill, which leads to improvements in the practiced task and typically in activities that are comparable to it (i.e., near transfer).

Improvement on a task that belongs to the same cognitive domain as the training task is referred to as “near transfer” (Morrison & Chein, 2011). To improve cognitive function, it also offers structured exercise of complicated mental activities (Martin et al., 2011).

Besides that the tower of Hanoi (TOH) and simple reaction times (SRTs) in the cognitive domain have been shown to be useful tasks for examining a range of executive functions, including planning, working memory, updating, inhibition, and attentional control (Handley et al., 2002; Milla et al., 2019; Rönnlund et al., 2001; Welsh & Huizinga, 2005; Zook et al., 2004).

Reaction time (RT) is a functional measure of numerous cognitive abilities, especially attention, inhibitory control, processing speed, and visual perception (Burle et al., 2004, Tuch et al., 2005). It can be described as the period between the appearance of a stimulus and the elicitation of a reaction, and it is seen as a useful indicator of how well the cognitive system can process information (Jensen, 2006; Kuang, 2017). While SRT is described as the amount of time between the appearance of an exciter, its identification, and the reaction that is given (Jayaswal, 2016). Some studies, such as Toschi et al. (2022) employed RT tasks to measure attention and impulsivity, whereas other studies revealed relationships between SRTs and attention, like Prinzmetal et al. (2005) and Reigal et al.(2019).

As for planning, it is regarded as a necessary step before tackling difficult thinking problems and calls for the restraint of in-the-moment activities. It is widely believed that the capacity to solve TOH represents planning ability, which is at the core of the abilities covered by the term “executive function” (Denckla, 1996; Lezak, 1995; Tranel et al., 1994). This includes TOH, a disk-transfer challenge requiring the least number of moves to transport discs from an initial configuration to a target configuration (Liang et al., 2016). Trainees in TOH must respond properly to novel circumstances and meet requirements relating to anticipatory, end-to-end problem resolution (Welsh & Huizinga, 2001). Therefore, TOH needs to pay attention and avoid impulsive behavior.

Regarding impulsivity, it is characterized by hasty decision-making, a deficiency of planning, proactiveness, and foresight, as well as a risk-taking mindset (Herman et al., 2018). In other terms, it is also described as a propensity for speed, an unplanned action in reaction to internal and external impulses, and a disregard for the undesirable results (Garofalo et al., 2018; Stanford et al., 2009). Furthermore, planning is critical in controlling impulsivity (Hohmann & Garzam 2022; Kanten 2018; Sokić et al., 2021). Additionally, certain characteristics such as poor planning, an absence of future orientation, a deficiency of attention, carelessness, impatience, eagerness, and desperation, as well as low anxiety and poor self-control, contribute to impulsive actions (Farmer & Golden, 2009).

While Stroop’s color-word stimuli became a key paradigm for studying attention, and particularly attentional control (e.g., Schneider, 2015; Zhang et al., 2013). Attention control is a crucial cognitive ability for individuals to pick up knowledge relating to the present task (Ma & Fu, 2020), and it includes the capacity to control their response to stress and keep focused attention (Fonagy & Target, 2002). Therefore, it is believed that the ability to exercise attentional control, or the ability to choose what is paid attention to and what is avoided, grows as the brain circuitry supporting certain cognitive processes improves (Deoni et al., 2011; Gordon et al., 2011; Johnson, 2010).

Planning and paying attention are crucial processes that influence one another. Attention-based planning for more complicated task requirements, such as temporally changing tasks, as demonstrated in the paper by Ma and Fu (2021). Also, there is a correlation between the tower of London (TOL) and continuous performance test-II (CPT-II) scores (to measure attention and impulsivity) (Pham Hoang, 2014).

In the same context, the findings of one study (Rönnlund et al., 2001) suggest that age-related declines in TOH performance reveal age-related declines in visuospatial ability in addition to executive function declines, while another study (Karimi Goodarzi et al., 2018) found that cognitive inhibition training limited attention symptoms and enhanced planning performance.

On the other hand, there is also a contradiction in the results of studies on CT, with some showing it has no effects (e.g., Buitenweg et al., 2017; Sala & Gobet, 2019) and others showing its efficacy in improving executive functions (such as Kawata et al., 2022; Tottori et al., 2019; Wiest et al., 2022), As we discussed in the paragraphs above, planning, SRT, attentional control, and impulsivity are all related, so we aim to determine how to resolve these contradictions by looking at how CT based on TOH and SRT tasks affect attentional control and impulsivity in university students.

Cognitive Training Using Mobile Applications

We can define CT as one of the cognitive interventions that includes the use of a group of activities and cognitive mobile applications tasks such as TOH and SRT, which aims to train the skill of planning, problem solving, as well as speed and accuracy in performance in order to reduce impulsivity and improve attentional control among university students.

In confirmation of the above, there are many studies and research that used CT using mobile applications to develop some positive cognitive variables or reduce negative variables closely related to the variables of the current study, including, for example The results of the study by Rabi et al. (2019) demonstrated that participants with autism who experienced CT accomplished improvements in their executive functioning skills, including attention, abstract planning, impulse control, and problem-solving. According to the findings of Chambon and Alescio-Lautier's (2019) study, older adults' executive functions were enhanced by a multifactorial CT program.

In a similar context, the results of the study by Ramos et al. (2019) showed that using cognitive games in an educational context improved students' executive function (specifically, operating memory, processing speed and attention).

The findings of the study by Shaban et al. (2021) revealed that most of the students with learning difficulties perceived a good experience with CT application, and after the training period, their verbal and nonverbal working memory performance were significantly improved. Results of the study of Wiest et al. (2022) also showed that CT improved working memory and attention for students with attention deficit with hyperactivity disorder (ADHD) and specific learning disorder.

In detail for the above, TOH is a non-verbal problem-solving task that does not require prior information like a mathematics background but does demand planning and sub goal management. TOH tests a variety of cognitive abilities, including planning, problem solving, inhibition, self-regulation, and monitoring (Strauss et al., 2006). The use of TOH generates various measures of speed of solution, accuracy, and planning time.

It is widely believed that the ability to solve TOH reflects one of the most important abilities covered by the term "executive function": planning (Lezak, 1995). It has been established that TOH puzzle is an appropriate task for examining several executive functions (Welsh & Huizinga, 2005) and is widely utilized in clinical as well as non-clinical samples. It has been shown that this task is sensitive to prefrontal lobe impairment (Miyake et al., 2000), and taps processes such as planning, working memory, updating and inhibition (Handley et al., 2002; Welsh et al., 1999; Zook et al., 2004).

Consistent with the above, planning is regarded as a higher-order executive function that involves the capacity to plan, define objectives, and foresee the use of problem-solving techniques and strategies (Meltzer, 2018). It is frequently helpful to approach the task analytically, step-by-step, and planning of future solving-steps while tackling complicated cognitive tasks, such as TOH (Welsh & Huizinga, 2001). Planning is also a centralized component of executive functions and is linked to it (Will et al., 2014; Crook & Evans, 2014).

The foregoing is supported by a study by, Gonzalez and Neander (2018), which concluded that Interventions aimed at teaching problem solving skills might help to reduce impulsivity. Mele'ndez et al. (2019) showed that a person's ability to solve problems depends on their memory capacity, which in turn depends on the preservation of executive functioning. Kovari (2020) also indicated that there is a relationship between problem solving and executive function, and TOH puzzle is one of the tests used to examine executive functions and train on problem solving. Hence, we can reduce impulsivity and improve attentional control by training university students to solve TOH puzzle.

TOH task's benefit is that it enables testing the impact of the two training protocols on transfer by independently examining task solution correctness, speed to the correct solution, and time planning before beginning to solve the task (Vakil & Heled, 2016). In the current study, TOH task was downloaded to the participants' mobile devices, three pegs with numbers ranging from one to three are displayed. Three discs are placed on one of the pegs according to the size of the largest disc at the bottom to start the task. There is an optimal time and recommended number of moves that change depending on the number of discs, and the number of discs can be gradually increased in accordance with training needs. The examiner instructed the participants to move the specified number of discs from the leftmost peg to the rightmost peg as quickly and with as few movements as possible. He also instructed them to follow the following rules: A large disc cannot be placed on a smaller disc, and only one disc can be moved at once.

There are some studies and research that used TOH, for example A five-disk version of TOH puzzle, considered to represent executive functioning, was used by Rönnlund et al. (2001) to investigate differences in performance considering some demographic and cognitive variables in population-based samples ranging in age from 35 to 85 years. While significant gender differences favoring men were found, no effects of education were found. The findings suggested that age-related deficits in TOH performance reflect age-related impairments in visuospatial ability in addition to executive function deficits.

The results of Chan et al.'s (2010) study emphasized the importance of memory components, particularly those involving visual- and auditory-based working memory, when performing TOH task. The results of the study by Salnaitis et al. (2011) revealed that Impulsive response is correlated with bad performance in the computerized version of TOH.

SRT is the shortest amount of time required to react to a stimulus and is used as a fundamental indicator of processing speed. Francis Galton was the first to examine SRT in the late 19th century (Johnson et al., 1985; Woods et al., 2015).

Consistent with the above, human information processing quality and speed are assessed using SRT (just one stimulus). SRT task is a measurement of sustained attention from the perspective of executive functions. SRT task assesses the capacity to remain continuously focused on a single stimulus. Since there is only one possible response to a single stimulus, SRT task also assesses processing speed in its purest form (Magill, 2011).

There are some studies and research that have focused on RT, for example: the study of Willoughby et al. (2018) found that SRT individual differences were significantly related to performance on all executive function tasks; slower performance on SRT task was related to worse performance on each executive function task.

The findings of the study by Willoughby et al. (2020) also showed a special relationship between executive function performance and both between-person and within-person sources of basic RT variance. The study's findings are discussed in relation to the interest in using SRT as a proxy for fundamental cognitive abilities that influence how well students perform executive function tasks, including it is appropriate to use SRT to improve executive function task scores.

Attentional Control

The allocation, maintenance, and activation of psychological activity are all cognitive processes that depend on attention (Chun et al., 2011; Greimel et al., 2011). Attention is known as the process through which individuals choose a portion of the information that is accessible to concentrate on for better processing and incorporation (Ward, 2008). In other words, it is the mechanism by which, at a set moment, some data is enhanced while other data is blocked (Smith et al., 2019). In psychology, the fundamental beliefs about attention include that it is finite, selective, somewhat under voluntary control, that it regulates access to consciousness, that it is necessary for learning and action control, and that it governs access to awareness (Schmidt, 2001). This attentional deployment–or attentional control–can be dependent on either aim appropriateness, such as the correspondence between an object and the goal being sought after, or stimulus components, such as the prominence of an item (Vecera et al., 2014). Attention control is implemented by

(1) keeping target behavior and information, especially in the face of confusion and meddling and

(2) blocking or otherwise preventing the transmission of incorrect and irrelevant information (Draheim et al., 2022; Föcker et al., 2019).

Thus, it includes several components, including the ability to

(1) focus attention,

(2) switch between tasks, and

(3) flexibly govern cognition (Derryberry & Reed, 2002).

While Judah et al. (2013) have proposed that attentional control functions are focused and shifting. Yet, it also encompasses the capacity for self-regulation of stress responses and attentional focus (Fonagy & Target, 2002).

According to some studies, attentional control can be improved through training. Wass et al. (2012) found that attentional training given to younger people should be relatively more effective in enhancing cognitive functioning across domains. We also find that CT given to younger people tends to result in significantly wider training impacts. Additionally, Chambers et al. (2008) study findings showed that, compared to a control group that did not receive any meditation instruction, those who completed the mindfulness training showed significantly better self-reported mindfulness, depressive symptoms, rumination, and performance measures of working memory and attentional control.

As for the study of Wass et al. (2011), attentional control tasks were trained using paradigms. And post-training evaluations showed gains in cognitive control and sustained attention, decreased saccadic RTs, and decreased latency to disengage visual attention after only a relatively brief training period. In the study Malloy-Diniz et al. (2007) revealed that ADHD group displayed more impulsivity on the three dimensions of the BIS (the Barratt impulsivity scale), made more unfavorable decisions on IGT, and made more errors on CPT-II (measures of sustained attention and impulsivity). These findings confirm that people with ADHD have abnormalities in three areas of impulsivity: motor, cognitive, and attentional.

Impulsivity

Impulsivity is a crucial component of personality traits and many theories. It has a relationship to neuropsychological functions (Evenden, 1999). Acting without consideration or before all the information is accessible is referred to as impulsivity. It is the inability to hold back or stop a response in the face of negative consequences (Arce & Santisteban, 2006).

Additionally, impulsivity is defined as having quick, unplanned responses to stimuli without appropriate thought to any potential negative implications for oneself or others (Moeller et al., 2001). There are several types of impulsivities, including cognitive impulse, motor impulsivity, and attention impulsivity (Venkatesan & Lokesh, 2019).

In addition to the above, the core subcomponents of impulsivity also include impaired impulse control, poor decision-making, risk-taking, motor hyperactivity and general inattentiveness (Eysenck & Eysenck, 1977). Impulsivity is correlated with a variety of behaviors, such as a preference for immediate reward, tendency to make immediate decisions, and to exhibit immediate motor responses (Ermis & Icellioglu, 2016).

Impulsivity is divided into two processes by cognitive neuroscience: action and choice (Stevens et al., 2014). The ability to suppress a prepotent motor response is referred to as impulsive action, and it is widely assessed using the go/no-go and stop-signal test (SST) paradigms. Smaller immediate rewards are preferred over bigger delayed rewards in impulsive choice, which is typically measured by delay discounting tasks, the Iowa gambling task, and the balloon analogue risk task.

It should be noted that Immaturity, stress, irritation, exhaustion, or a lack of sleep can all contribute to impulsivity. In essence, features like urgency, sensation seeking, and low consciousness can be used to describe impulsivity (Forgan & Richey, 2015).

It is consistent with the above that It was shown that the impulsivity dimension's negative urgency was linked to detrimental outcomes such a low sense of self and disturbances in thinking and task completion that might be caused by a lack of persistence (Sperry et al., 2016).

It is worth noting that several studies have shown statistically significant negative relationship between impulsivity, and executive functions (including attentional control), and impulsivity is correlated to executive functions defects and impairment (for example, Foroozandeh, 2017; Hayashi et al., 2017; Quintero Reynaga et al., 2020).

The results of the study by Korpa et al. (2020) also concluded that Working memory, inhibitory control, and sustained attention were all significantly improved by the training program based on executive functions. Additionally, impulsivity was decreased as a symptom of ADHD.

There are many of studies and research aimed at verifying the effectiveness of some training programs in reducing impulsivity, for example The findings of Rivera-Flores' (2015) study indicated that CT based on self-instructional decreased impulsivity and number of errors for children with ADHD and significantly increased latency. The results of the study by Franco et al. (2016) revealed a significant reduction in levels of impulsivity using a mindfulness training psycho-educative program in the experimental group compared to the control group. While the results of the study of Ghahramani et al. (2016) showed that both high and low impulsivity groups of students who participated in physical activity had lower impulsivity scores than control groups. Additionally, both levels of impulsivity showed improved attention compared to their control groups.

The findings of the study by Munoz-Olano & Hurtado-Parrado (2017) additionally demonstrated that just an online intervention (SMART intervention) on clarifying of academic goals resulted in a statistically significant reduction in impulsivity in college students. According to the study of Shafiee-Kandjani et al. (2017), parent management training enhanced executive functions and attention and reduced impulsivity for students with ADHD in terms of RT and omission errors. While the results of the study by Peckham and Johnson (2018) indicated that individuals with high emotion-driven impulsivity appear to tolerate cognitive control training program well. The findings offered early evidence in favor of the effectiveness of CT interventions in decreasing emotion-related impulsivity. Whereas results of Karimi Goodarzi et al. (2018) study showed that cognitive inhibition training reduced attention-deficit symptoms and improved planning performance, there was no significant difference in hyperactivity/Impulsivity between the experimental group and control group.

The findings of the study conducted by Torto-Seidu et al. (2021), showed that the experimental groups displayed decreased impulsivity as compared to the control groups at post-test and delayed post-test measures while employing a cognitive modelling procedure. The findings offered early evidence in favor of the effectiveness of cognitive modelling training as a strategy for reducing impulsivity in students. The results of the study of Alqarni and Hammad (2021) indicated that a mindfulness training program significantly reduced impulsivity in the experimental group of participants with learning difficulties. By looking at the theoretical frameworks and previous studies related to the variables of the current study, namely (CT, impulsivity, and attentional control), the following becomes clear:

There are statistically significant relationships between the ability to solve problems and planning, which is replaced by TOH task, and this task is a problem that needs planning to reach its correct solving, and both impulsivity, and attentional control. Impulsivity is associated with executive dysfunction, and it is possible that if we perform a cognitive intervention using CT to reduce impulsivity, this will improve attentional control as one of the executive functions of students, and vice versa.

Impulsivity and attentional control are associated with a large number of personal, emotional and cognitive variables , including positive (such as emotional control, self-esteem, mindfulness, working memory and cognitive inhibition) and negative (such as aggression, behavioral problems, addiction, depression, anxiety, stress, suicidal behavior, anti-social behaviors, and writing errors) from which the positive may improve, and the negative may decrease thanks to CT in which the students of the experimental group participated. Some of studies recommended that an intervention through training programs should be made to reduce the impulsivity of students in different educational stages, especially university students with high impulsivity (for example, Al-Yagon & Borenstein, 2022). The scarcity of studies aimed at reducing impulsivity combined with improving attentional control. There is no–within the limits of the researchers' knowledge–any study that dealt with CT in general, which includes TOH and SRT task, especially to reduce impulsivity, and improve attentional control among students of the Faculty of Education at Helwan University. Therefore, the current study attempts to verify the effect of CT in reducing impulsivity and improving attentional control among university students.

MATERIALS AND METHODS

Method and Approach

There are various methods for collecting data. Purposive sampling is a non-probability method for gathering a sample in which researchers utilize their experience to select participants who will aid the study in achieving its objectives. These participants have characteristics that the researchers must consider when analyzing their study problem. In other words, participants have been selected by the researchers "on purpose". The researchers used a technique based on experimentation with a quantitative approach in their study. The researchers want to know The influence of CT using mobile applications on attentional control and impulsivity among pre-service teachers: experimental research the impact is assessed by providing a specific treatment. Effectiveness will depend on knowing the significant differences between the experimental and control groups. The training group engaged in CT tasks (TOH and SRT), whereas the control group did not participate in training sessions or understand the main goal of the study. In the criterion tasks (matching familiar figures and numerical Stroop), all participants were pre- and post-tested. CT using mobile applications helps us see how the trained group's attentional control and impulsivity have changed.

Participants

Participants in the experimental group were 25 university students (four males, 21 females) aged 18-22 years (mean [M]=19.76 years, standard deviation [SD]=1.05). Participants in the control group were 14 (four males and 10 female) aged 18-22 years (M=19.57 years, SD=1.39). Two groups were selected from a large sample (n=718) (300 males, 418 females) at Helwan University aged 18-22 years (M=19.41 years, SD=3.39) (see **Table 1**). Participants with high impulsivity were 88 undergraduate students, and 63 participants in this group did not complete the study because they did not have enough time and were therefore excluded. Two groups did not differ in age ($t[37]=.477$, $p=.636$), and they also were not significantly different in sex ($t[37]=.919$, $p=.364$).

Table 1. Lower quartile, upper quartile, median, & mean for impulsivity(n=718)

Scales	Lower quartile (Q1)	Median	Mean	Upper quartile (Q3)
Number of errors	81.5	159	239.64	276.25
Time (sec)	28.25	50	47.35	66

Procedures

Briefly, Helwan University's College of Education approved the study and allowed the researchers to begin the research. The participants were then required to sign an informed consent form. This was simply done for the students who joined up to take part in the study. In the pre-test, all participants were assessed. All the tests used had acceptable reliability and face validity.

Participants in the experimental groups were trained three times a week for 28 sessions. Each session was 20 minutes long. The pre- and post-test stages were 52 days apart. Due to our limited ability to control the quality of self-training, we asked participants not to practice at home. Additionally, we only sought to evaluate the impact of the 28-session training group. Students in the control group did not attend training sessions or understand the study's main goal. The participants were encouraged to complete the tasks appropriately in the meantime. CT using mobile applications (TOH and SRT) were implemented in this study to train undergraduate students. SRT task was implemented by Psych Lab 101 software-neurobehavioral systems, Inc. The four-, five-, and six-discs versions of TOH problem were employed in the experiment. A mobile application that was readily available was used to carry out the modified TOH job ("the tower of Hanoi" by Pani, 2022). Sonoio.net software carried out this task.

Tasks and Measures

Cognitive training using mobile applications

The tower of Hanoi: TOH, also known as the problem of the Benares Temple, the tower of Brahma, Lucas' Tower, or simply the "pyramid puzzle," is a mathematical game or puzzle that uses three rods and a variety of discs with different diameters that can slide onto any rod. To approximate a conical shape, the discs are piled on one rod in decreasing order of size, with the smallest at the top (Cohn ,1963; Hofstadter, 1985). To solve the puzzle, you must slide the complete stack to the final rod while adhering to the following rules: Each move involves taking the upper disc from one of the stacks and placing it on top of another stack or on an empty rod. Only one disc may be moved at a time. A disc that is smaller cannot be stacked on top of another disc.

TOH problem-solving puzzle was chosen for the study because it is frequently used to assess students' problem-solving, executive functioning, and planning skills (Huber et al., 2016). The puzzle can be finished in

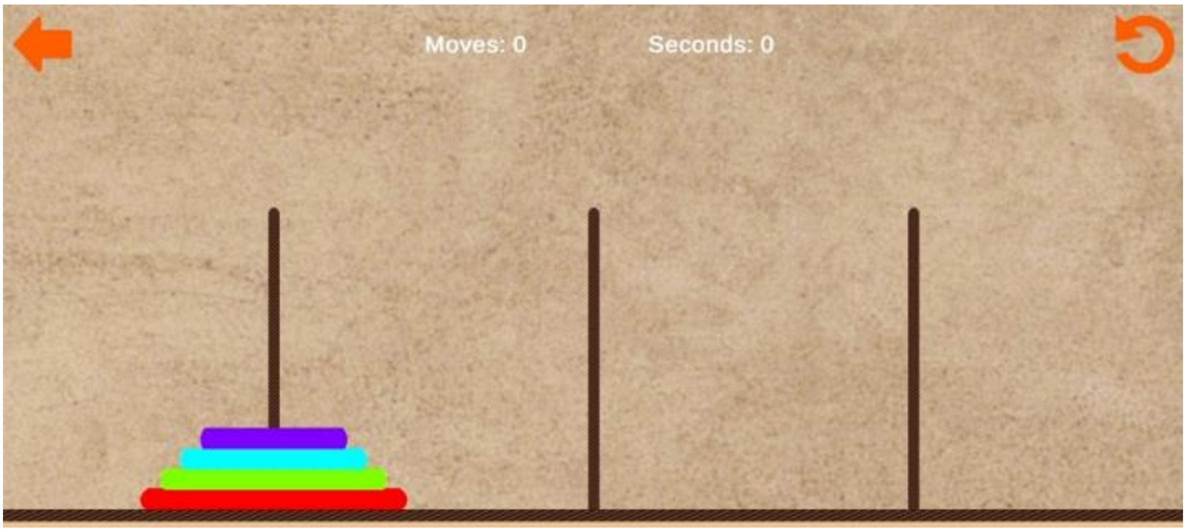


Figure 1. Sample tower of Hanoi item (four discs) (Pani, 2022)

seven moves using three discs. With four discs, the puzzle can be solved in 15 moves. With five discs, the puzzle can be solved in 31 moves. The puzzle can be solved in 61 moves using six discs. A TOH puzzle can be solved in as few as 2^{nd} movements, where n is the total number of discs. According to the legend, it would take the priests 585 billion years–or nearly 42 times as long as the universe has been around–to complete the task if they could transfer discs at a rate of one per second while making the fewest number of moves possible (Moscovich, 2001; Petković,2009) . Although many toy versions have between 7 and 9 discs, the puzzle can be played with any number of them. A Tower of Hanoi puzzle can be solved in as few as 2n movements, where n is the total number of discs (see **Figure 1**).

Simple reaction time: One of the core ideas in cognitive psychology is response time measurement. The time between the start of a stimulus or response cue and a participant's response is commonly used to quantify RT (often a button press, but may be vocal, motor responses, or other behaviors).

The time needed to process or complete a particular element of the task can be determined by comparing RTs between tasks (or between circumstances of the same task). For instance, a person could respond to any stimuli in 200 milliseconds (as described below, 200 milliseconds are their SRT). Their response time (RT) might rise to 350 milliseconds if the task were adjusted so that they had to respond to one stimulus while delaying responses to another. To calculate how long it takes to distinguish between stimuli and choose the best answer, we can deduct SRT from that value: 150 milliseconds (i.e., 350-200). We would know that the processing of the additional stimuli takes 100 milliseconds if further stimuli were introduced to the task and RT rose once more to 450 milliseconds (450-350).

Sternberg (1969) mental scanning experiments are among the best instances of applying RTs to measure the speed of mental processing. Participants in those studies watched as a series of numbers were revealed one at a time. The next step was to ask them if a particular digit appeared in the study sequence after showing them a single digit. Sternberg (1969) observed that RTs increased as the length of the research sequence increased; the more numbers the participants had to recall, the longer it took to ascertain if the test digit had appeared in the sequence. The growth was linear. The research sequence's additional digits caused RTs to rise by around 40 milliseconds. Thus, according to Sternberg (1969), it took approximately 40 ms to "scan" one element in short-term memory, and the increasing RTs with bigger sets were due to the participant "scanning" through more numbers. Similar applications of RTs can be seen in mental rotation tests (e.g., Shepard & Metzler, 1971), where the amount of rotation accomplished, and the time needed to perform it are inversely correlated.

In essence, a person's SRT serves as a "baseline" indicator of how quickly they react when no additional mental processing (such as discrimination or response type) is needed. College students typically need roughly 160 milliseconds for auditory cues and 190 milliseconds for visual stimuli to elicit a basic reaction (Galton, 1899; although, interestingly, SRTs seem to have increased since they were first measured in the 1800s, Silverman, 2010).

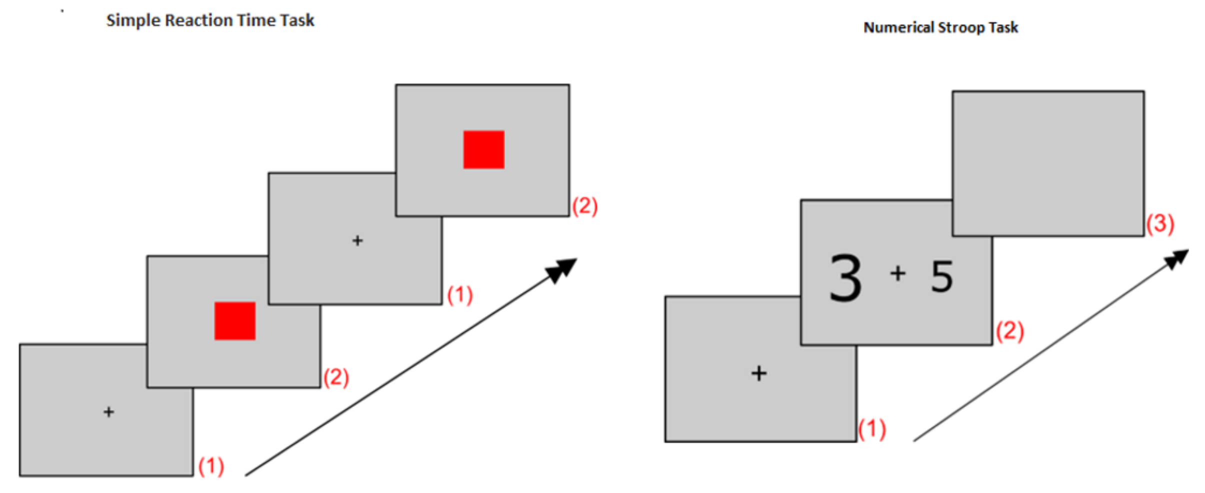


Figure 2. Sequence of events for study tasks (Source: Authors, using Psych Lab 101 software)

Table 2. Stability coefficients for numerical Stroop task & matching familiar figures test scales (n=50)

Scale	Time 1			Time 2			R
	M	SD	Range	M	SD	Range	
Numerical Stroop task							
Size accuracy	.929	1.47	.44-1	.916	.14	.47-1	.509**
Number accuracy	.797	.21	.30-1	.838	.20	.36-1	.343*
Size RT	479.9	167.04	89-949.9	474.15	157.4	138.04-949.9	.712**
Number RT	667.3	230.3	89-1,102.5	686.7	201.6	15-1,102.5	.815**
MFFT							
Number of errors	78.4	111.6	1-757	108.04	141.1	1-757	.715**
Time (sec.)	44.58	20.99	.47-1	35.28	18.67	0-70	.597**

Note. *Test-retest means significantly different at p<.05 & **Test-retest means at p<.001

Table 3. Means, standard deviations, skewness, kurtosis, & omega & alpha coefficients for numerical Stroop task & matching familiar figures test scales (n=720)

Scale	M	SD	Skewness		Kurtosis		McDonald's	Cronbach's
			Statistic	SD	Statistic	SD	ω	α
Numerical Stroop task								
Size accuracy	.942	.147	-3.324	.091	12.360	.182	.98	.907
Number accuracy	.868	.180	-1.720	.091	2.699	.182	.92	.97
Size RT	919.6	280.1	19.337	.091	378.367	.182	.36	.449
Number RT	1,363.2	11994	26.525	.091	708.842	.182	.49	.502
MFFT								
Number of errors	39.36	53.19	2.711	.091	8.558	.182	.591	.607
Time (sec.)	239.48	265.7	8.984	.091	108.617	.182	.968	.958

Participants respond to the task box target (default) is a straightforward visual response time task with a red box as the target. 75 trials are finished with an ISI range of 1,000-2,000 ms. Letter target is the letter A, but the time and trial counts are the same as they are for the default. Participants respond to the task box target (default) is a straightforward visual response time task with a red box as the target. 75 trials are finished with an ISI range of 1,000-2,000 ms. Letter target is the letter A, but the time and trial counts are the same as they are for the default (see **Figure 2**).

Attentional Control

Numerical Stroop: Stroop effect is one of the most well-known psychological effects. Participants in the traditional paradigm (Stroop, 1935) are asked to identify the color of the ink used on letter strings. One scenario asks participants to identify the color of nonwords' ink (e.g., "XXXX" in red ink). They identify the ink color of color words in a different circumstance (e.g., "blue" in red ink or "green" in red ink). When asked to name the ink color of color words (such as "blue" in red ink), participants take longer to respond and make more mistakes than when asked to name the ink color of nonwords (see **Figure 2**, **Table 2**, and **Table 3**).

Stroop interference presumably happens because of the automatic reading of the word and activation of the semantic concepts it relates to (such as the color it denotes). In other words, even though the word itself is unimportant for designating the ink color and might be disregarded, that information is processed automatically and hinders our capacity to do so.

Despite being very old, Stroop effect is nevertheless intriguing since there is disagreement over its precise cause. It happens in part because of automatic reading. However, some studies have shown that Stroop effects for the naming of color words are largest when the response is verbal (for example, "say the name of the ink color out loud"), smaller when it requires some sort of button press, and even eliminated when the participant merely points to a color patch that is the same as the ink color (Durgin, 2000). This implies that some of the Stroop effect may be due to response competition, which would explain why there is a reaction delay while people sort through their options.

Random block order (default) is met with responses from participants after 45 trials are run in two blocks. Congruent, incongruent, and neutral trials make up 45 trials total, equally distributed throughout each block. The two tasks–a physical size assessment test and a numerical magnitude judgement task–are carried out in a random order and are divided into two blocks. The time, trial counts, and stimuli are all the same as in the default for the size task first. Although it is always run first, the physical size assessment blocks the time, trial counts, and stimuli for number task I are the same as the default values. Though the numerical magnitude judgement block is always executed first.

Impulsivity

Matching familiar figures test: The researchers designed mobile app test in the light of the theoretical framework, previous studies, and some scales that were used to measure impulsivity as a cognitive method, the Kagan-matching familiar figures test (MFFT) (1965). This is followed by four responses representing the four classification categories based on the time and the number of errors. These categories are fast-inaccurate, fast-accurate, slow-inaccurate, and slow-accurate.

A visual test in which the subject is required to choose one of six comparable figures from the group that most closely resembles the provided example. Items are graded based on the number of accurate first-choice options, the number of errors, and the response time to the first pick. The test measures conceptual pace, or the relative speed at which a person makes decisions on challenging tasks.

This is an individual perceptual matching test that takes 15 to 20 minutes to complete on average. It has 20 measurement items. Each item has a model sketch, six variations of it, and only one perfect replica of the model. Finding the alternative that corresponds to the model is the subject's task. Six tries are possible for the subject. If the subject does not choose the right answer, the answer is explained to them, and they move on to the next item. The number of errors for each item as well as the response time for the initial selection are noted. After the test is complete, the overall number of mistakes and the mean response delay are noted (see **Figure 3**, **Table 2**, and **Table 3**).

The researchers assess the assumptions of mixed-model ANOVA, Although the assumption of normality in the study distribution was not confirmed, the researchers used a mixed-model ANOVA test for several considerations: The study by Blanca et al. (2017) showed that ANOVA is robust and still a valid option for groups in 100% of cases, regardless of the degree of deviation from a normal distribution, sample size, balanced or unbalanced cells, and equal or unequal distribution in the groups. Furthermore, in terms of type I error, ANOVA remains a valid method of statistical analysis under non-normality in a variety of conditions. Data transformation or nonparametric analysis is frequently advised. When data is not distributed normally. However, data transformations provide no extra benefits beyond the F-test's robust control of type I errors. Furthermore, determining which transformation is appropriate for a piece of data is typically challenging, and a given transformation may not be beneficial when groups differ in shape.

Likewise, when data alterations are used, the findings are frequently difficult to comprehend. There are also drawbacks to using non-parametric techniques, such as lower power than parametric tests. This indicates that if a difference exists between two groups, these tests are less likely to identify it. This should be intuitively obvious because there is always a cost for ignorance (in this case, ignorance about the distribution), and that penalty normally makes things more difficult to estimate. These tests turn quantitative continuous data into

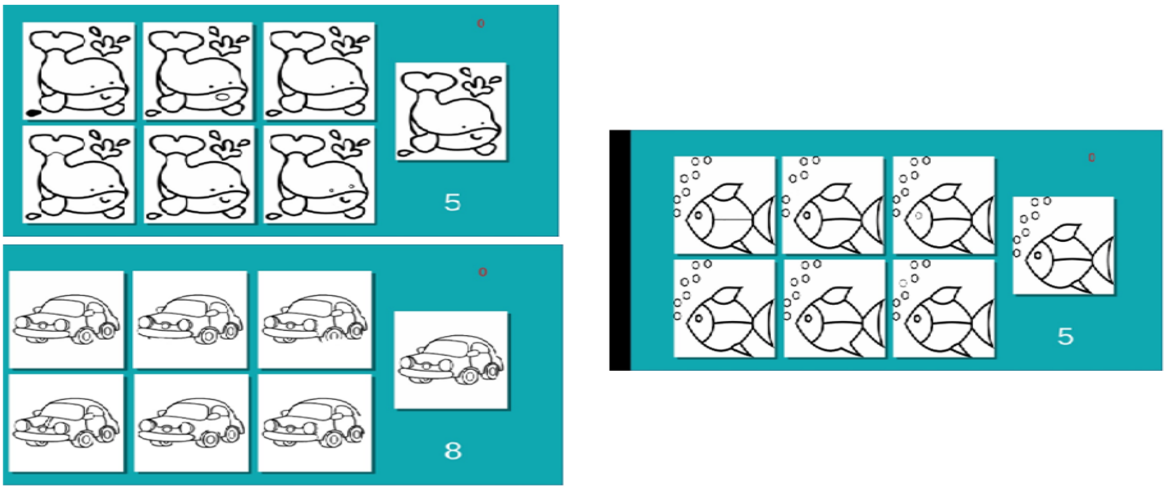


Figure 3. Samples of MFFT items (Source: Authors)

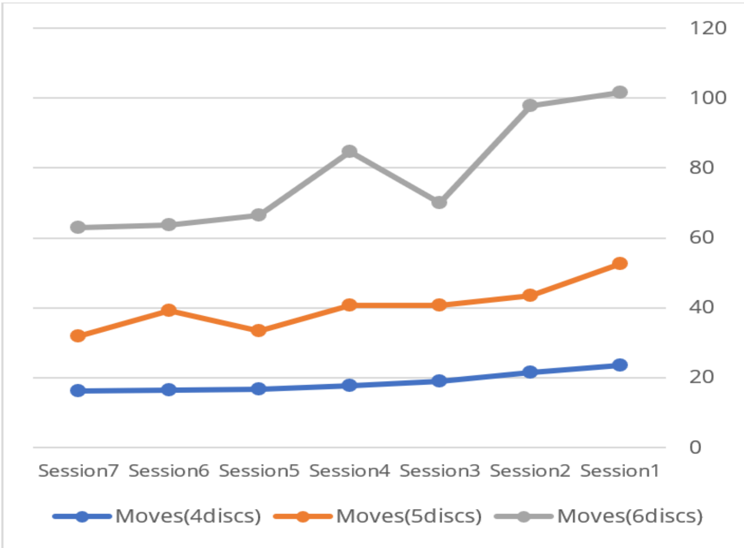


Figure 4. Improvement of training group in TOH task as measured by moves (Source: Authors)

rank-ordered data, resulting in information loss. Furthermore, the null hypothesis connected with these tests differs from the null hypothesis associated with ANOVA test unless the distribution of groups has the same shape (Maxwell & Delaney, 2004). Given such limitations, there is no reason to prefer non-parametric tests under the conditions examined in this study. However, other studies suggest that the mixed model ANOVA test is robust, in terms of power, to violations of normality under certain conditions (Ferreira et al., 2012; Islam & Abbas, 2022; Schmider et al., 2010), even with a very small sample size (n=3; Khan & Rayner, 2003).

RESULTS

Training Performance

The training curves for the training tasks of the training group are presented in **Figure 4**, **Figure 5**, and **Figure 6**. The training group in TOH task as measured by means of number of moves are improved from 23.49 in session 1 to 16.16 in session 7 for four discs, and from 52.68 in session 1 to 31.73 in session 7 for five discs, finally from 101.52 in session 1 to 63.00 in session 7 for six discs .Also, the training group improved in TOH task as measured by means of times from 60.11 sec in session 1 to 15.24 sec in session 7 for four discs, and improved from 89.28 sec in session 1 to 31.46 sec in session 7 for five discs. Finally, they improved from 139.84 sec in session 1 to 63.00 sec in session 7 for six discs (see **Figure 4** and **Figure 5**).

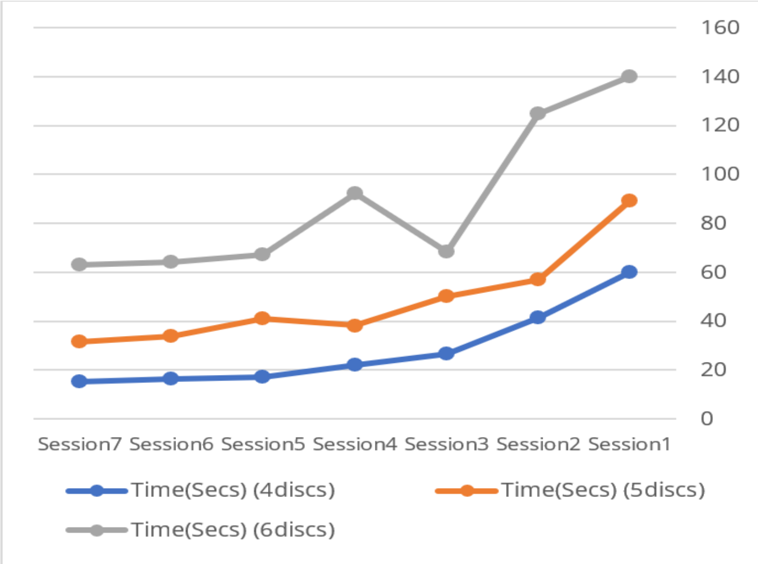


Figure 5. Improvement of training group in TOH task as measured by times (Source: Authors)

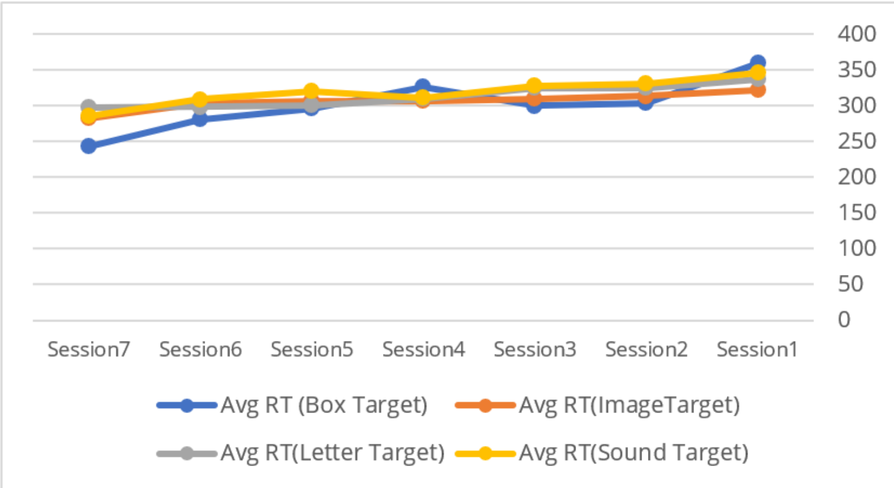


Figure 6. Improvement of training group in SRT task as measured by Avg RT (Source: Authors)

According to SRT task, the training group also are improved as measured by average RT from 321.71 ms in session 1 to 282.48 ms in session 7 for image target, from 337.25 ms in session 1 to 298.12 ms in session 7 for letter target, from 345.34 ms in session 1 to 285.01 ms in session 7 for sound target, finally from 359.45 ms in session 1 to 243.31 ms in session 7 for box target (see **Figure 6**).

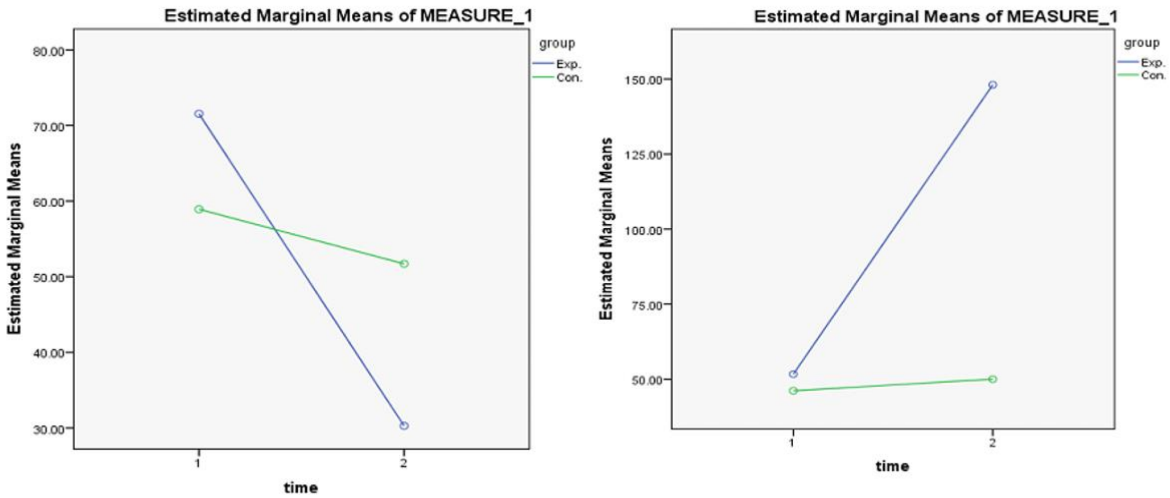
As it all, the trained pre-service teachers are improved in TOH as measured by number of moves or time, and they are improved also in SRT as measured by RT.

Changing in Impulsivity and Attentional Control

Table 4 summarizes the findings of the MFFT and numerical Stroop task for both groups (training and control). Using mixed-model ANOVA with time (pre- vs. post-test) as the within-participant factor and group (control vs. training) as the between-participants factor, the components of MFFT and numerical Stroop task were examined independently. Firstly, intended for Impulsivity, which measured by MFFT, for the number of errors component, the main effect of time was significant, $F(1, 37)=15.698$, $p=.000$, $\eta^2_P=0.298$, but the main effect of group was nonsignificant, $F(1, 37)=0.606$, $p=0.441$, $\eta^2_P=0.016$, with significant interaction of time (pre- and post-test) × training (control, training), $F(1, 37)=7.746$, $p=0.008$, $\eta^2_P=0.173$. Additional analysis showed that the two groups do not differ at pretest ($F[1, 37]=1.464$, $p=0.234$, $\eta^2_P=.038$). Importantly, the training group outperformed the control group ($F[1, 37]=15.375$, $p=.000$, $\eta^2_P=.294$) at post-test (see **Figure 7** and **Table 4**).

Table 4. Progress of performance in impulsivity & attentional control for two groups

		Training (n=25)		Control (n=14)	
		Pre: M (SD)	Post: M (SD)	Pre: M (SD)	Post: M (SD)
Impulsivity	Number of errors	71.56 (37.356)	30.28 (18.370)	58.93 (14.403)	51.71 (11.841)
	Time (sec.)	51.68 (22.673)	148.08 (129.603)	46.14 (21.915)	50.00 (48.806)
Attentional control	Size accuracy	.988 (.028)	.946(.140)	.895 (.196)	.9070 (.149)
	Number accuracy	.878 (.156)	.843 (.195)	.797 (.255)	.802 (.218)
	Size RT	546.160 (197.99)	415.812 (77.78)	527.190 (135.29)	641.99 (156.55)
	Number RT	1,005.33 (736.53)	643.012 (112.26)	794.544 (179.73)	857.397 (164.14)



Improvement in the training group from pre- to posttest in number of errors.

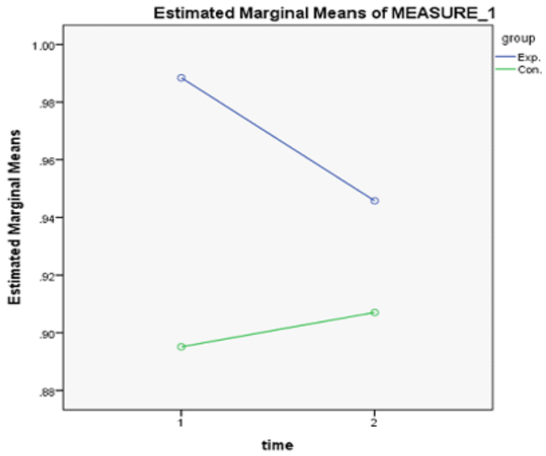
Improvement in the training group from pre- to posttest in time component

Figure 7. Improvement in performance of two groups from pre- to post-test in impulsivity (Source: Authors)

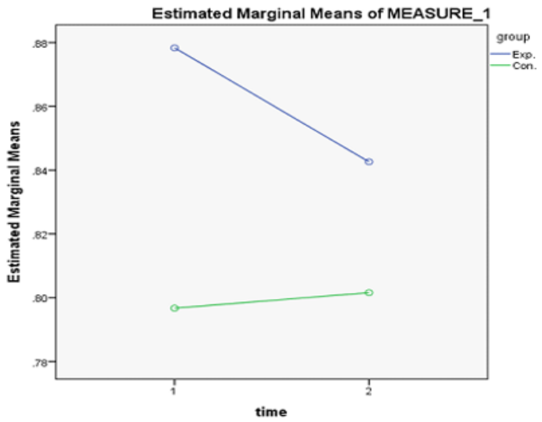
For the time component (in seconds), the main effect of time was significant, F(1, 37)=6.838, p=.013, η^2_p=0.156, and the main effect of group was also significant, F(1, 37)=8.545, p=0.006, η^2_p=0.188, with significant interaction of time (pre- and post-test)×group (control, training), F(1, 37)=5.826, p=.021, η^2_p=0.136. Additional analysis showed that the two groups do not differ at pretest (F[1, 37]=0.548, p=0.464, η^2_p=0.015). Importantly, the training group outperformed the control group (F[1, 37]=7.358, p=0.010, η^2_p=0.166) at post-test (see **Figure 7** and **Table 4**).

Secondly, intended for attentional control, which measured by numerical Stroop task, for (size) accuracy component, the main effect of time was nonsignificant, F(1, 37)=0.367, p=0.548, η^2_p=0.01, and the main effect of group was also nonsignificant, F(1, 37)=3.394, p=0.073, η^2_p=0.084, with nonsignificant interaction of time (pre- and post-test) × group (control, training), F(1, 37)=1.156, p=0.289, η^2_p=0.03. Additional analysis showed that the two groups differ at pretest (F[1, 37]=5.590, p=0.023, η^2_p=0.131). But there is no statistical difference between two groups (F[1, 37]=0.653, p=0.424, η^2_p=0.017) at post-test. For (number) accuracy component, the main effect of time was nonsignificant, F(1, 37)=0.159, p=0.692, η^2_p=0.004, and the main effect of group was also nonsignificant, F(1, 37)=1.275, p=0.266, η^2_p=0.033, with nonsignificant interaction of time (pre- and post-test)×group (control, training), F(1, 37)=0.275, p=0.603, η^2_p=0.007. Additional analysis showed that the two groups do not differ at pretest (F[1, 37]=1.549, p=0.221, η^2_p=0.040). Also, there is no statistical difference between two groups (F[1, 37]=0.366, p=0.549, η^2_p=0.010) at post-test (see **Figure 8** and **Table 4**).

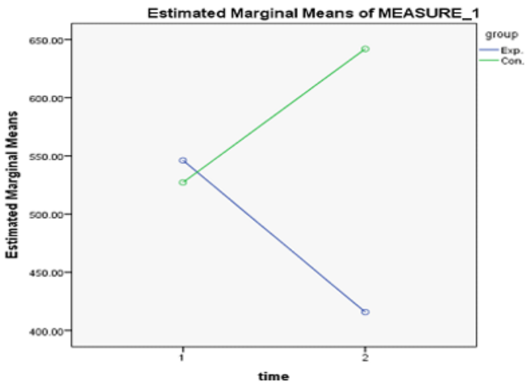
For (size) RT component, the main effect of time was nonsignificant, F(1, 37)=0.084, p=.774, η^2_p=0.002, while the main effect of group was significant, F(1, 37)=6.122, p=0.018, η^2_p=0.142, with significant interaction of time (pre- and post-test)×training (control, training), F(1, 37)=20.873, p=0.000, η^2_p=0.361. Additional analysis showed that the two groups do not differ at pretest (F[1, 37]=0.101, p=0.752, η^2_p=.003). Importantly, the training group outperformed the control group (F[1, 37]=36.626, p=.000, η^2_p=.497) at post-test (see **Figure 8** and **Table 4**).



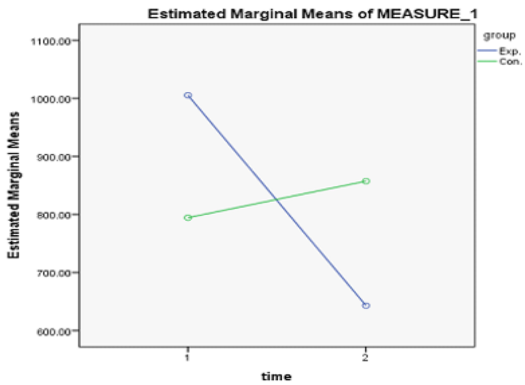
Change of (size) accuracy component from pre- to posttest



Change of (number) accuracy component from pre- to posttest



Improvement in the training group from pre- to posttest in (size) reaction time component



Improvement in the training group from pre- to posttest in (number) reaction time component

Figure 8. Improvement in performance of two groups from pre- to post-test in attentional control (Source: Authors)

For (number) RT component, the main effect of time was nonsignificant, $F(1, 37)=2.511$, $p=.122$, $\eta^2_P=0.064$, and the main effect of group was also nonsignificant, $F(1, 37)=0.000$, $p=0.987$, $\eta^2_P=0.000$, with significant interaction of time (pre- and post-test)×training (control, training), $F(1, 37)=5.061$, $p=0.031$, $\eta^2_P=0.120$. Additional analysis showed that the two groups do not differ at pretest ($F[1, 37]=1.098$, $p=0.302$, $\eta^2_P=.029$). Importantly, the training group outperformed the control group ($F[1, 37]=23.381$, $p=.000$, $\eta^2_P=.387$) at post-test (see **Figure 8** and **Table 4**).

DISCUSSION

According to the results, there were changes in attentional control and impulsivity in the post-test through CT using mobile applications among pre-service teachers in favor of the trained group. These findings can be explained by the fact that CT included TOH task, through which the students were trained to plan to solve problems, and this requires them to be aware of the circumstances surrounding them, the potential negative consequences of their impulsive behavior, and the requirements and steps for success in performing this task. So, by continuing to rehearse the task, the students became more reflective and were able to control their responses. And these results can be attributed to the fact that TOH task requires following a set of rules and instructions so that students can perform successfully on it, and it has levels that range in difficulty from the easy to the more difficult level, and we have followed the appropriate gradation with them, and this attracts them to perform effectively on the task, which had the best effect in reducing their impulsiveness.

The results of this study are consistent with the results of some other studies, which concluded that the training programs (including those on CT) are effective in reducing impulsivity and improving attentional control (for example, Alqarni & Hammad, 2021; Chambers et al., 2008; Franco et al., 2016; Ghahramaniet al., 2016; Munoz-Olano & Hurtado-Parrado, 2017; Peckham & Johnson, 2018; Rivera-Flores, 2015; Shafiee-Kandjani et al., 2017; Torto-Seidu et al., 2021; Wass et al., 2011, 2012). In contrast, the results of the current study differed with the results of some studies, for example, the study of Karimi Goodarzi et al. (2018) concluded that there was no significant difference in hyperactivity/impulsivity between the experimental group (the group to which CT was applied) and control group.

As well, these results can also be attributed to the existence of a statistically significant negative correlation between the ability to solve problems, planning, and impulsiveness, as solving problems requires the student to plan and organize his thoughts well and think reflectivity before acting, deliberation, non-recklessness, self-control, and proper control of his behavior and actions. These were included in CT. In other words, when solving problems, students should be careful when choosing the best solution and not rush into experimentation before thinking about all possible alternatives, studying them well, and gathering enough information to find the right solution. This is applied when solving the tasks within CT using mobile applications.

This can also be explained by the fact that CT based on the use of modern technology with its advanced means and techniques, such as computerized CT or CT using mobile applications, is better than traditional CT. CT using the mobile application keeps students away from the academic routine that they are accustomed to in college, as it corresponds to their interests in modern technological means and invests well their energies and excessive activity, which makes them use mobile applications to achieve important goals and reconsider their goals set before, and this is in itself training in conscious planning and organized, calm, careful thinking, and this may limit their impulsivity. It is consistent with the foregoing that the tasks of TOH and Simple Reason Time are purposeful and useful educational games that attract the attention and interest of students to perform them successfully, get them out of school boredom, employ their energy properly, increase their level of focus, mindfulness, and self-awareness, and make them talk to themselves before acting and doing, which makes them less impulsive, and this is what the students themselves mentioned to the researchers.

The results of the study can also be interpreted in view of the negative correlation between impulsivity and attentional control and the fact that the higher the individual's attentional control, the lower the impulsivity. Thus, if CT using mobile applications affects one of the two variables, the other variable is likely to be affected. Attention is also associated with reaction speed (RT), which is also associated with impulsivity. The task of SRT was trained through CT using mobile applications, where students are trained to respond correctly and accurately at an appropriate time, and this requires attentional control and limiting impulsiveness.

As mentioned above, the improvement of attentional control and decreasing of impatience among pre-service teachers may be because the students were directed during the training on TOH task to focus on the quality, efficiency, and accuracy of their performance by avoiding making many wrong attempts and not being too hasty in responding. Also, students were reinforced and praised for following rules and instructions and implementing them when the number of wrong attempts decreased, and correct attempts increased. And all cognitive tasks need high accuracy, organized behavior, and validation of the response before issuing it to succeed, and this is evident through the decrease in the number of wrong attempts when solving TOH task.

As was already indicated, there are several potential reasons why pre-service teachers' attentional control has improved, and impulsivity has decreased. These can be explained by the fact that CT is an important input aimed at stimulating and arousing mental activity and improving the capabilities and various cognitive processes such as planning, problem solving, and attention. These processes are related to cognitive styles, including impulsivity and reflectivity. Consistent with the foregoing, CT using mobile applications keeps students away from all factors that lead to anxiety, distress, and stressful situations that cause them to be reckless and impulsive, as it is considered a suitable environment and climate for students that is characterized by positivity, joy, and fun. These findings can be interpreted in view of the correlation between problem solving and attention, as general problems require the ability of the individual to pay attention to be able to find a proper solution to them. In addition, the solution of TOH task requires the student to have an appropriate level of attention and the ability to control attention.

CONCLUSIONS

In the present study we investigated changes in Impulsivity and attentional control after CT with TOH and SRT for pre-service teachers. After 28 sessions of CT, we observed the progress of trained group as measured by number of moves or time for TOH, and RT for SRT.

Other effects were observed in comparison to a control group that underwent no training. There were changes in impulsivity in post-test in favor of training group according to number of moves, and time component of MFFT.

Corresponding to attentional control, the finding indicated that there were changes in (number and size) RT component in post-test in favor of training group.

Researchers believe that training with a variety of activities enhances trainees' general learning processes and capacity to acquire new tasks, whether related or unrelated to the previously taught task. This method, which does not just apply to middle-aged, healthy people, is consistent with ideas of environmental enrichment learning. To further complicate efforts to pinpoint the specific benefits of CT, instruction is spread across numerous areas. Future research in this area must be clearly segmented into ecologically valid studies designed to identify general cognitive benefits associated with training (e.g., examining and contrasting various training programs to ascertain their effects) and highly controlled laboratory experiments intended to isolate mechanisms of behavior.

CT is beneficial for planning, RT, attentional control, reasoning, and psychotherapy. Additionally, CT affects how well other psychological therapies for psychotic illnesses. On the other hand, CT improves pre-service teachers' attentional control and reduces impulsivity. Therefore, merging cognitive psychology with clinical psychology and developmental psychology might result in insightful results. There is still a great deal of disagreement on the effectiveness of this training, even though numerous training experiments and a few meta-analyses have been carried out. According to the researchers, a large portion of the controversy is caused by the disparate training studies' choices for training and transfer tasks, the control group, and the research population. This variation is evident in meta-analyses as well, because various researchers would categorize tasks, participant groups, and studies differently.

CT provided by TOH since the task was presented to the students as an educational game and they had never encountered such activities before, their SRTs can be linked to how they interacted with it. This allowed them to transcend stereotypes and the usual academic routine and avoid academic monotony. The best impact on attentional control and cognitive capacities was achieved because it grabbed their attention and increased their motivation to perform it with vigor and activity.

There is limited research on what specific executive tasks truly assess and how dependable they are over time, as was previously mentioned. Small sample sizes and low task reliabilities, which are frequent in training research, lead to low statistical power, which reduces the possibility of observing a putative training effect. We believe it is more important for future studies to address problems with task reliability and validity, pairing of training and transfer tasks, and statistical power rather than continuing training studies with the current methodological defects

Strengths and Limitations of the Study

First, we are acutely aware that many adults suffer from impulsivity and are in desperate need of CT to improve their problems, so we used CT based on SRT and TOH for them. Thus, caring for adults allows many of them to take an active role in their academic achievement, improving their attentional control and reflectivity, and managing and identifying the problems they face.

Second, in our study, we used comprehensive cognitive tasks.

Third, because educational apps have such a significant impact on achieving the pleasure of learning, boosting students' motivation, and bringing joy to the teaching routine, it is also possible to benefit from the improvement of students' performance by incorporating some educational apps related to improving attentional control and decreasing impulsivity into the courses of study. Laboratory tests on related themes conducted in the educational psychology laboratory provide evidence in support of this.

Despite these obvious advantages, the small sample size of this study should result in certain limitations. Although we tried to communicate the task requirements to the participants, a sizable portion of them were disqualified from the final analysis due to random responses. We believe the deletion and ensuing decrease in sample size influenced our statistical power. Therefore, it is recommended to expand the use of CT to improve other attentional control and decrease impulsivity, which will have implications for changing the mental orientation of individuals, increasing selective attention, and mitigating their cognitive load, thereby improving their achievement levels. And the difference in attentional control and impulsiveness of students considering, using appropriate teaching methods, including in the curricula tasks that stimulate the nature of individual differences among students and the difference in attentional control and their level of impulsivity, and holding training workshops for students on the importance of CT in general and in improving attentional control and reducing impulsivity.

Suggestions for Future Research

Altogether, CT offers a highly promising topic for psychology, neurology, and allied disciplines, as well as for applying discoveries in real-life situations. Furthermore, the findings of the current CT study pose several key theoretical problems regarding the processes and mechanisms underpinning training and transfer effects, including training features. Furthermore, most of the present research on CT is concerned with expectations for the relevance of findings in real-world scenarios and activities of daily life. The study paints a positive picture of the potential of CT for improving cognitive functions in a variety of everyday situations. This refers to college and professional education, among others. However, the current work emphasizes the need to further investigate CT from both a theoretical and an applied standpoint to discover the processes mediating training and transfer effects. Based on our findings, the following research can be suggested:

1. Designing similar experimental studies on the effect of CT using mobile applications on attentional control and impulsivity in different educational stages.
2. Conducting research concerned with studying the relative contribution of CT to attentional control and impulsivity among student teachers.
3. Implementing studies to reveal the effect of CT using mobile applications on attentional control and impulsivity among people with learning disabilities, normal, slow learners, retarded students, people with learning problems, people with poor achievement, and other categories; to see the difference between them on these variables.
4. Clinical studies are being conducted to identify brain activity while performing CT tasks.
5. Carrying out cross-cultural studies to evaluate the effect of CT utilizing mobile applications on attentional control and impulsivity in other cultures.

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Ethics declaration: Authors declared that the study was approved by the appropriate ethics committee and was conducted in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. The participation was on a voluntary basis. Informed consent was obtained from the students participating in the current study.

Declaration of interest: Authors declare no competing interest.

Data availability: Data generated or analyzed during this study are available from the authors on request.

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