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Research Article

Enhancement of Executive Functions with Cognitive Rehabilitation in Older Adults

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ABSTRACT

Introduction: Age-related decreases in cognitive functions such as executive functions are a common phenomenon. Cognitive rehabilitation with two main approaches, compensation and remediation, is used to help elderlies coping with these deficits. Despite reported benefits, there are doubts on the efficacy of each of these approaches. We tried to provide effective computerized cognitive tasks as a rehabilitation intervention for elderlies to help them regain their lost executive functions.

Material and Methods: A 10-session cognitive training, in which 16 participants trained to regain their executive function shortcomings, was held using attentive rehabilitation of attention and memory (ARAM). Data from all 32 participants, assigned randomly to trained and control groups, were analyzed by paired and independent t-tests to examine each group's improvement over time and to evaluate the effectiveness of the intervention. Wisconsin card sorting test, continuous performance test, and Stroop color-word test were used as assessment tools.

Results: Results showed that general executive functioning that requires strategic planning and the ability to use environmental feedback to shift cognitive improved effectively using the intervention ($P < 0.010$). In overall, findings showed that ARAM is an effective tool for cognitive rehabilitation in elderlies. It overcomes limitations of most strategy learning programs.

Conclusion: Although improvements were observed in executive functions such as attentional control, sustained attention, inhibitory control, and cognitive shifting in elderlies, further study needs to investigate the ARAM's transfer and long-term effects.

Keywords: Attentive rehabilitation of attention and memory; Cognitive rehabilitation; Older adult

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Introduction

Normal aging is accompanied by deteriorations in cognition as well as changes in brain structure and function such as reduction in brain volume (1, 2) and cortical thickness (3). Functional neuroimaging studies have found that older adults show different brain activation patterns than younger ones, among which the most common is a pattern of increased activation in frontal lobes which mediate cognitive functions (4-8). Studies of neurocognitive aging also report altered executive functions in older people (9-11) so that most cognitive functions such as working memory (12), inhibitory control (1), dual task (13), language (14), and decision-making (15) decline with age. Yet, executive functions as fundamental processing resources are required for everyday functioning of older adults also for successful aging (16, 17).

Although normal aging is associated with progressive failures in cognition and memory, because of the brain lifelong capacity for plasticity and adaptive reorganization, some dimensions of these losses should be even partially reversible using an appropriately designed training program (18, 19). Meanwhile, considerable theories have tried to explain the increased frontal activity in older adults. Among them are compensation theories which claim that the frontal increases in older adults are the representation of a positive form of cognitive plasticity (20). This capability helps older adults to compensate age-related degeneration of brain structure and functions (7, 21).

One way for older adults to maintain and improve their cognitive performance is cognitive rehabilitation which includes lifestyle interventions, psychotherapy, and/or traditional cognitive training approaches, specifically implemented as a treatment to address cognitive impairments (22-27). Several studies have shown the effectiveness of cognitive training in improving various aspects of cognitive functioning as well as in maintaining or strengthening cognitive skills for older adults (28-32), such as memory (33, 34), processing speed (35, 36), and reasoning (35).

There are also two approaches of cognitive training in cognitive rehabilitation; one approach is compensation that relies on strategy learning for cognitive demand of activities of daily living (37). The second method is remediation that focuses on improving impaired cognitive functions using cognitive task (38, 39).

Although several studies have shown that cognitive training improves ability to regulate learning (40), performance of working memory tasks (41), both objective and subjective memory (42), use of memory strategies (43), executive functions (44), cognitive functions and quality of life (45, 46), self-efficacy (47), and it directly enhances independency of older adults (24), and so on (31); it can be inferred that most cognitive rehabilitation interventions for older adults are directed to improve cognitive functioning and neuropsychological interventions focus on memory performance (48).

Therefore, it would be a challenging opportunity to examine whether the training of executive functions of frontal lobes is beneficial for older adults. Hence, the purpose of the present study was to examine the effectiveness of the executive function training and to understand better its effect on the improvement of executive functions in older adults.

Materials and methods

Thirty-two older adults with a mean age of 65.15 years participated in the study, whom were selected by non-probability sampling. This sample was assigned randomly into trained and control groups such that there were 16 (8 women and 8 men) participants in each group, with a mean age of 65.13 years in trained group and 65.16 years in control group. All participants were healthy and none of them used psychoactive medication and reported any neurological or psychiatric impairment based on a general health questionnaire.

Wisconsin card sorting test (WCST)

The WCST consists of four stimulus cards and 128 respond cards that display one to four symbols, including stars, triangles, crosses, or circles, which are blue, green, yellow, or red – no two response cards are ever alike (49-51). The subject is required to sort the response cards according to an underlying sorting principle that he or she is supposed to deduce from his or her “right” or “wrong” card placements (49). After 10 correct responses, the underlying sorting principle changes and the subject is required to determine a new sorting principle (51).

Two WCST test indices, total number of categories achieved and number of perseverative responses, were selected for this study. These indices have been reported as representative of general executive functioning (52) that requires strategic planning and the ability to use environmental feedback to shift cognitive set (53). They have also been shown to be sensitive to frontal lobe damage, especially dorsolateral prefrontal cortex (DLPFC) dysfunction (54), and to bilateral DLPFC damage (49, 55).

The Stroop Color-Word test

An adapted version of the original Stroop task (56) was used in this study. The task consisted of three speeded trials in milliseconds using a computer. In the first trial, participants were asked to identify the color of stimuli, a set of color names (e.g., red, green, blue, yellow), by pressing corresponding colored key on the keyboard. In the second trial, different color hues (e.g., red, blue, green, yellow) were presented and participants should name the color of each hue. The third trial was incongruent condition in which the meaning of the color word and the print color differed and participants should call the color of the word. For this stage, participants should inhibit the well-learned, now-ingrained tendency to blurt the printed word.

Continuous performance test (CPT)

CPT is a standardized computerized tool used to assess different aspects of attention/executive functions (57) such as response inhibition (58). The modified version used in this study consisted of pairs of numbers which were printed on both sides of the screen, and respondents were asked to press the space bar if both numbers on the screen were similar. Stimuli were presented pseudorandomly so that 20% of stimuli were targets and should be answered by participants. In addition, interstimulus interval which is the temporal interval between presenting two stimuli was 500 milliseconds. CPT’s omission and commission errors as well as hit reaction time were used to assess attention and inhibitory control in this study. Omissions indicate the number of targets which the individual misses to respond, commissions show the number of times that the individual responds to non-target stimuli, and hit reaction time is the average speed of correct responses for the entire test and is the main measure of speed of processing (57, 58). These selected variables have been well represented in the literature as measuring different aspects of attention such as its sustainability (59-61).

Attentive rehabilitation of attention and memory (ARAM) is a software application that is a part of NEurocognitive Joyful Attentive Training Intervention as cognitive rehabilitation intervention. In the ARAM, four joyful computer-based tasks were presented to participants. These tasks were graded and increased in level of difficulty based on responses. Grading was based on the number of flanker stimuli, velocity of presented stimuli, number of goal stimuli, and changing task rule. For example, in one task, a subject should arrange faces in different categories based on a given rule and three properties: emotional expression (sad, angry, and neutral), hair color (green, white, and black), and skin color (yellow, white, and black). Each face had one property from each category, and the subject should assign it to just one category based on the property specified by the given rule. Thus, in each set of tasks, the subject should inhibit two properties and act based on one property designated by the given rule. In other words, the cognitive demand of these tasks is inhibition of unrelated properties and selectively attending to related one.

In trained group, after an evaluation session, participants were trained by ARAM app in 10 sessions, 1 hour 3 times per week, then reassessed in the 12th session. Control group was evaluated only in the 1st and 12th sessions.

Evaluation was conducted by WCST, CPT, and Stroop color and word interference test. These tools were used to assess the different aspects of executive functions before and after the implementation of the intervention.

Results

Data were analyzed using SPSS (version 21; SPSS Inc., Chicago, IL, USA). Paired sample t-test was used for evaluation of the executive functions before and after intervention in each group. Independent sample t-test was used to examine the effectiveness of intervention on improving the executive functions by comparing the means of trained and control groups.

Demographic data of participants such as age, education, and gender are shown in table 1. According to table 2, findings showed that before intervention, all cognitive measures were similar in both trained and control groups ($P > 0.05$). This confirms random assignment to both groups. From pretest to posttest, the omission index of CPT significantly decreased in trained group while it did not change in the control group ($P < 0.010$). Furthermore, after the invention, the omission index of CPT in the trained group was significantly lower than the control group ($P < 0.050$). Therefore, it can be concluded that the intervention was significantly effective to improve sustained attention (62) and attentional control (63).

In Stroop color-word test, the speed of participants in trained group improved significantly from pretest to posttest (Table 2), but it did not show any change in the control group ($P < 0.010$). The reaction time of trained group was also significantly lower than the control group ($P < 0.010$). Error rate index was significantly reduced in both groups; however, regarding significant levels (0.010 vs. 0.050), its reduction in the trained group was significantly greater than the control group, and in contrast to the control group, the trained group significantly had lower errors in posttest ($P < 0.010$). These results indicate the effectiveness of the intervention in the improvement of the inhibitory control.

In contrast to the control group, as shown in table 2, the number of completed categories in WCST increased significantly in the trained group after the intervention ($P < 0.010$). This index was significantly upper in the trained group compared to the control group ($P < 0.010$). Although preservation errors reduced significantly from pretest to posttest in both trained and control groups ($P < 0.010$, $P < 0.050$), it was significantly lower in the trained group ($P < 0.010$). Non-preservative errors also significantly decreased over time in the trained group ($P < 0.050$) but not in the control group, and it was significantly lower in the trained group ($P < 0.010$). These results show that general executive functioning that requires strategic planning and the ability to use environmental feedback to shift cognitive improved effectively using the intervention ($P < 0.010$).

Discussion

Findings supported the idea of plasticity in cognitive functioning in older adults (41, 64) and showed that the different aspects of executive functions, specifically sustained attention, attentional control, inhibitory control, strategic planning, and cognitive shift were improved using ARAM app as a cognitive rehabilitation in older adults.

In this study, we used remediation approach of the cognitive rehabilitation while some other research used compensation approach. Indeed, while there is plenty of research on using strategy learning (34, 37, 39), but they are somehow problematic.

Table 1. Demographic variable and independent t-test between them

Variable	Case group (n = 16) Mean ± SD	Control group (n = 16) Mean ± SD	t-ratio	P value
Age (years)	65.13 ± 4.82	65.16 ± 4.28	−0.182	0.856
Education (years)	14.250 ± 2.294	13.870 ± 2.125	0.480	0.635
Gender	8 female/8 male	8 female/8 male	-	-

SD: Standard deviation

Table 2. Cognitive measure before and after intervention)

Cognitive measures	Before intervention Mean ± SD	After intervention Mean ± SD	t-ratio (P value)
CPT			
Omission error			
Case	17.69 ± 11.53	9.94 ± 6.50	3.312 (0.006**)
Control	13.07 ± 9.25	16.00 ± 9.36	−0.209 (0.838)
T (P value)	0.489 (0.622)	−2.174 (0.038*)	
Commission error			
Case	1.750 ± 1.653	2.69 ± 1.25	0.628 (0.539)
Control	3.07 ± 2.97	2.36 ± 2.43	1.199 (0.249)
T (P value)	−0.2 (0.057)	−1.442 (0.160)	
Reaction time			
Case	0.422 ± 0.050	0.424 ± 0.014	0.392 (0.701)
Control	0.224 ± 0.026	0.365 ± 0.155	0.001 (0.999)
T (P value)	1.303 (0.202)	1.526 (0.147)	
Color-word Stroop test			
Reaction time			
Case	2.008 ± 0.946	1.429 ± 0.293	2.962 (0.010**)
Control	2.978 ± 1.838	2.935 ± 0.306	0.098 (0.923)
T (P value)	−1.886 (0.070)	−4.496 (< 0.001***)	
Error rate			
Case	2.130 ± 2.391	0.342 ± 0.130	3.341 (0.004**)
Control	3.098 ± 3.560	2.190 ± 1.377	2.416 (0.029*)
T (P value)	−1.469 (0.152)	−5.815 (< 0.001***)	
WCST			
Completed cluster			
Case	2.560 ± 1.365	4.250 ± 6.830	−4.061 (0.001**)
Control	2.310 ± 0.873	2.250 ± 0.931	0.324 (0.751)
T (P value)	0.617 (0.542)	6.928 (< 0.001***)	
Preservation error			
Case	22.130 ± 8.717	11.75 ± 3.85	4.251 (0.001***)
Control	24.94 ± 5.55	21.25 ± 5.09	2.151 (0.048*)
T (P value)	−1.088 (0.285)	−5.949 (< 0.001***)	
Non-preservation error			
Case	11.81 ± 9.82	5.69 ± 4.52	2.229 (0.042*)
Control	12.38 ± 7.69	15.31 ± 7.10	−1.640 (0.122)
T (P value)	−0.181 (0.558)	−4.480 (< 0.001***)	

The last column showed t-ratios and P values of paired sample t-tests used to evaluate executive functions before and after intervention in each group. The third row of every measurement index showed t-ratios and P values of independent t-tests used to examine the effect of intervention between groups. *P ≤ 0.050, **P ≤ 0.010, ***P ≤ 0.001. CWST: Color-word Stroop Test, CPT: Continuous performance test, WCST: Wisconsin card sorting test

For instance, findings of behavioral studies have shown that when older adults are trained in a particular strategy, if they believe that it is less effective than their current system, they will rapidly revert to their own initial strategies (65); or while training can affect the use and adherence of a specific strategy (66, 67), using different strategies in daily living is an individual characteristic that is rather stable over time (68). Moreover, Saczynski et al. (69) showed that self-generated strategies are associated with several demographic characteristics, including higher education, younger age, and race. Our results have shown that ARAM app using cognitive tasks versus strategy learning improves the execution functions though further study needs to examine its transfer and maintenance effects.

There are several behavioral interventions for executive function training such as Goal Management Training (GMT) (70). GMT was originally developed to teach patients with brain injury a strategy to improve their ability to plan activities and structure intentions. The GMT was based on the theoretical framework of disorganization of behavior (71). van Hooren et al. (72) used GMT in older adults and showed that after the intervention, participants did not improve on the objective test measuring executive functioning. They concluded that the older adults were not as impaired as patients with brain injury, so their capacity for improvement on objective test performance may have been more limited. In contrast, our findings showed that executive functions could be trained so that its objective measurement improves in older adults. Thus, the findings of van Hooren et al. may be related to their behavioral intervention versus to ARAM cognitive task intervention.

Thus, one limitation of strategy learning approach such as GMT versus cognitive task approach such as ARAM is the level on which intervention was defined so that intervention is defined on the behavioral level in former while it is defined on the cognitive level in latter.

Although the skill learning might be beneficial (73), its improvement is observed only in the trained task, with little or without transferring to similar untrained tasks (74). This is problematic for rehabilitation since it is expected that therapist should be able to increase the quality of everyday life. Everyday life requirements vary among different individuals, and it is not possible to design a program for each client. Based on this limitation, rehabilitation focus should be shift from behavior to cognitive demands in a deeper level. Another considerable issue is the fact that strategy training is often boring and unpleasant, so it may not be able to invoke participants or it may even reduce their motivation to perform it consistently (75). However, ARAM with joyful cognitive tasks with elevating mood and increasing motivation can lead to improvements in performance.

Another important issue in cognitive training is whether the behavioral improvement would also be achieved after training; in other words, is behavior trained with cognitive training? In a bottom-up approach, all behaviors originate from basic cognitive functions and strengthening these functions improve behaviors. For example, Willis et al. (76) found that self-reported reduction in the difficulty of complex home activities such as meal preparation and shopping using cognitive training. Cassavaugh and Kramer (38) also found that attention and working memory training improve driving performance.

Conclusion

The results of this study add to a growing body of evidence that shows the benefits of cognitive training programs. It extends the previous work in several ways. For example, in contrast to strategy learning programs in which the amount of involvement of each cognitive function is not clear, since the deficit in one cognitive process would be compensated with other one, ARAM was designed to improve different aspects of execution function separately. The rationale was that training in important areas (such as sustained attention, intentional and inhibitory controls, and cognitive shifting) would lead to improvement in overall cognitive function.

Yet, there is a need for further study to investigate whether the benefits of this program would extend to other tasks or outside the training environment. Another important questionability relates long-term benefits. It is clear that some follow-up assessments with different long intervals should be conducted to examine the long-term effects of ARAM app. Another obvious limitation of the present study was the small sample size which raises questions of external validity. Finally, while the experimental design allowed us to conclude that changes in the groups' performance were the direct result of rehabilitation, however, some other primary and secondary factors should still be investigated.

Conflict of Interests

Authors have no conflict of interests.

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