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Can computerized cognitive training enhance executive functions in healthy young adults? A preliminary study

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Abstract

Computerized cognitive training (CCT) is a computer-based intervention that targets cognitive functioning that has become increasingly popular in the recent decade. We examined the effectiveness of RehaCom as a standard computerized cognitive training on the executive functions of healthy adults in this preliminary study. The study was a quasi-experimental study using a pretest-posttest experimental design without a control group. The participants included 10 healthy adults. The participants were evaluated before and after the intervention using Trail Making Test (TMT), Intra-Extra Dimensional Set Shift (IED), and Stockings of Cambridge (SOC) computerized tasks. The subjects trained by RehaCom software for 45 minutes per day, one day per week, for a total of four sessions over one month. Data were analyzed in the SPSS software (version 26) using the paired t-test test. Results show significant enhancement in participants' central executive functioning ($p < 0.01$), shifting ($p<0.05$), and planning ($p<0.05$). A computerized cognitive training program can improve cognitive functions of healthy adults.

Keywords: Computerized cognitive training, Central executive, Shifting, Planning.

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1. Introduction and preliminaries

Cognitive enhancement is the process of improving cognitive functioning beyond what is necessary for maintaining or restoring good health in humans [1, 2]. This intervention is defined as behavior training aiming to improve cognitive function by maintaining and enhancing constancy and generalization of abilities [3]. It includes methods such as brain training (i.e., mentally challenging computerized programs) and non-invasive brain stimulation [4]. In cognitive enhancement, computer-facilitated training is most commonly used [5]. Computerized cognitive training (CCT) is explained as computer-based interventions involving the repeated practice of standardized tasks that target cognitive functions [6, 7]. CCT can improve different skills such as attention, working memory, inhibition control, and decision making [8]. It can be used for treating various clinical populations such as individuals with psychosis [9], depression [10], mild cognitive impairment and Alzheimer [11], autism [12], stroke [13], traumatic brain injury [14] and multiple sclerosis [15].

Furthermore, CCT has been found effective for improving executive functions (EFs) in healthy populations [16]. EFs are a complex of top-down cognitive processes supports goal-directed behavior [17, 18]. In fact, EFs are cognitive functions that refers to the behaviors of prefrontal lobe [19]. EFs have been divided into various skills such as working memory, attention, problem solving, verbal reasoning, cognitive flexibility, shifting, planning, response inhibition and starting and monitoring activities [17, 20, 21]. Miyake, Friedman [22] distinguish three major core executive processes in EFs: cognitive flexibility, working memory, and inhibitory control. Through EFs, we are able to monitor and to adapt our behavior to changing conditions, and to learn new and complex actions and strategies [16]. Learning, working, and managing daily life require the use of EFs throughout our lives [23]. Therefore, EFs improvement is an interesting topic in rehabilitation services. Having the opportunity to develop one's EFs has lifelong benefits for individuals as well as society.

CCT are widely used to target EFs [24]. In previous studies, Martin, Liu [3] have done a study about cognitive training in healthy participants. Sixty healthy individuals were randomized in three groups that one received active tDCS+CCT, the other received sham tDCS+CCT and the last group received active tDCS-only. participants attended 13 sessions: baseline testing, 10 experimental sessions, post-testing and 4 weeks follow-up. The results have shown that the participants in the active tDCS+CCT condition perform more accurately on the CCT task than participants who received sham tDCS+CCT. At follow-up, the active tDCS+CT group, but not the sham tDCS+CT group, showed greater gains on a non-trained test of attention and working memory than the tDCS- only group. Also, [25] have studied the effectiveness of the short multi-domain cognitive training in healthy Italian elderly people. The training consisted of a weekly session of multi-domain and ecological cognitive exercises performed in small homogenous (i.e., same cognitive level) groups. The experimental group and the control group were compared at pre- and post-training. They also evaluated the indirect effect of the program on participants' mood, socialization and perceived impact on everyday activities. Overall, the experimental group showed improvements in cognitive functioning and greater improvements have been seen on EFs and short-term memory. It is considerable that most of the participants reported to have experienced an improvement in their everyday life and a positive influence on both mood and socialization. So, it appears that CCT can be beneficial to EFs in various populations. In the present study, we investigated the effectiveness of RehaCom program as a standard computerized cognitive training on healthy adults' executive functions.

2. Methods

2.1. Participants and procedures

The subjects of this study were 10 healthy young adults (9 females, mean age 20.30 years, SD = 4.42 years). Inclusion criteria were: 1. had normal vision. 2. Subjects signed the written informed consent. Exclusion criteria were: 1. Non-attendance at intervention sessions ؛2. Simultaneous receiving of similar interventions. The subjects received CCT using RehaCom software (RehaCom, Hasomed Inc., Germany, http://www.hasomed.de). The RehaCom software includes five programs designed to improve attention, memory, and executive function, as well as visual field. The difficulty level of each program varies from 3 to 5. In this study we used attention/working memory training programs. The therapist selected different difficulty levels based on the specific circumstances of each participant. The subjects trained under the supervision of a therapist for 45 minutes per day, one day per week, for a total of four sessions over one month. The participants were evaluated before and after the intervention using Trail Making Test (TMT), Intra-Extra Dimensional Set Shift (IED), and Stockings of Cambridge (SOC) computerized tasks.

2.2. Instruments

2.2.1 Trail Making Test (TMT)

The TMT is a neuropsychological test involving two parts: TMT-A and TMT-B (central executive functioning) Participants must draw a line from 1 to 25 connecting consecutive numbers in Part A (TMT-A). A participant in Part B (TMT-B) connects numbers and letters in an alternate progressive sequence, 1 to A, A to 2, 2 to B, and so on. TMT-B, which stresses central executive processes such as task-set inhibition, cognitive flexibility, and the ability to maintain a response set, is used to measure central executive functioning [26-28]. The TMT is scored based on how long it takes to complete. TMT was used in paper-pencil format.

2.2.2 Cambridge Neuropsychological Test Automated Battery (CANTAB)

CANTAB was originally developed at Cambridge University [29]. The CANTAB tests are sensitive to detecting changes in neuropsychological function and include tests of working memory, learning, and executive function; visual, verbal, and episodic memory; attention, information processing, and reaction time; social and emotion recognition, decision making, and response control [30]. The following CANTAB sub-tests were used in the current study:

2.2.3 Intra-Extra Dimensional Set Shift (IED)

The IED test measures acquisition and reversal of rules. It involves attentional shifting and flexibility. The IED is a computerized version of the Wisconsin Card Sorting test. Participants must use feedback to determine which stimulus is correct based on feedback. The stimuli and/or rules change after six correct responses [31]. IED outcome measures include errors made, the number of completed trials, the number of stages completed, and latency. As a set shifting ability index, we used the number of stages completed in the current study.

2.2.4 Stockings of Cambridge (SOC)

SOC is a test of planning in which individuals must use problem-solving strategies to match stimuli. This task requires the participant to move the balls on the bottom display to copy the pattern on the top display. These measures include the problem difficulty level reached, the number of moves used, and the amount of time spent thinking. As a planning ability index, we used the number of moves used in the current study.

2.3 Intervention

The RehaCom software package has been translated into different languages and used extensively in the treatment of cognitive deficits and cognitive enhancement. Five different therapeutic programs are included in this software which aims to restore attention, memory, executive functions, and visual function. Each program contains one to four different tasks that participants can choose from during their therapy session. RehaCom provides a battery of standardized tasks with immediate feedback, which makes it useful for patient follow-up examinations as well as for clinical trials [32-34]. In this study, we used four individual 1-hour sessions (RehaCom working memory/divided attention modules) over a four-week period.

2.4. Statistical analysis

A paired t-test is used to compare participants' performance on computerized tasks in pre-test and post-test.

3. Results

The paired t-test was used to examine the effect of the intervention on participants' executive functions (Table 1).

Table 1. Paired t-test results

	Measurement	Ability	Time	*M*	*SD*	*MD*	*t*	*P*
Cognitive domines	TMT-A	Central Executive	Pre-test	29.40	9.25	12.10	4.37	0.002
			Post-test	17.30	4.03			
	TMT-B		Pre-test	62.90	18.03	21.90	4.97	0.001
			Post-test	41	13.07			
	IED	Shifting	Pre-test	7.80	1.03	-0.70	-2.33	0.04
			Post-test	8.50	0.085			
	SOC	Planning	Pre-test	4.95	0.77	-0.80	-2.26	0.05
			Post-test	5.75	0.87			

Abbreviations: M; mean, SD; standard deviation, MD; mean differences.

In the analyses presented in Table 1, results show statistically significant change in participants'' executive functions from the beginning of intervention to the end of intervention. Intervention was effective for increasing central executive functioning ($p < 0.01$), shifting ($p<0.05$), and planning ($p<0.05$). Figure 1 shows the changes.

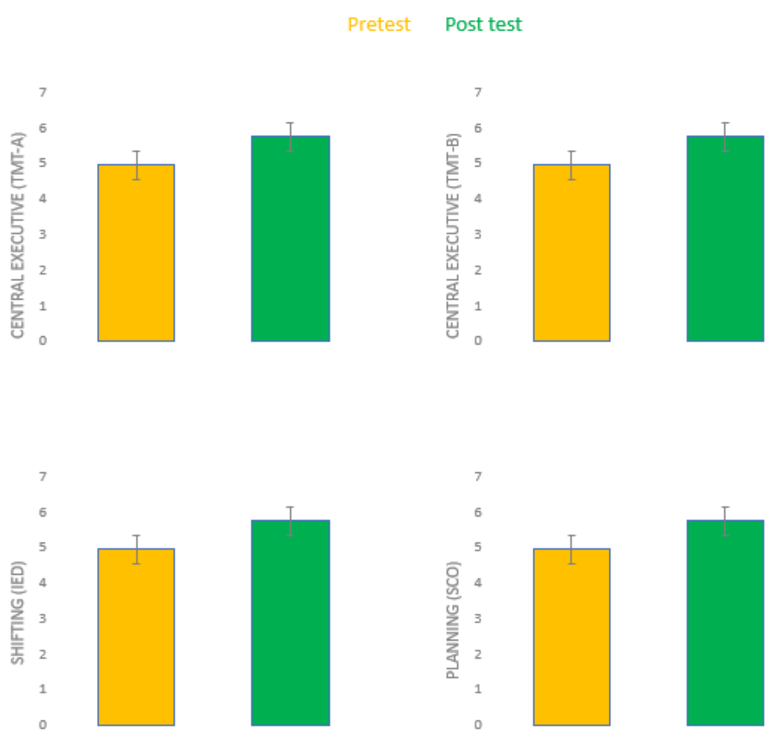

Figure 1. Changes in participants executive functions

4. Discussion

In this study, we investigated the effectiveness of the RehaCom program on the executive functions of healthy adults. As a result of cognitive training, participants showed significant improvements in their central executive function, shifting, and planning. The results of this study are in line with the findings of Tulbure and Siberescu [35] and Chiu, Chan [36] that examined the effectiveness of cognitive training on executive functions in healthy participants. Tulbure and Siberescu [35] in a pilot study proposed a new online cognitive training program. Twenty-five young healthy adults completed the training on their home computers. Before and after the training participants' working memory (WM) and attention capacity were measured. Results demonstrated that a short cognitive training produce significant improvements in participants' WM and attention capacity. It appears that healthy adult participants benefit from such a cognitive training. In another study Chiu, Chan [36] evaluated the effectiveness of executive function training on mental set shifting, working memory and inhibition for healthy older adults. Two groups of 62 participants attend three 30-minute training sessions per week for eight weeks. Executive function training group received the training content that focused on the mental set shifting, working memory and inhibition. Active control group engaged in passive information activities. The primary outcome was mental set shifting, measured by the Wisconsin card sort test. The secondary outcomes were working memory, measured by digit span; and inhibition, measured by the Stroop color word test. The executive function training group had statistically significantly higher scores of mental set-shifting and working memory at immediate follow up and that its effect on mental set shifting could be maintained for 3–6 months. However, this training did not have any statistically significant results on inhibition.

Executive function (EF) is a set of neurocognitive skills involved in problem-solving, such as working memory, inhibitory control, and set shifting and flexibility [37]. A central executive system sits at the top of the cognitive architecture hierarchy. It is involved in higher-order computations (decisions, monitoring, planning, etc.) and controls lower-level subsystems [38]. Also, shifting involves the ability to switch between multiple tasks, operation or mental sets, or change strategies as required when carrying out a task [39]. Furthermore, planning refers to the ability provide cognitive control and organize behaviors for achieving the desired goal, which can be seen as a higher-order EF, supported by core EFs, like working memory and inhibition, as well as processing speed [39]. Improvement in central executive functions, in addition to shifts and planning, can enhance other executive functions in individuals. To explain these results, we can mention that divided attention and working memory are the base of the other cognitive processes. In fact, we can claim that the necessity of all high-level cognitive systems' function is consistency of attention and working memory. Therefore, as rehabilitation of divided attention as a component of attention and working memory can lead to upgrade other executive functions.

Although our study is novel, there are limitations that need to be considered. One of the main limitations in this study was the small sample size, which can make it difficult to generalize the findings of the study. Also, subsequent studies can consider the effectiveness of divided attention and working memory rehabilitation on central executive functions, planning and shifting attention in different age groups. Moreover, it is suggested that further studies be conducted on larger samples and in experimental and control groups.

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Declaration of Competing Interest

None.

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