Cognitive Processing (2020) 21:383–390
https://doi.org/10.1007/s10339-020-00975-7

RESEARCH ARTICLE

Feasibility of using a computer-assisted working memory training program for healthy older women

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Received: 29 December 2018 / Accepted: 25 March 2020 / Published online: 28 April 2020

Abstract
Interventions for age-associated cognitive impairment are of increasing significance as populations age. Using N-back and memory strategy enhancement, the present study aimed to explore the feasibility of using, and outcomes of a working memory (WM) training program on visuospatial and verbal WM in older female adults. Older women from two comparable local health centers who scored 26 and higher on Mini-Mental State Examination were invited to participate. Women at one center (experimental group) received three sessions on memory enhancement techniques and a computerized training program with N-back. Women at the other center (control group) received three sessions on memory and aging and training on using various features of cellphones. All participants completed the Corsi Block Task and Digit Span Task at pre- and post-training. The experimental group showed significant improvements in their visuospatial and verbal WM compared to the control group. These findings support the brain's plasticity in the elderly. WM training for improving cognitive performance in older adults has potential and should be further investigated.

Keywords Cognitive training · Elderly · Older adults · N-back task · Visuospatial working memory

Introduction

The number of adults over age 65 has increased worldwide during the last century (Noroozian 2014), presenting challenges for a need to preserve cognitive functioning (Hendrie et al. 2006) and quality of life (Canbaz et al. 2003; Lee et al. 2006) with aging. Maintaining cognitive abilities is crucial for social interactions, goal-seeking and independence in older adults (Hendrie et al. 2006). Among different areas of cognitive function, memory is of particular importance in older adults (Lawlor-Savage and Goghari 2016; Negash et al. 2011). Working memory (WM) is the ability to maintain and process information in a short period of time (Berry et al. 2010). WM is critical to high-level cognitive abilities including the processes of learning, logical reasoning, problem-solving and fluid intelligence (Carretti et al. 2009) and is involved in emotion regulation and social interaction (Zinke et al. 2012). WM performance declines with age (Grady et al. 2003; Westerberg and Klingberg 2007) and is more susceptible to age-related cognitive changes than short-term memory (Brickman and Stern 2009). The brain reserve hypothesis (Valenzuela and Sachdev 2009) suggests that social and cognitive stimulation may protect against the effects of aging on cognitive function (Leman 2012).

Several studies based on the Adult Development and Enrichment Project (ADEPT) suggest that cognitive training and practice conducted with older people can lead to degrees of plasticity with WM (Baltes and Willis 1982). A recent systematic review of randomized controlled trials (Papp et al. 2009) suggests it is possible to improve cognitive performance in later adulthood in areas of nonverbal memory, verbal memory, working memory, processing speed and visuospatial skills. In addition, neuroimaging studies support cognitive training as able to enhance activity in brain

Handling editor: Stefano Federici (University of Perugia).

Reviewers: Linette Lawlor-Savage (University of Calgary) and a second researcher who prefers to remain anonymous.

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areas thought to be involved in WM tasks (Westerberg and Klingberg 2007).

Models of adult cognitive plasticity suggest that the brain is able to optimize its functions in response to environmental demands, and therefore cognitive training may enhance memory function (Lovden et al. 2010). However, improving WM in older adults is, at least in part, dependent on the cognitive training strategies and individual differences (Tardif and Simard 2011; von Bastian and Oberauer 2014). Studies suggest cognitive training in older adults is associated with improvements in certain aspects of their cognitive performance (Chiu et al. 2018; Goghari and Lawlor-Savage 2017), which could improve perceived quality of life (Hudes et al. 2019; Weng et al. 2019).

To date, no studies have examined the feasibility of improving WM among non-clinical, older female adult populations in Iran. The present study tested the effectiveness of a WM training program among a small sample of older women in Mashhad, the second largest city in Iran, using a quasi-experimental design.

Method

Participants

Initially, 70 older women answered an advertisement for the study at two local health centers that offer services for older adults from the same civil catchment area in Mashhad, Iran. The two centers provide similar services to older adults. Of the 70 women, those who met inclusion criteria for age (60–75 years) and language (Persian), and who did not have a history of psychiatric disorders or previous participation in a cognitive rehabilitation program were selected for further testing with the Mini-Mental State Examination (MMSE) (Folstein et al. 1975) and Clock Drawing Test (CDT) (Aprahamian et al. 2009). Women were eligible for the study if they scored ≥ 26 on the MMSE. Among the 45 who were eligible and agreed to participate, 20 were from the first health center and 25 were from the second. Based on a power analysis (below), 15 women from each center were randomly chosen. Considering the similarities of the two health centers and the socio-economic status of their clients, one center was randomly assigned to the experimental intervention and the other center was assigned to an active control group. The experimenter was aware of the allocation to study groups. There were two reasons for randomizing at the health center level instead of randomizing participants within each center: (a) all participants within each center were in close contact with each other in their daily activities; therefore, it was not possible to control for knowledge and skill transfer among the participants within the same center, and (b) the researchers and the ethics committee of the health centers considered it unethical to convey a sense of differentiation among the participants due to their group assignment. Participants did not receive any monetary compensation or other forms of incentives for their participation. The study was approved by the ethics committee of the Department of Psychology at Ferdowsi University of Mashhad and the management boards of the two health centers. Written informed consent was obtained from participants.

Power *analysis*

To calculate the number of participants needed, a power analysis was conducted using effect sizes (Cohen's d ranging from 0.29 to 2.71) found by previous, similar studies on cognitive training (Kueider et al. 2012). With a calculated mean effect size, $f^2 = 1.40$ (for statistical models based on F values); number of groups, $g = 2$; statistical power set at 0.80 and multivariate analysis of covariance (MANCOVA) as the statistical test, a sample of 20 participants (10 per group) was determined (Erdfelder et al. 1996).

Based on results from previous studies, and considering age and cultural issues, a maximum 50% attrition rate was expected from baseline to post-test. Therefore, each group enrolled 15 participants. Of the 15 participants assigned to the experimental group, ten (66.7%) completed all sessions. Of the 15 participants assigned to the control group, 12 (80%) completed the sham intervention; 10 of these participants were randomly matched to women in the experimental group and selected for the post-test comparison.

Instruments

Mini-mental status examination (MMSE)

The MMSE (Folstein et al. 1975) measures five different domains of cognitive function: (a) orientation; (b) memory; (c) attention and calculation (a measure of WM); (d) language and (e) design copying. The maximum score is 30, and a score of 25 or below can indicate significant cognitive impairment or related syndromes. Previous researchers (Seyedan et al. 2007) have reported a test–retest reliability (with a time interval of 24 h) of 0.89 and the inter-rater reliability of 0.82 for the Persian MMSE.

Clock drawing *test (CDT)*

The CDT (Aprahamian et al. 2009) is one of the oldest and most widely used neuropsychological assessment tools to measure cognitive abilities that may be involved in early Alzheimer's disease, such as short-term memory, spatial orientation, abstract thinking, planning, concentration, executive and visuospatial skills. The test requires the participant to draw the face of a clock with all the numbers and set the hands to a specified time. We used the Shulman scoring system (Shulman et al. 1993), which classifies test results in categories of 0 to 5 (lower score indicates poorer cognitive performance).

The MMSE and CDT were used as screening tools to exclude older woman whose scores could suggest abnormal cognitive functioning. All measurements were administered by one research assistant to rule out issues with inter-rater reliability.

Tests of working *memory (WM)*

Considering available standardized tests in the Persian language, we used two commonly used measures of verbal and visuospatial domains of WM (Bellack and Hersen 1998): (a) the Digit Span Task of the WAIS-III which has been standardized for Persian speakers. A Cronbach's Alpha of $\alpha = 0.65$ (Moradi et al. 2008) and a test–retest of $r = 0.83$ (Groth-Marnat 2000) have been reported for the Persian version. The Digit Span Task (Wechsler 1997) contains a series of digits that are presented at a rate of 1 s per digit, and participants are asked to repeat them in the same (forward) or reverse (backward) order. On each series, the task is stopped after two continuous recall errors. The forward Digit Span is largely accepted as a measure of attention, because even people with anterograde amnesia show normal scores on the forward Digit Span, and the backward test is a well-known test for the assessment of WM (Bellack and Hersen 1998; Conway et al. 2005). (b) The Corsi Block Task is a widely used test to assess short-term and WM by a non-verbal analogue of the Digit Span Task procedure, originally proposed by Hebb (1961). The Corsi Block-Tapping Task measures *visuospatial* memory with minimal verbal intervention. The test requires the retention of visual and spatial patterns.

Kessels et al. (2008) have shown that Corsi Block-Tapping Task relies on processing within working-memory systems, and the Digit Span backward relies on the central executive component of working memory. Three of the commonly used scores of the Corsi Block-Tapping Task are (a) *Corsi Block Span*, the longest sequence of trials that the participant can remember (as a measure of visuospatial short-term memory); (b) *Visuospatial Memory Span* that is calculated as immediate block forward span divided by immediate block backward span; and (c) Corsi Total Score that is calculated as the sum of numbers of blocks in all correctly recalled trials.

WM training task

We used a modified version of the N-back task, a frequently used instrument to measure WM (Owen et al. 2005) and as a WM training task (Lilienthal et al. 2013) among older adults (Stepankova et al. 2014). The task requires codification, temporary storage of information and response to task demands. Information must be updated and maintained continuously in the WM to access it readily (Harbison et al. 2011). Convergent and divergent validities of the task through clinical measurements and an *f*MR study support high validity for the test (Kearney-Ramos et al. 2014). In the current study, the structure of the N-back task was adapted from one used by Miller et al. (2009) and was comprised of four levels of difficulty (0, 1, 2 and 3-back) and included four types of stimuli: two-syllable words (Braver et al. 2001), three-digit numbers (Bragin et al. 2008), simple images or shapes (i.e., fruits, furniture, people, geometric and meaningless shapes) (Hautzel et al. 2003) and spatial stimuli (Carlson et al. 1998). The first level of difficulty (i.e., 0-back) was used as a warm up. For 0-back trials, participants were asked to simply identify a fixed target stimulus (e.g., any appearance of letter *X* in a sequence of stimuli). In the 1-back task, the participant identified two consecutively similar stimuli (e.g., *Y*, *Z*, *X*, "*X*"), whereas in the 2-back trial, the participant identified an identical stimulus that is two trials apart (e.g., *Y*, *X*, *Z*, "*X*"). It was assumed that the diversity of stimuli in each level helps maintain task involvement during the training program. We also utilized a random presentation of stimuli in order to reduce the possibility of developing response strategies by the trainees. SuperLab Pro (SKD) software (Cedrus-Corporation 1999) was used to develop the N-back task. A PC laptop (Dell 1700-200) with a 15.6″ DSTN color display was employed to present the stimuli. The viewing distance was 36–40 cm. The laptop's keyboard was used as the input device.

Procedure

The training procedure for the experimental group was comprised of two phases. First, three psychoeducational sessions were held to teach memory strategies (i.e., face-name associations, mental imagery, semantic organization, story making and chunking) (Tardif and Simard 2011). Participants were asked to use the strategies during the next computerized training sessions that aimed to improve their WM. The sessions were part of the cognitive training program that was approved by the health centers ethical committee, exploring the effectiveness of a computer-assisted memory enhancement intervention. Second, they received another 14 training sessions (2 sessions a week, 30–45 min each) using the N-back training task. The N-back training was conducted individually in a quiet room at the health center that was dedicated to the study. The N-back stimuli were randomly presented at the center of the laptop display for 500 ms, dispersed by an inter-stimulus interval of 2500 ms. Participants completed 12 blocks of trials (three blocks of trials and four conditions of difficulty), with each block comprising of 25 trials. The participants were instructed to monitor a series of stimuli and respond if the current stimulus was identical to the previous one (1-back). When the responses were correct at least in 85% of trials, the difficulty of the task was increased by adding one N-back trial to remember; on N-back trials ≥ 2, when responses were correct less than or equal to 85%, the task was adjusted to be easier. To control for initiation effect, the first three trials of each block did not include a target, the ratio of target to non-target trials was 30–70%, respectively. Participants were required to press the space bar on the laptop when they detected a target stimulus. Reaction times (RTs) and accuracy of responses were obtained for each trial. The results of each stage were calculated by Cedrus software (Cedrus-Corporation 1999). A short break (20 s) between blocks was provided to allow the participants to rest.

Similarly, the training procedure for the active control group was comprised of two phases. First, participants received three educational sessions on issues related to aging and natural changes in memory, such as how memory works, feelings about memory decline, factors affecting memory including diet, sleep and stress. Second, they participated in three sessions on how to use their cellphones more efficiently, including locking-unlocking their phone in various ways, using sound and alarm features, managing their contact list (adding, deleting, re-naming), composing and sending text messages (to individuals or lists), setting and using date and time features (e.g., for alarms, calendar). The groups classes lasted for 3 weeks. Next, they were required to practice what they had learned at home for the next 4 weeks and ask any questions prior to the post-test session. It was not necessary to have the subsequent sessions at the health center because there was nothing new to teach on how to use the cellphones. Therefore, participants were asked to practice the materials and tasks at least for 30 min at home twice a week. They logged their hours and turned the log in at the end of each training week when visiting the center. All participants continued visiting the center as normal for other activities as scheduled, so their social activities at the health center were not interrupted. Finally, the number of practice sessions and their lengths were equivalent across the two groups. For all participants, post-testing followed their final training session at week nine.

Statistical analysis

A series of *t* tests were calculated to compare the experimental and control groups' age, education and scores on the MMSE and Clock Test at pre-test assessment. An analysis of covariance (ANCOVA) was used to examine differences between the experimental and control group in order to test the hypothesis that WM training and memory strategies can enhance visual WM function of the older women. For the analysis, group (experimental vs. control group) was the independent variable; age, education and pre-test *total* scores of Corsi Block Task were covariates; and post-test total scores of Corsi Block Task were the dependent variable. Another ANCOVA was used to test the hypothesis that WM training and memory strategies can enhance the older women's verbal WM function. For this test, group (experimental vs. control group) was entered as the factor; age, educational level and the pre-test scores on the *total* Digit Span Task were covariates; and the post-test scores on the total Digit Span Task were the dependent variable.

We also conducted two multivariate analysis of covariance (MANCOVA) in order to include in our model more than one dependent variable so as to compare the two groups on Corsi Block-Tapping Task subscales (i.e., Corsi Block Span and Visuospatial Memory Span) and Digit Span subscales (i.e., forward and backward digit span). In each of the MANCOVA models, group (experimental vs. control group) was entered as the factor; age, education and the measures' pre-test scores as covariates; participants' scores on the post-test measures were dependent variables. Normalized data were used in all data analyses.

Results

There were no differences between the experimental and control groups in age and education, MMSE and CDT scores at pre-test (Table 1). Means and standard deviations of scores on Corsi Block Task and Wechsler Digit Span, in pre- and post-test measurements are presented in Table 2 for experimental and control groups.

First, after controlling for age ($F_{(1,\ 15)} = 0.44$, $p = 0.51$, $đ = 0.29$), education ($F_{(1,\ 15)} = 0.13$, $p = 0.72$, $đ = 0.19$), and pre-test *total* scores of Corsi Block-Tapping Task ($F_{(1,\ 15)} = 13.63$, $p = 0.002$, $đ = 1.88$), there was a main effect for group, with the experimental group scoring significantly higher than the control group on post-test *total* scores of Corsi Block-Tapping Task ($F_{(1,\ 15)} = 18.48$, $p = 0.001$, $đ = 2.21$). *Second*, after controlling for age ($F_{(1,\ 15)} = 0.71$, $p = 0.41$, $đ = 0.1.84$), education ($F_{(1,\ 15)} = 0.17$,

Table 1 Age, education and scores on Clock Test and MMSE at pre-test for experimental and control groups

	Experimental group		Control group		*p* value*
	Mean	SD	Mean	SD	
Age	68.40	5.89	67.00	4.52	> 0.05
Education	11.9	2.92	13.2	1.93	> 0.05
Clock Test	4.70	0.48	4.90	0.31	> 0.05
MMSE	28.10	1.66	29.4	1.07	> 0.05

MMSE Mini-Mental State Examination

*From *t* test

Table 2 Scores on Corsi Block Task and Wechsler Digit Span at pre- and post-test for experimental and control groups

Dependent variables	Pre-test				Post-test			
	Experimental group		Active control group		Experimental group		Active control group	
	M	SD	M	SD	M	SD	M	SD
Block Span	3.60	1.07	4.00	1.15	5.10	0.57	4.30	0.82
Memory Span	3.15	0.67	3.20	0.75	4.70	0.59	3.80	0.71
Total Block Task score	14.35	9.83	19.10	9.87	38.30	9.93	25.00	11.21
Forward Digit Span	6.10	1.60	4.90	0.74	7.00	.94	5.80	1.14
Backward Digit Span	5.80	1.23	5.00	1.49	7.40	1.35	6.10	1.20
Total Digit Span score	11.90	2.18	9.90	1.97	14.40	1.71	11.90	1.79

$p=0.68$, đ=0.73) and pre-test *total* scores of Digit Span ($F_{(1, 15)}=5.26$, $p=0.037$, đ=1.18), there was not a main effect for group on the post-test total scores of Digit Span ($F_{(1, 15)}=3.90$, $p=0.067$, đ=1.00). *Third*, MANCOVA results indicated that after controlling for age ($F_{(2, 13)}=1.66$, $p=0.34$, đ=0.84), educational level ($F_{(2, 13)}=0.30$, $p=0.74$, đ=0.42) and the participants' pre-test scores on the Block Span ($F_{(2, 13)}=0.12$, $p=0.88$, đ=0.27) and Visuospatial Memory Span ($F_{(1, 13)}=1.95$, $p=0.18$, đ=1.09), the main effect for group was significant ($F_{(2, 13)}=6.50$, $p=0.011$, $\wedge = 0.50$, đ=2.00). On the post-test, the experimental group scored significantly higher than the control group on Block Span ($F_{(1, 14)}=8.52$, $p=0.011$, đ=1.53) and on Visuospatial Memory Span ($F_{(1, 14)}=13.99$, $p=0.002$, đ=2.00).

Fourth, MANCOVA results indicated that after controlling for age ($F_{(2, 13)}=1.97$, $p=0.17$, đ=1.09), educational level ($F_{(2, 13)}=1.43$, $p=0.27$, đ=0.93) and the participants' pre-test scores on the Forward Digit Span ($F_{(2, 13)}=9.80$, $p=0.003$, đ=2.44) and Backward Digit Span ($F_{(1, 13)}=0.80$, $p=0.46$, đ=0.70), the main effect for group was not significant ($F_{(2, 13)}=2.76$, $p=0.10$, $\wedge = 0.70$, đ=1.30). Although on the post-test, the difference between the experimental and control group did not reach statistical significance on the post-test Forward Digit Span ($F_{(1, 14)}=0.47$, $p=0.50$, đ=0.36), the experimental group scored significantly higher than the control group on the post-test Backward Digit Span ($F_{(1, 14)}=5.91$, $p=0.029$, đ=1.31).

Discussion

This study of an N-back WM training program had two general findings. *First*, practicing with the memory training helped improve visuospatial WM in a group of older women with no apparent cognitive decline. *Second*, the training led to improvements in the trainees' verbal WM, as shown by increased scores on the Backward Digit Span Task, a measure of WM. However, as expected, there were no changes in the Forward Digit Span, which is largely a measure of attention (Bellack and Hersen 1998; Conway et al. 2005). These results are in agreement with earlier findings suggesting that cognitive plasticity can extend into older age (Borella et al. 2013; Dahlin et al. 2008; Degen and Schroder 2014; Karbach and Kray 2009; Li et al. 2008; Lindenberger et al. 2006; Salminen et al. 2016). Given that the majority of research to date has focused on individuals suffering from Alzheimer's disease, the present study is the first of its kind in Iran to explore the efficacy of a cognitive training program on verbal and visual WM among healthy, non-demented older women.

The rationale of the present study was based on two theories. *First*, cognitive plasticity could enable the brain to compensate for the loss of neurons or synaptic connections in one area of the brain by finding alternative processes or shortcuts to return the same level of cognitive efficiency (Leman 2012). *Second*, cognitive engagement suggests that older adults who participate in cognitive stimulation activities will experience less cognitive decline during their lifetime and will be less likely to develop dementia than people who are cognitively inactive (Fratiglioni et al. 2004). Our findings for WM are potentially consequential and should be followed up since WM is an essential component for many high-level cognitive functions that are related to everyday life activities, such as learning, logical thinking, problem solving and fluid intelligence (Alloway et al. 2006), emotion regulation and social interactions (Zinke et al. 2012). Furthermore, WM tends to decline with aging (Bopp and Verhaeghen 2005) and its deficit is an early symptom of Alzheimer's disease (Rosen et al. 2002). Further research is needed and should address the question of whether improvements in WM of non-demented older women could lead to improvements in their everyday activities and quality of life.

One limitation of the study is related to the experimental group's receiving instruction on using memory strategies prior to their N-back training sessions. This makes it difficult to stratify the source of post-training outcomes for the experimental group. However, it was not the goal of the present study to isolate the individual versus combined effects of each training type on WM modules or executive function. Therefore, based on the outcomes of this study, it is not possible to isolate the effects of each training method (i.e., N-back training vs. memory strategies) on measures of WM. For example, we assumed that the experimental group's performance on the N-back training task could benefit from learning memory enhancement techniques (i.e., mnemonics and hierarchical rehearsal) in that they could better remember relevant information and instructions related to practicing with the N-back task. However, there is ample evidence suggesting that training one WM module can be transferred to other WM modules and even to other executive cognitive functions (Borella et al. 2013; Degen and Schroder 2014; Salminen et al. 2016). Training programs may produce positive plasticity by involving multiple processes, including encoding, maintenance of information, inhibition of irrelevant information, simultaneous management of two tasks, shifting attention and ability to control attention (Carretti et al. 2013). Previous studies have shown that memory training is an effective tool for improving various memory abilities, such as WM, short term memory and episodic long-term memory among older adults (Rebok et al. 2007). This may have important implications for the older adults who experience age-related cognitive decline. That is, to improve cognitive function, it may not be necessary to address every cognitive ability individually with training exercises.

Results of this study will need to be replicated with additional, larger-scale studies. The sample was small and limited to older women who utilized the health centers' services and may not be representative of the older adult female population of Mashhad. Unfortunately, due to the uneven distribution of sexes in the health centers, we could not measure the effectiveness of the training in men or compare the results of the training between older adults and elderly participants. Thus, findings of the study may not be generalizable to older adult males or the elderly.

Despite the reasons stated for randomizing at the health center level, there is still a possibility that the study outcomes have been confounded by center allocation. Therefore, whenever possible, we suggest randomization of participants within a given center. Another criticism is that cognitive outcomes for the experimental vs. control group could be due to the experimental group being involved in more social activities than the control group who did the majority of their sham intervention at home. We consider this a very unlikely explanation because during the study, all participants were receiving all other routine services at the health center which required considerable social activities. Normally, older women in Iran have an important social status, receive considerable attention and are actively involved in family relationships as well as household activities, shopping, family gatherings and looking after their grandchildren. We also cannot rule out that women improved their performance on the N-back training over repeated trials. The study included participants with no detectable cognitive impairment; thus, studies of the effectiveness of the same intervention in those with cognitive impairment will warrant additional studies.

Based on participants' reaction to computerized tasks, we suggest further research on computer technology for older adults. The computerized techniques are cost-effective, self-administered, flexible with training times and easy to distribute (Kueider et al. 2012). During the training, most computerized programs can measure changes, provide immediate feedback and scoring and give persuasive messages to motivate the participant. Computerized training can also be adapted at the level of each individual participant's needs and level of cognitive performance. This provides an optimal level of challenge for the training.

To summarize, results of this study (a) support the feasibility of using computerized cognitive training among older adult women and (b) suggest positive outcomes of computerized WM training among older adult women in Iran on their visuospatial and verbal WM. Such programs should continue to be researched for their potential to be offered by local health centers serving older adult women. Future studies may address the potential benefits of using the presented WM trainings for the other areas of cognitive function.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants in the study.

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