The Spanish Journal of Psychology (2017), **20**, e39, 1–16.

doi:10.1017/sjp.2017.38

Effects of Cognitive Training on Cognitive Performance of Healthy Older Adults

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Abstract. The purpose of this study was to determine the immediate effects of cognitive training on healthy older adults and verify the transfer effects of targeted and non-targeted abilities. The design consisted of a semi-randomized clinical controlled trial. The final sample was composed of 80 volunteers recruited from a Brazilian community (mean age = 69.69; *SD* = 7.44), which were separated into an intervention group (*N* = 47; mean age = 69.66, *SD* = 7.51) and a control group (*N* = 33; mean age = 69.73, *SD* = 7.45). Intervention was characterized by adaptive cognitive training with 12 individual training sessions of 60 to 90 minutes (once a week). Eight instruments were used to assess effects of cognitive training. Five were used to assess trained abilities (near effects), including: Memorization Tests (List and History), Picture Completion, Digit Span, Digit Symbol-Coding, and Symbol Search (the last four from WAIS-III). Two instruments assessed untrained abilities (far effects): Arithmetic and Matrix Reasoning (WAIS-III). The non-parametric repeated measures ANOVA test revealed a significant interaction between group by time interaction for Picture Completion [$F(74) = 14.88$, $p = .0002$, $d = 0.90$, CLES = 73.69%], Digit Symbol-Coding [$F(74) = 5.66$, $p = .019$, $d = 0.55$, CLES = 65.21%] and Digit Span [$F(74) = 5.38$, $p = .02$, $d = 0.54$, CLES = 64.85%], suggesting an interventional impact on these performance tasks. The results supported near transfer effects, but did not demonstrate a far transfer effects.

Received 9 August 2016; Revised 31 July 2017; Accepted 3 August 2017

Keywords: aging, Brazil, cognitive training, intelligence.

Modifying intelligence during the aging process has been a target of intensive research over the past decade (Buschkuehl & Jaeggi, 2010). The role of lifestyle factors, such as education, engaging in stimulated mental activities, physical exercise, expertise, leisure activities and others, have been indicated as moderators of individual differences in cognitive aging and as protective factors for the development of dementia (Hertzog, Kramer, Wilson, & Lindenberger, 2008; Kramer & Willis, 2003; Valenzuela & Sachdev, 2009). Based on this, cognitive training sessions formulated within an experimental protocol are designed to test the degree of plasticity of cognitive functioning during aging (Kramer & Willis, 2003). One of the underlying assumptions when applying cognitive interventions is that the application of mental exercises and cognitive learning strategies may potentially improve or preserve some cognitive domains of the participating individuals.

A relative consensus regarding the classification of cognitive interventions, which are appropriate for use in older adults, seems to have been reached. For instance, Bahar-Fuchs, Clare, and Woods (2013) identified three cognitive intervention approaches: 1) cognitive stimulation related to the involvement in mental activities, which could be structured (as attention or speed exercises) or including supervised discussions; 2) cognitive rehabilitation involving individual sessions, which target a patient's daily life and/or family needs; and 3) cognitive training involving practice of mental exercises linked to learning strategies and skills. Cognitive interventions may be performed in small groups or individually, targeting different cognitive domains (multi-domain) or the same cognitive domain (e.g., memory training), as well as the use of pencil and paper or computerized stimuli.

There are several criteria from the literature that support the efficacy of cognitive interventions, such as: improvement in performance on cognitive tasks, maintenance of cognitive gain over time (by follow-up) and generalization of effects to other contexts, as solve daily problems or everyday functioning. Another common criterion to verify the cognitive training efficacy is to analyze transfer of training effects to different tasks

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How to cite this article:
Santos Golino, M. T., Flores Mendoza, C., & Fernandes Golino, H. (2017). Effects of cognitive training on cognitive performance of healthy older adults. *The Spanish Journal of Psychology, 20*. eXX. Doi: 10.1017/sjp.2017.38

within the same cognitive domain (near transfer) or other domains (far transfer) (Martin, Clare, Altsgassen, Cameron, & Zehnder, 2011). Near transfer is observed when there is an improvement on trained cognitive abilities (target abilities) and far transfer effect is observed when there is an improvement on untrained cognitive abilities (non-target abilities).

Through cognitive programs designed in the 1980's, such as the Adult Development and Enrichment Project (ADEPT, Baltes & Willis, 1982) and the Seattle Longitudinal Study (SLS, Schaie & Willis, 1986), systematic investigation of the impact of elderly cognitive function interventions have been well documented. One of the most well recognized intervention program was the Advanced Cognitive Training for Independent and Vital Elderly – ACTIVE. This program divided 2832 persons aged 65 to 94 years which were assigned into a control group (N = 704) and three training groups: one focusing on verbal episodic memory (N = 711), the second on reasoning (N = 705) and the third on speed of processing (N = 712). Each intervention improved the target ability compared with baseline, durable two years (p < .001 for all). Each training group maintained effects on its specific target cognitive ability through five years (memory: effect size, 0.23 [99% CI, 0.11–0.35]; reasoning: effect size, 0.26 [99% CI, 0.17–0.35]; speed of processing: effect size, 0.76 [99% CI, 0.62–0.90]) (Willis et al., 2006). After ten years, only reasoning and speed of processing groups maintained their effects on their target abilities (reasoning: effect size = 0.23, 99% CI = 0.09–0.38; speed of processing: effect size = 0.66, 99% CI = 0.43–0.88) (Rebok et al., 2014). These results provide robust evidence of cognitive training effect for abilities which were target on intervention.

Meta-analyses and systematic reviews studies have provided important information about the effectiveness of cognitive programs in healthy older adults. For example, a meta-analyses of 31 randomized controlled trials with healthy older adults (Kelly, Loughrey, Lawlor, & Robertson, 2014) revealed that executive function, when compared to active control groups, was improved through cognitive training (working memory, p = .004; processing speed, p < .001), as well as composite measures of cognitive function improved their scores after training (p = .001). Transfer effects for different contexts, like daily activities, were the most commonly reported results when training was adaptive (linked with everyday solving problems) and when it had been implemented with a minimum of 10 intervention sessions. Transfer effects for other cognitive domains were recorded in five out of seven trials: four trials reported transfer to untrained tasks within the same cognitive domain, and one trial reported transfer to other cognitive domain.

In a meta-analytic study with seven randomized controlled trails (Valenzuela & Saschdev, 2009), the results showed that cognitive exercise training in healthy older adults produces strong and positive effects on cognitive performance measured by neuropsychological tests. The study reported a strong effect size for cognitive interventions compared with control condition (WMD – 1.07, CI: 0.32–1.83, z = 2.78, N = 7, p = .006, N = 3.194). Additionally, the study revealed transfer effects to dementia-relevant domains, such as general cognition and daily functioning.

Analyzing several studies (Belleville, 2008; Gates, Sachdev, Singh, & Valenzuela, 2011; Law, Barnett, Yau, & Gray, 2014; Martin et al., 2011; Papp, Stephen, & Peter, 2009; Reijnders, van Heugten, & van Boxtel, 2013; Simon, Yokomizo, & Bottino, 2012), it is possible to observe consistent support regarding the positive impact of interventions aimed at target abilities (i.e., trained abilities), which support near transfer effects. However, far transfer effects are less reported, indicating a challenge for researchers. Few studies have reported transfer effects to untrained tasks within the same domain (Bottiroli & Cavallini, 2009; Cavallini, Dunlosky, Bottiroli, Hertzog, & Vecchi, 2010; Mahncke et al., 2006) or to other cognitive domain (Cheng et al., 2012).

Contrarily, there is no consensus regarding which specific cognitive strategies and intervention structure (e.g., multi-domain versus uni-domain; group versus individual settings, number of sessions, etc.) are more effective in promoting immediate gains in cognitive task performance. Heterogeneous intervention protocols make it difficult to contrast comparative meta-analysis associated with this topic (Martin et al., 2011; Papp et al., 2009). Given this scenario, some researchers are skeptical about structural cognitive changes (especially regarding fluid abilities) that have enduring effects in elderly (Hertzgov et al., 2008). In a review on cognitive training, Salthouse (2006) concluded that there was insufficient evidence supporting the cognitive enrichment hypothesis. This was due to either a lack of studies regarding far transfer effects or to methodological problems (for a review of methodological issues: Green, Strobach, & Schubert, 2014; Shubert, Strobach, & Karbach, 2014).

Databases such as PubMed and PsychInfo have indicated only 21 Brazilian studies published between 2000 and 2014 that address cognitive training in elderly individuals. Almost all of these studies implemented the group intervention modality (N = 20) while none presented procedures directed at accommodating individual levels of difficulty. The number of sessions ranged between 2 and 48 meetings. From these studies, 66.6% (N = 14) focused on episodic memory training, while 47.6% (N = 10) identified training effects of at least one cognitive measure. A complete list of the Brazilian studies can be found at Appendix 1.

The present study aims to address the evidence gap regarding far transfer effects, as well as add new data to the currently published Brazilian cognitive experimental studies with elderly people, with particular focus on individual session modality. An important point is to note the innovative aspect of this study: the procedures of intervention used to accommodate the individual levels of difficulty.

Method

Design

The study used a semi-randomized controlled trial, two group-design, including one treatment group and one control group. Independent teams conducted the administration of the cognitive measures and the training sessions. After informed consent, participants were randomly assigned into the experimental group (EG) or control group (CG). Some participants were reassigned in order to balance age and years of education between groups.

As a null hypothesis (Ho), this study does not consider differences in cognitive performance between experimental and control group. The experimental hypothesis, in turn, considered the existence of differences in cognitive performance between the groups, both for target abilities (H1) and for non-target abilities (H2).

Participants

The sample consisted of 80 volunteers recruited from Brazilian communities located in the city of Vitoria da Conquista, Bahia (Northeast region). The average age of the participants was 69.69 years (*SD* = 7.44), 77.5 % female and 7.25 years of education (*SD* = 5.09). Participants were recruited between March and October 2014. Exclusion factors included younger than 60 years; cognitive impairment, detected by the Mini Mental State Examination with reasonable reliability: sensitivity = .69 and specificity = .91 (according to O'Bryant et al., 2009), depressive symptoms (Geriatric Depression Scale, score $\geq$ 7), self-reported diagnosis of Alzheimer disease, severe losses in vision, hearing or communicative ability, and 30 % of absences in the training sessions. The total sample was divided into experimental group (*N* = 47; mean age = 69.66, *SD* = 7.51; average education of 7.40 years, *SD* = 4.86) and control group (*N* = 33; mean age = 69.73, *SD* = 7.45; average education of 7.06 years, *SD* = 5.42). Table 1 presents sociodemographic and clinical characteristics of the sample. Note that some participants with 1 to 4 years of education were not able to read and write and therefore were considered illiterate. The sample size can be justified by convenience and it is in accordance with previously published Brazilian papers: 66% of the studies (cited on Appendix 1) presented sample sizes varying from 50 to 112 people. The participants medical history were not included as interest variable considering that medical or pharmacological interventions were not integral to this study.

The participants were randomly assigned to their respective groups and, after analyze their social characteristics, some reallocations were made in order to equilibrate age and education levels between the groups.

Table 1. *Sociodemographic and clinical characteristics*

Group			
Variable	Experimental Group (*n* = 47)	ControlGroup (*n* = 33)	*p*
Age	69.66 (7.51) 60 – 89	69.73 (7.45) 60 – 84	.98[b]
Sex			
Female	39 (83%)	23 (69.7%)	**.04**[a]
Male	8 (17%)	10 (30.3%)	.63[a]
Education	7.40 (4.86) (1–17)	7.06 (5.42) (1–18)	
1 to 4 yrs	18 (38.3%) (illiterates = 7)	14 (42.5%) (illiterates = 4)	
5 to 8 yrs	8 (17%)	10 (30.4%)	
9 to 11 yrs	4 (8.5%)	1 (3%)	.83[b]
12 or more yrs	17 (36.1%)	8 (24.1%)	
MMSE Score	27.13 (4.66)	28.20 (4.20)	.67[b]
GDS Score	3.59 (2.63)	4.00 (3.55)	.92[b]

Note: Sex and Education variables represented with frequencies and valid percent in parenthesis.
MMSE: Mini Mental State Examination
GDS: Geriatric Depression Scale
[a]Chi-Square Test
[b]Kruskall-Wallis Test

This procedure imposed limitations on the randomization process, but ensured that both groups had equivalent levels of age and educational level, two important factors that affect cognitive function.

Intervention

According to longitudinal studies, cognitive training focused attention, processing speed, episodic memory and working memory, all include some form of cognitive abilities that decline with age (Krame & Willis, 2003; Salthouse, 2006). Due to stimulation of different cognitive domains, training was classified as multidomain intervention (Cheng et al., 2012). The training was designed to be conducted during 12 individual sessions, lasting between 60 and 90 minutes each, once a week. The sessions were conducted in an adaptive format, i.e., the difficulty level of the session was adapted to the participant's skill level and is linked to the individual's everyday problem solving.

The choice of such cognitive abilities for intervention was guided by four sets of evidence reported in literature: 1. Episodic memory training seems to be one of the most investigated domains in the cognitive intervention field. Systematic review and meta-analytic studies commonly reported significant effects (around .7) of training gain (Belleville et al., 2006; Verhaeghen, Marcoen, & Goossens, 1992); 2. Multidomain training usually presented better results when compared with unimodal interventions (Auffray & Juhel, 2001; Willis et al., 2006) 3. Attention and processing speed exercises prior to episodic memory training (format known as pretraining), improve effect size, which range from 0.1 – 1.21 (without pretraining) for 0.88–1.18 (with pretraining) (Gates et al., 2011); 4. Working memory exercises showed better results in transfer effects (Hertzgov et al., 2008).

In attention training, five activities were presented using auditory and visual stimuli. For processing speed training, three tasks were assigned, demanding visual search and the ability to process increasingly complex sets of information (presented during a limited period). For episodic memory training, seven tasks were presented, which focused some mnemonic strategies, such as visual imagery, face-name recall, immediate/spaced recall and idea association. Finally, executing activities involving working memory training, five tasks were presented, of which verbal and auditory stimuli were needed to be simultaneously processed.

The present intervention was developed and customized especially for this study, consisting of individualized training for the Brazilian population. As cognitive tasks were performed, participants received instruction regarding cognitive strategies to assist them in their performance. The following is a brief description of the tasks performed during each session. Detailed program information can be found in Golino and Flores-Mendoza (2016).

- *Session 01:* Identifying differences between figures; fill, as quickly as possible, the correct path of the mazes.
- Session 02: Analyze a figure and reproduce it. Then reproduce the same figure from memory.
- Session 03: Identify, in a set of several words, the one incorrect word or word that does not exist; listening carefully a story divided into sections. Retell a part of the story, followed by full story recital.
- Session 04: Mark the target stimulus within a set of distracters.
- Sessions 05 to 07: Learn and practice several mental visualization techniques in order to memorize information, such as names, numbers, schedules and important dates.
- Sessions 08 and 09: Learn and practice idea association techniques in order to memorize information, such as names, numbers, schedules and important dates.
- Session 10: Count a number of target stimulus within a set of distracter stimuli while singing in rhythm.
- Session 11: Read a story divided into disorganized sections. Then, organize the story in a chronological order and recount it.
- Session 12: Repeat a sequence of months and order according to calendar. Counting the number of letters in words, without the aid of printed stimuli.

Participant selection screening tests

- Anamnesis interview: items regarding clinical health, sociodemographic data, emotional and behavioral state, and psychiatric disorders and/or dementia diagnosis, as self-reported.
- Geriatric Depression Scale - GDS (Yesavage et al., 1983) (exclusion for scores $\geq$ 7): self-reported scale used to detect symptoms of depression in the elderly. The short version was used (15 items) according to Brazilian criteria (Almeida & Almeida, 1999).
- Mini-Mental State Examination - MMSE (Folstein, Folstein, & McHugh, 1975): scale used to detect the presence of dementia symptoms. This study used Brazilian criterions samples according to education level, using the following cut-off scores indicating no dementia: 20 for illiterates; 25 for 1 to 4 grade; 26.5 for 5 to 8 grade; 28 for 9 to 11 grade and 29 for higher education levels (Brucki, Nitrini, Caramelli, Bertolucci, & Okamoto, 2003).

Pre- and Post-training cognitive measures

- Six subtests from Wechsler Intelligence Scale for Adults, WAIS-III, 3rd edition (Nascimento, 2004; Wechsler, 2004): picture completion, digit symbol-coding, arithmetic, matrix reasoning, digit span, and symbol search. The raw scores were converted to a standard scale (1 to 19) according to Brazilian age norms.

- Memorization Test – Supermarket List (adapted from Yassuda, Lasca, & Neri, 2005). Task related to episodic memory, in which 35 supermarket items must be memorized. Replacement of some non-familiar items for familiar items were made according to cultural and socioeconomic background of the sample studied, which differed from the standardized sample. The scores ranged from 0 to 35 (one point for each correct answer).
- Memorization Test – History (adapted from Yassuda et al., 2005): this task assesses episodic memory, consisting of reading a text using griffon strategy, followed by story recollection. Some adaptations from original version were necessary in order to assess illiterate participants, which included oral text during two consecutive sessions. Afterward, participants should orally recount the previously heard story. For literate participants, normal procedures were conducted. Due to this alteration, scores were computed in the present study as follows: 1 point when the main message was not recalled; 2 points when the main message was recalled, but without specific details, such as names, numbers or places; 3 points when the main message was recalled accompanied by inclusion of some specific details; and 4 points when the main message was recalled with inclusion of all (or almost all) specific details.

In order to investigate near transfer effects, the following were considered as cognitive measures for target-abilities (trained abilities): Memorization Test (Supermarket List and History), Picture Completion, Digit Symbol-Coding, Digit Span and Symbol Search.

In order to investigate far transfer effects, two outcomes assessed non-target abilities (untrained abilities): Arithmetic and Matrix Reasoning, which measures mental calculation and logical and abstract reasoning, respectively.

Procedures

After the recruitment, enrollment and group assignment, all participants underwent a pre-test session. In sequence, the EG received 12 individual cognitive training sessions, ranging from 60 to 90 minutes each, once a week. Finally, post-test assessments were conducted. It is noted that in individual sessions, pre-test and post-test were immediately conducted before (pre-test) and following (post-test) the training. While professionals that were responsible for pre- and post-tests assessment were different from those who conducted the training session, they were not blinded from the experimental condition of the participants. This could impose some design limitation, however, we argue that all cognitive measures were objectives and therefore exempt from examiner's bias. Ethical procedures were carefully applied and all participants provided informed written consent. Note that at the conclusion of the study, the control group participants received training. Following the post-test, all participants (EG and CG) received an individual interview in order to transmit their results (orally and written).

Data Analysis

Initially, descriptive statistics pre- and post-test were estimated for both groups (EG and CG). Statistics were calculated from the weighted scores of the Brazilian norms, according to age (Scale 1 to 19; Nascimento, 2004). For the Memorization Test - Supermarket List, the number of correct answers was used (scale 0 to 35). For Memorization Test – History, scale adjustments were made as previously described. Then, pre-test differences between the two groups were evaluated using the Mann-Whitney test.

The normality test Shapiro-Wilk, which is appropriate for samples with less than 100 participants, was used for testing the hypothesis that the sample is derived from a normally distributed population. For measures that refuted the null hypothesis of the Shapiro-Wilk test, i.e., with higher values than 0.05, repeated measures ANOVA were conducted. For measures that showed significance in the Shapiro-Wilk test, the rank transformation ANOVA was used (Baguley, 2012), which is a non-parametric test for ANOVA repeated measures. The effect size was computed using the compute.es package (Del Re, 2013) which computed Cohen's d (Cohen, 1988), confidence interval, *p* value and common language effect size (CLES). McGraw and Wong (1992) developed the CLES indicator as an intuitive tool to estimate the effect size, converting the effect on the probability that a score randomly obtained from a distribution will be higher than a randomly obtained score from another distribution. More precisely, it expresses how much (as a percentage) higher a population score is than a score from other population, if both scores were randomly selected. Finally, all analyses were performed using software R (R Core Team, 2012).

Results

The Table 1 shows the baseline sociodemographic and clinical characteristics for each group from the final sample:

Sample distribution was balanced between groups in relation to sociodemographic and clinical variables, except for females ($\chi^2 = 4.12$, $p = .04$).

https://doi.org/10.1017/sjp.2017.38 Published online by Cambridge University Press

Descriptive Statistics

Initially, the Shapiro-Wilk normality test was performed on raw data. Results showed a non-normality distribution for all measures, except for Arithmetic (WAIS-III), which showed a normal distribution (W = 0.98, p = .09) (Table 2).

Next, mean, median, maximum and minimum values and standard deviation for pre and post-test, separated for EG and CG, were calculated (Table 3).

The Mann-Whitney test (for non-normal distribution), revealed significant differences using the following: Memorization Test List (W = 3406.5; p = .03) favoring the CG, Matrix Reasoning (W = 3369.5; p = .04) favoring the EG and Symbol Search (W = 3599.5; p = .003) favoring the EG.

To analyze this difference in Arithmetic, Student's t test was performed in independent samples, which revealed no significant difference between EG and CG before intervention (t = 0.26; p = .79). Additionally, no significant differences were revealed for the other measures.

Table 2. *Shapiro-Wilk test normality*

Outcome	W	Sig.
Memorizationtest (List)	0.9453	< .001
Memorizationtest (History)	0.8457	< .001
Complete Figures	0.942	< .001
Codes	0.9625	< .001
Arithmetic	0.9849	.09
Matrix Reasoning	0.9291	< .001
Digits	0.9263	< .001
Symbol Search	0.9373	< .001

Training Effects

In order to estimate the immediate gain effects of cognitive training, a *rank transformation* ANOVA was conducted for measures with non-normal distribution and ANOVA repeated measures for Arithmetic, with normal distribution. Table 4 demonstrates all outcomes:

For Memorization Test (Word List) (Figure 1), there was a significant difference when evaluating time $F(79)$ = 9.47, p = .002 for both groups (EG and CG), suggesting an important scores change during this interval. No significant effects between Group (EG or CG) was found $F(79)$ = 3.44; p = .006. The absence of significant interaction effects between Time by Group $F(79)$ = 0.52, p = .047 indicates that differences between pre- and post-test for EG may not be attributed to the intervention.

Similarly, results from the Memorization Test (History) (Figure 2) demonstrated a significant effect for Time $F(79)$ = 5.01; p = .002, but not for Group $F(79)$ = 0.55; p = .045. There was no significant interaction effects when comparing Time by Group $F(79)$ = 2.67; p = .010, suggesting an absence of the training effect.

For Picture Completion (Figure 3), a significant interaction effect was observed for Time by Group $F(79)$ = 14.88;

Table 3. *Descriptive Statistics for EG and CG*

	EG				CG			
	Pre-test		Post-test		Pre-test		Post-test	
Memorization	**Mean/Median**	*SD*	**Mean/Median**	*SD*	**Mean/Median**	*SD*	**Mean/Median**	*SD*
Test (List)	11.15 /11.00 (6 – 21)	4.61	14.68 / 17.00 (5–23)	4.77	13.52 / 11.00 (5–24)	5.59	14.87 / 13.00 (7–25)	5.42
Memorization	**X/x**	*SD*	**X/x**	*SD*	**X/x**	*SD*	**X/x**	*SD*
Test (History)	1.70 / 2.00 (1–3)	0.82	2.25 / 2.50 (1–4)	1.07	2.36 / 2.00 (1–4)	1.11	2.39 /2.00 (1–4)	1.15
Complete	**Mean/Median**	*SD*	**Mean/Median**	*SD*	**Mean/Median**	*SD*	**Mean/Median**	*SD*
Figures	10.53 / 9.50 (6–17)	3.24	13.09 / 14.00 (7–19)	3.50	11.00 /11.00 (7–16)	3.05	11.39 /10.50 (6–17)	3.23
Codes	**Mean/Median**	*SD*	**Mean/Median**	*SD*	**Mean/Median**	*SD*	**Mean/Median**	*SD*
	9.26 / 9.50 (0–17)	3.10	10.18 / 10.00 (0–17)	3.31	9.10 / 8.50 (5–13)	2.48	9.23 / 9.00 (5–15)	2.56
Arithmetic	**Mean/Median**	*SD*	**Mean/Median**	*SD*	**Mean/Median**	*SD*	**Mean/Median**	*SD*
	9.16 / 9.00 (0–16)	3.18	9.39 / 10.00 (0–16)	3.28	8.76 / 9.00 (3–18)	3.70	8.97 / 9.50 (2–18)	3.74
Matrix	**Mean/Median**	*SD*	**Mean/Median**	*SD*	**Mean/Median**	*SD*	**Mean/Median**	*SD*
Reasoning	10.72 / 10.00 (5–19)	3.00	11.45 /11.00 (6–19)	3.50	9.58 / 9.00 (5–16)	2.56	10.15 /10.00 (6–15)	2.53
Digits	**Mean/Median**	*SD*	**Mean/Median**	*SD*	**Mean/Median**	*SD*	**Mean/Median**	*SD*
	9.94 / 9.00 (4–19)	3.26	11.47 /11.00 (6–19)	3.55	10.16 / 9.50 (5–19)	3.65	10.00 /9.50 (4–19)	3.75
Symbol	**Mean/Median**	*SD*	**Mean/Median**	*SD*	**Mean/Median**	*SD*	**Mean/Median**	*SD*
Search	10.83 /10.00 (4–19)	3.44	11.69 /11.00 (6–19)	3.42	10.42 /9.00 (7–15)	2.35	10.71 / 9.00 (7–16)	2.59

Note: Maximum and minimum in parenthesis.
Scale: Memorization Test List (0–35), Memorization Test History (1–4), Subtests WAIS-III (1–19).

Table 4. *Rank transformation ANOVA*

Outcome				
		DF	*F*	*P*-value
Memorization Test List	(Intercept)	79	325.5222	<.0001
	Time	79	9.4794	.0029*
	Group	79	3.4438	.0675
	Time x Group	79	0.5234	.4717
		DF	*F*	*P*-value
Memorization Test History	(Intercept)	79	302.46189	<.0001
	Time	79	5.0193	.0281*
	Group	79	0.55308	.4594
	Time x Group	79	2.67153	.1064
		DF	*F*	*P*-value
Picture Completion	(Intercept)	79	281.94014	<.0001
	Time	79	35.88892	<.0001*
	Group	79	0.21085	.6474
	Time x Group	79	14.88001	.0002*
		DF	*F*	*P*-valuer
Digit Symbol-Coding	(Intercept)	79	254.46321	<.0001
	Time	79	9.31093	.0032*
	Group	79	0.98948	.3231
	Time x Group	79	5.66828	.0198*
		DF	*F*	*P*-value
Matrix Reasoning	(Intercept)	79	281.45166	<.0001
	Time	79	2.80586	.0981
	Group	79	2.6161	.11
	Time x Group	79	0.02068	.886
		DF	*F*	*P*-value
Digit Span	(Intercept)	79	284.69432	<.0001
	Time	79	8.12043	.0057*
	Group	79	1.2244	.2721
	Time x Group	79	5.38977	.023*
		DF	*F*	*P*-value
Symbol Search	(Intercept)	79	278.92205	<.0001
	Time	79	7.42665	.008*
	Group	79	5.19488	.0255*
	Time x Group	79	2.4647	.1207
		DF	*F*	*P*-value
Arithmetic	(Intercept)	79	554.3726	<.0001
	Time	79	3.9017	.050*
	Group	79	0.2615	.6106
	Time x Group	79	1.7446	.1906

*p-value < .05.

p = .002, suggesting that differences between pre- and post-test for EG may be due to training. The effect size for this interaction was strong (d = 0.90, CI = 95%), indicating that for 100 randomized selections, 73.7% of the results will be similar (CLES = 73.69%).

The Digit Symbol-Coding results (Figure 4) also demonstrated a significant interaction effect for Times by Group $F(79) = 5.66$, $p = .019$, indicating that differences exist between the pre- and post-test could be attributed to intervention for EG. The effect size for this interaction was moderate (d = 0.55, CI = 95%), and indicated that for 100 randomized selections, 65.2% of the results will be similar (CLES = 65.21%).

For Matrix Reasoning (Figure 5), there was no significant effect for either Time $F(79) = 2.80$; $p = .009$; Group $F(79) = 2.61$; $p = .011$ or for interaction factors between Time and Group $F(79) = .02$, $p = .088$. These results suggest that there are no significant differences between

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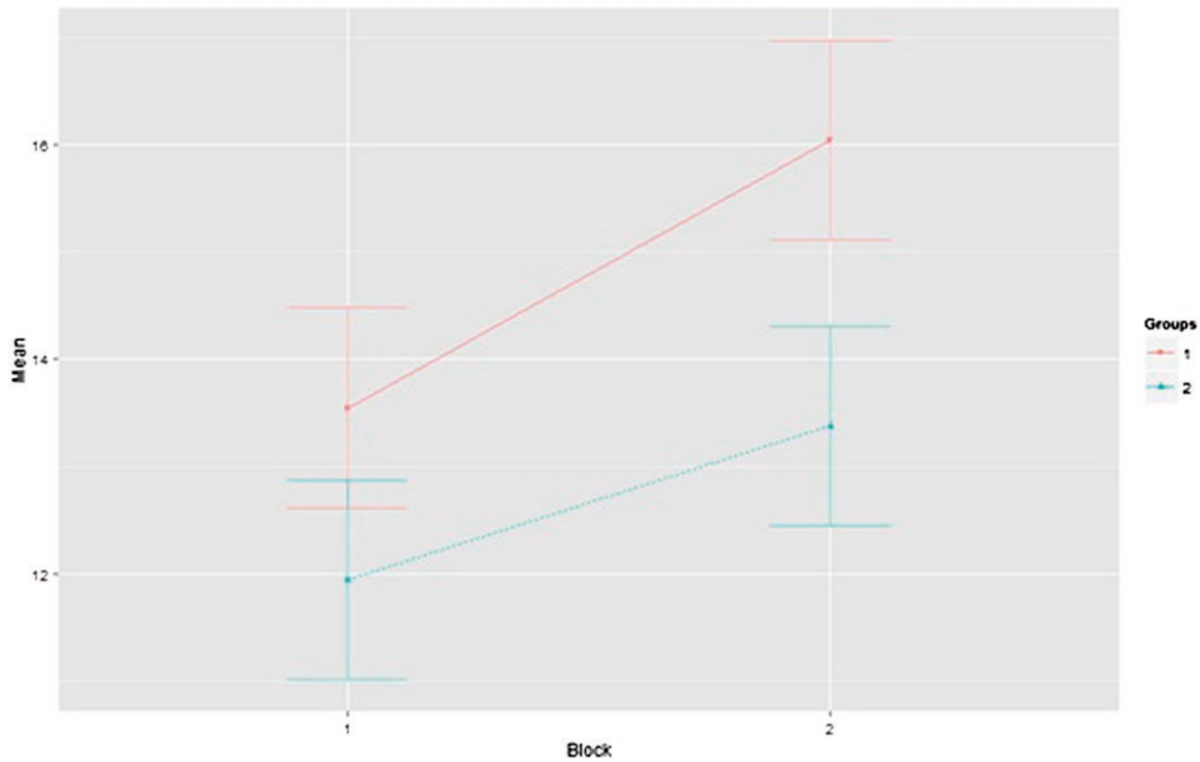

Figure 1. Memorization Test (List): rank transformation ANOVA.
Legend: Group 1 = EG (red line); Group 2 = CG (blue line); Block 1 = pre-test; Block 2 = post-test

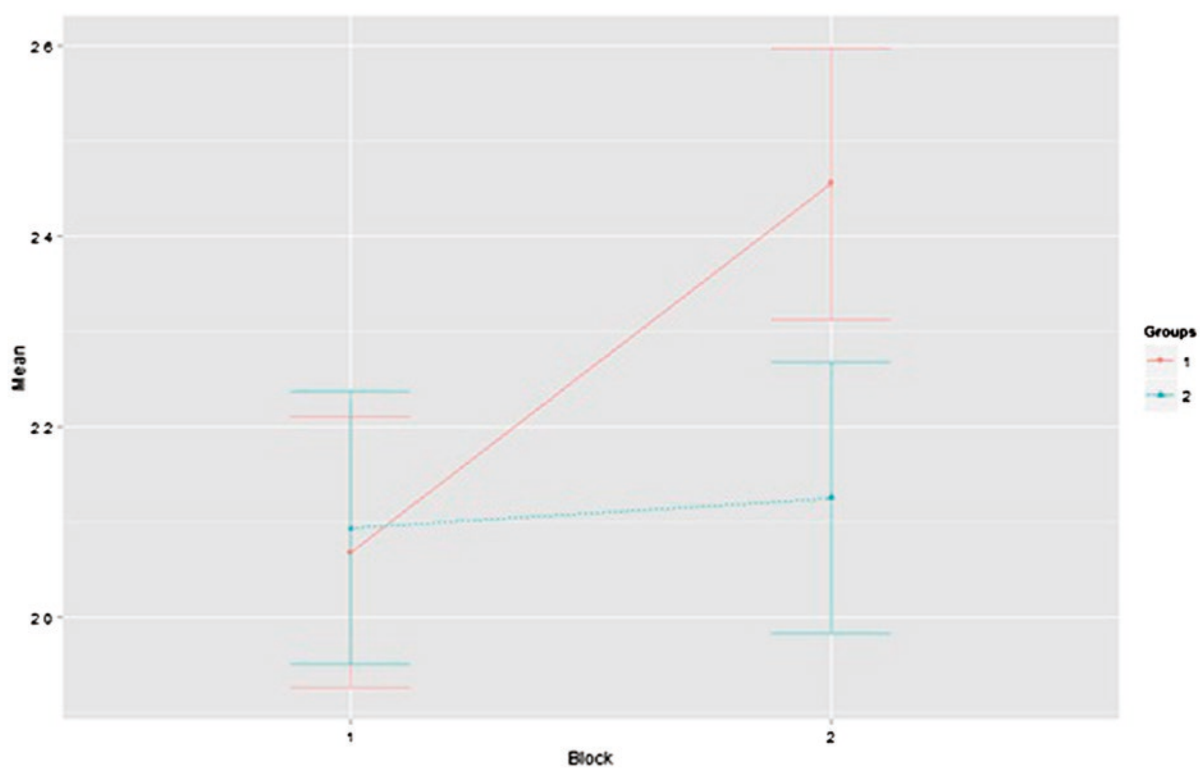

Figure 2. Memorization Test (History): rank transformation ANOVA.
Legend: Group 1 = EG (red line); Group 2 = CG (blue line); Block 1 = pre-test; Block 2 = post-test

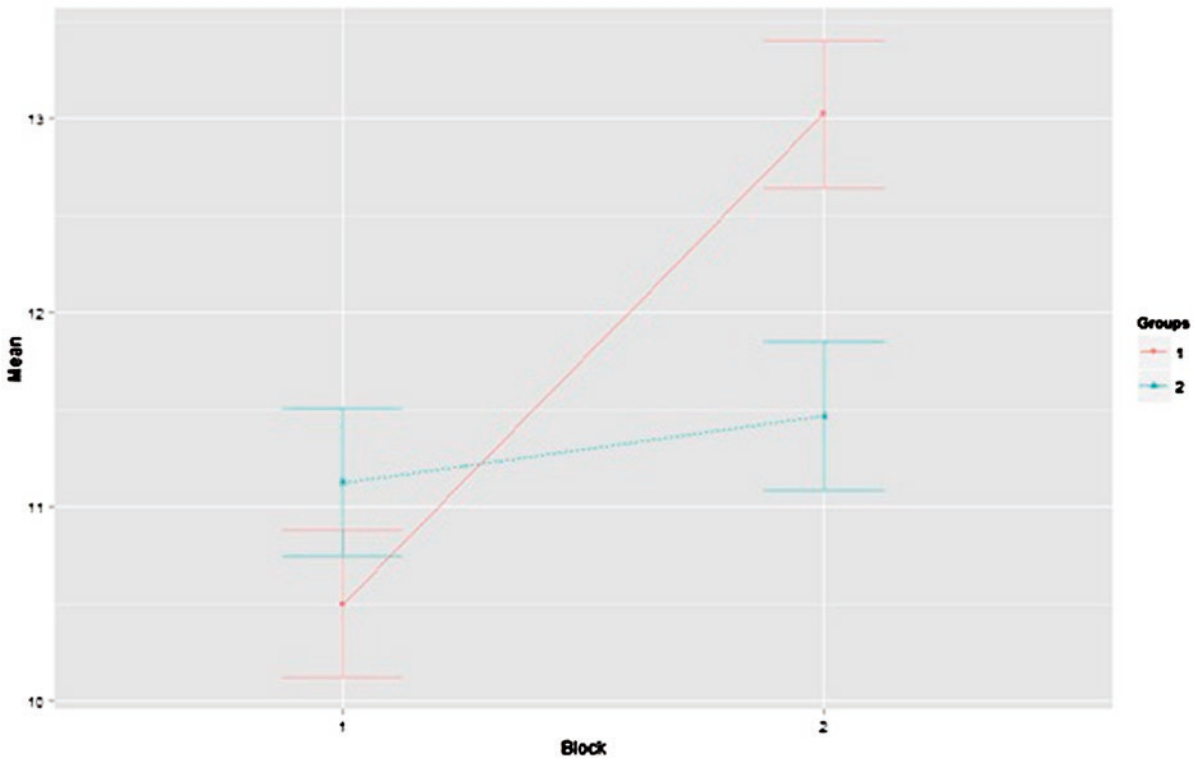

Figure 3. Picture Completion: rank transformation ANOVA.
Legend: Group 1 = EG (red line); Group 2 = CG (blue line); Block 1 = pre-test; Block 2 = post-test

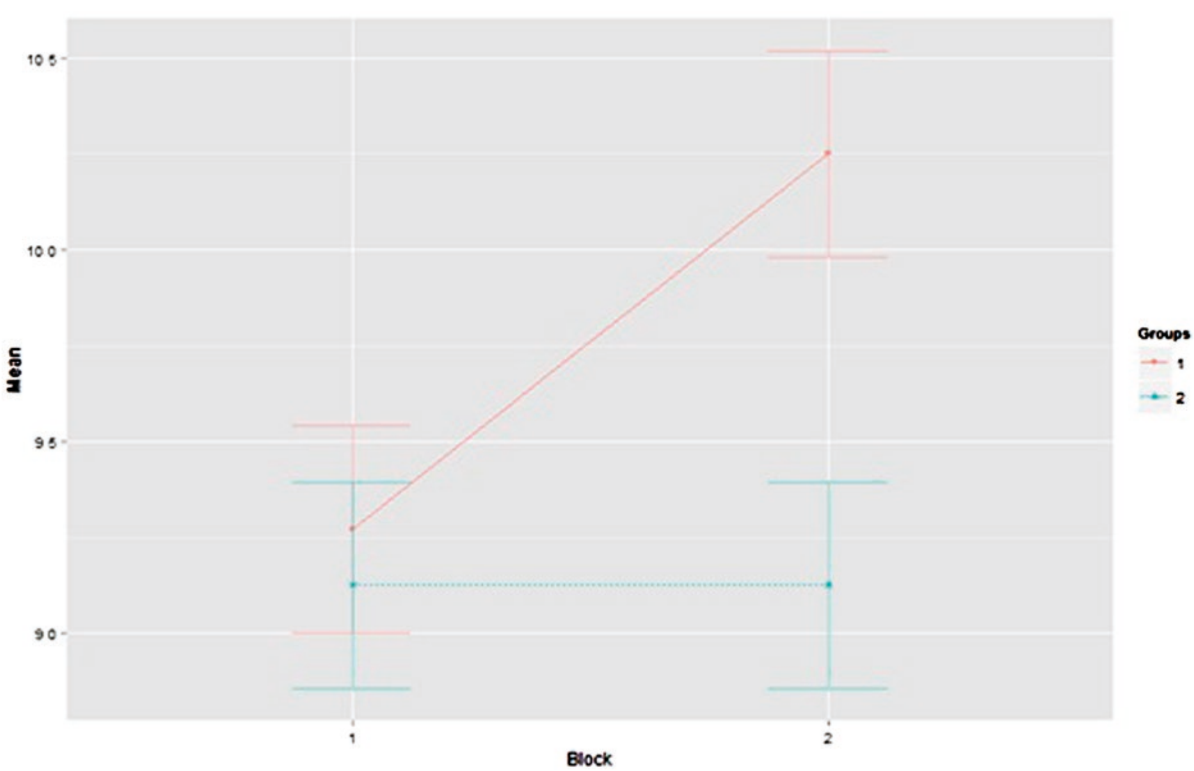

Figure 4. Digit Symbol-Coding: rank transformation ANOVA.
Legend: Group 1 = EG (red line); Group 2 = CG (blue line); Block 1 = pre-test; Block 2 = post-test

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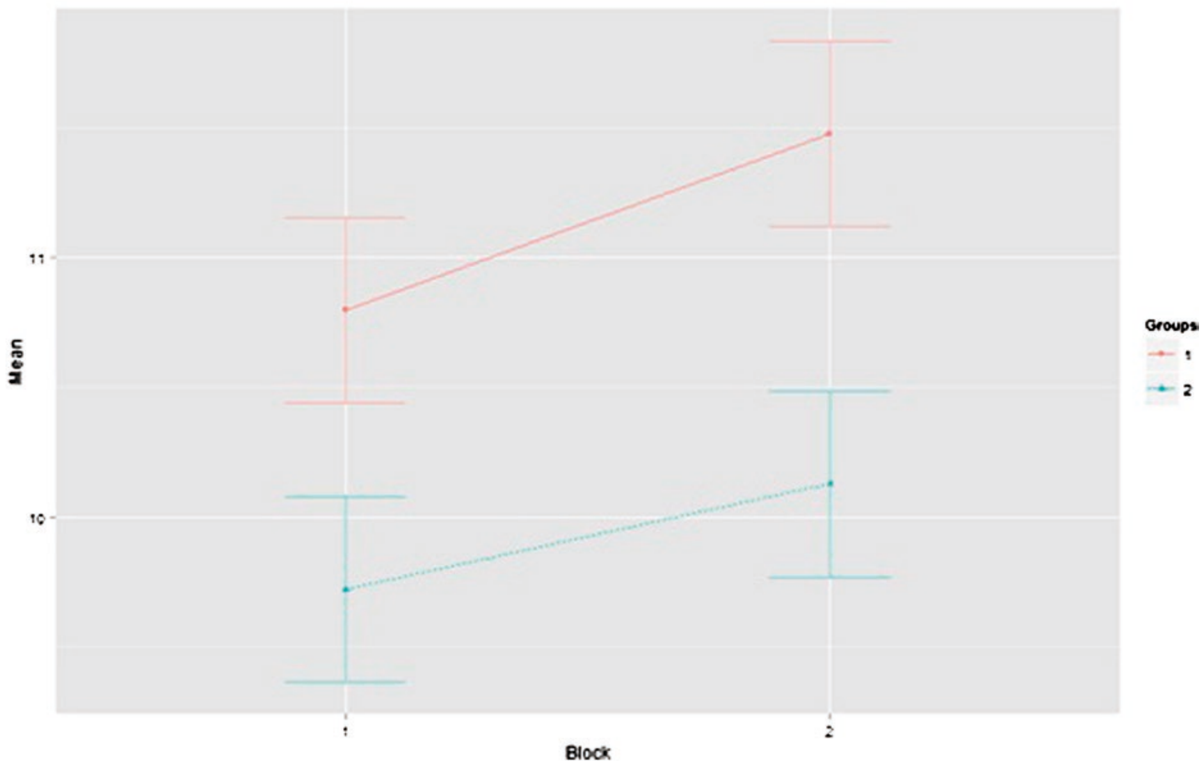

Figure 5. Matrix Reasoning: rank transformation ANOVA.
Legend: Group 1 = EG (red line); Group 2 = CG (blue line); Block 1 = pre-test; Block 2 = post-test

groups during the intervals that could be attributed to the training.

For Digit Span (Figure 6), a significant interaction was observed for the effect of Time by Group $F(79) = 5.38$, $p = .002$, indicating that differences between pre- and post-test for EG could be attributed to the intervention. The effect size for this interaction was moderate ($d = 0.54$; CI = 95%), and indicated that for 100 randomized selections, 64.85% of the results were similar (CLES = 64.85%).

Symbol Search (Figure 7) investigation demonstrated a significant effect for Time $F(79) = 7.42$; $p = .008$ and Group $F(79) = 5.19$; $p = .002$, but not for interaction factors $F(79) = 2.46$; $p = .012$, indicating that differences between the groups during the interval could not be attributed to the training.

Finally, Arithmetic was evaluated using ANOVA repeated measures (Figure 8). A significant effect for Time $F(79) = 3.90$; $p = .005$ was measured, suggesting a difference between pre- and post-test for both groups (EG and CG). No significant effect was measured for Group $F(79) = 0.26$; $p = .061$ or interaction $F(79) = 1.74$; $p = .019$, which means both groups (EG and CG) had similar gains through time.

Discussion

The present study tested the effects of cognitive training in healthy elderly. The obtained results supported the H1 hypothesis (cognitive differences between groups for target abilities). However, the H2 hypothesis (cognitive differences for non-target abilities), was rejected.

Recent publications have consistently shown a positive effect on objective cognitive measure performance, when assessed immediately following intervention (Gates et al., 2011; Law et al., 2014; Martin et al., 2011; Papp et al., 2009; Reijnders et al., 2013; Simon et al., 2012). The present study observed positive effects for intervention training in 3 out of 8 cognitive measures used, which were: Picture Completion, Digit Symbol-Coding and Digit Span. This finding has been previously reported in older adults, since large-scale studies generally report intervention effects for some or all of the cognitive measures. However, cognitive gains were observed in trained abilities (near transfer), but not in untrained abilities (far transfer).

The literature reports a high agreement regarding the impact of cognitive training on abilities trained during intervention for healthy older adults, as shown in meta-analysis and systematic review studies (eg., Kelly et al., 2014; Martin et al., 2011; Papp et al., 2009; Reijinders et al., 2013; Tardif & Simard, 2011). Comparing the results of this research with experimental studies with similar design (individual setting), it is possible to observe the same results pattern. In multidomain cognitive interventions, near transfer

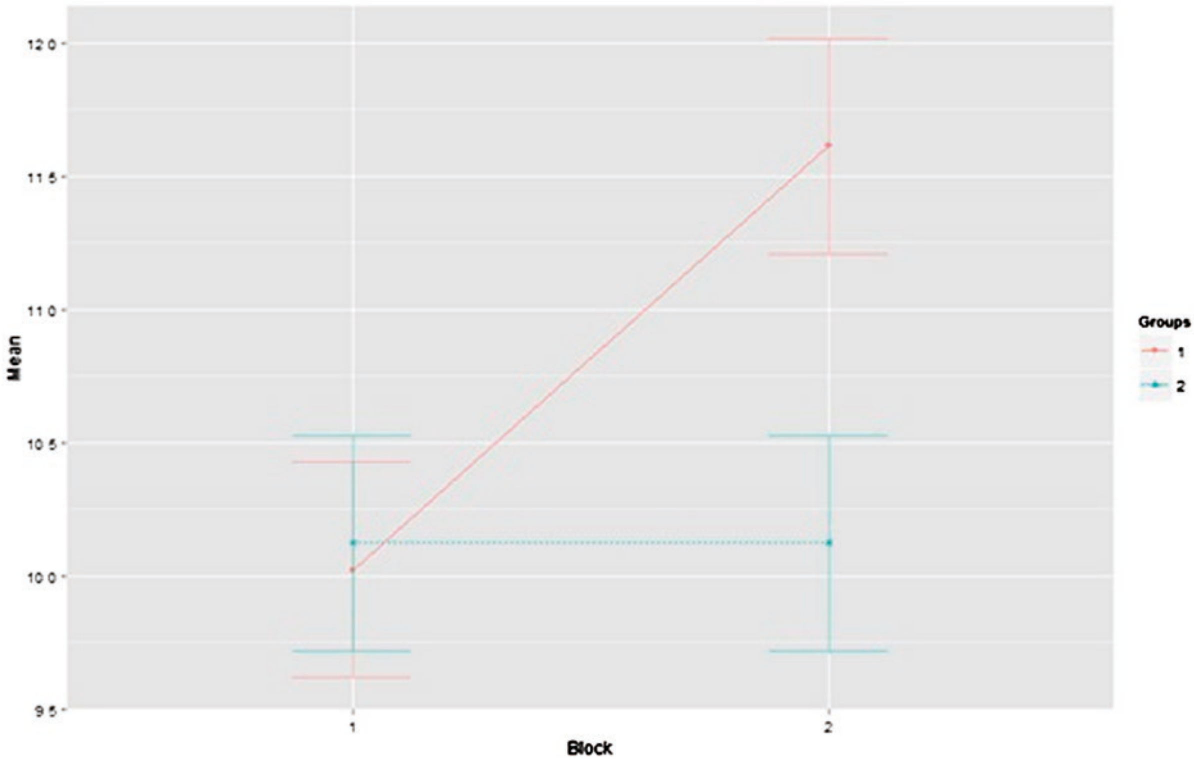

Figure 6. Digit Span: rank transformation ANOVA.
Legend: Group 1 = EG (red line); Group 2 = CG (blue line); Block 1 = pre-test; Block 2 = post-test

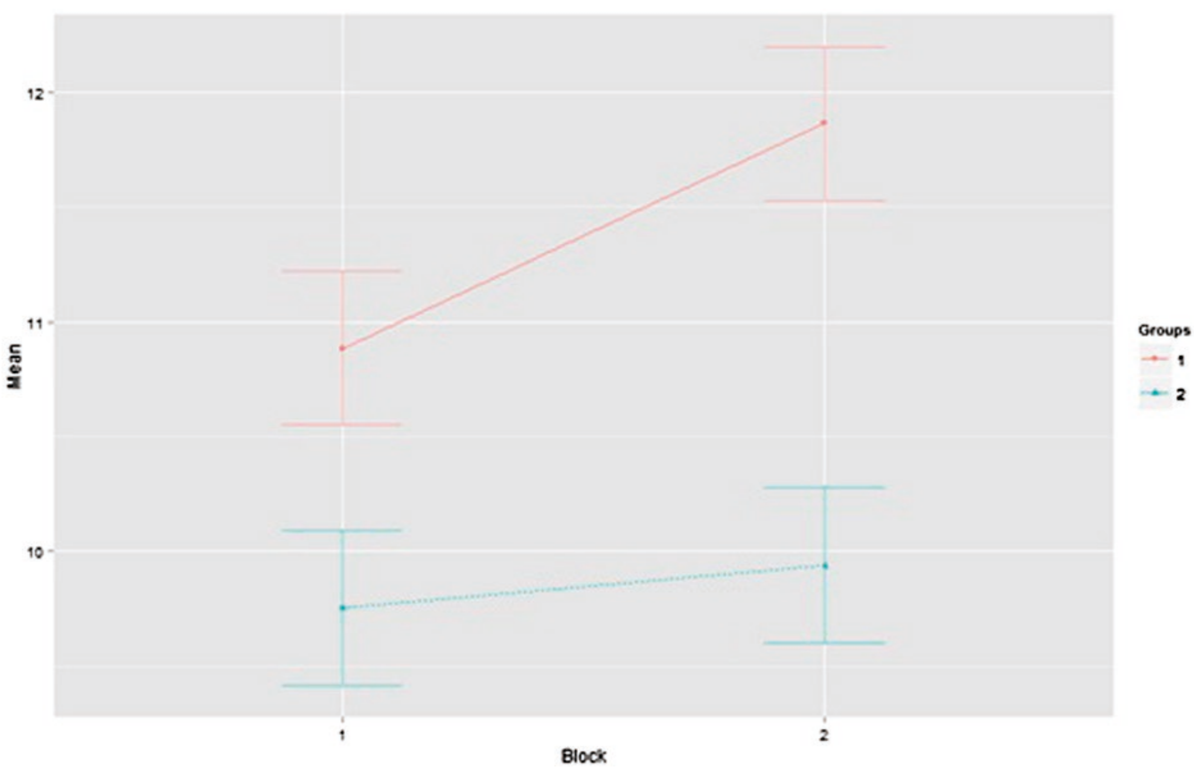

Figure 7. Symbol Search: rank transformation ANOVA.
Legend: Group 1 = EG (red line); Group 2 = CG (blue line); Block 1 = pre-test; Block 2 = post-test

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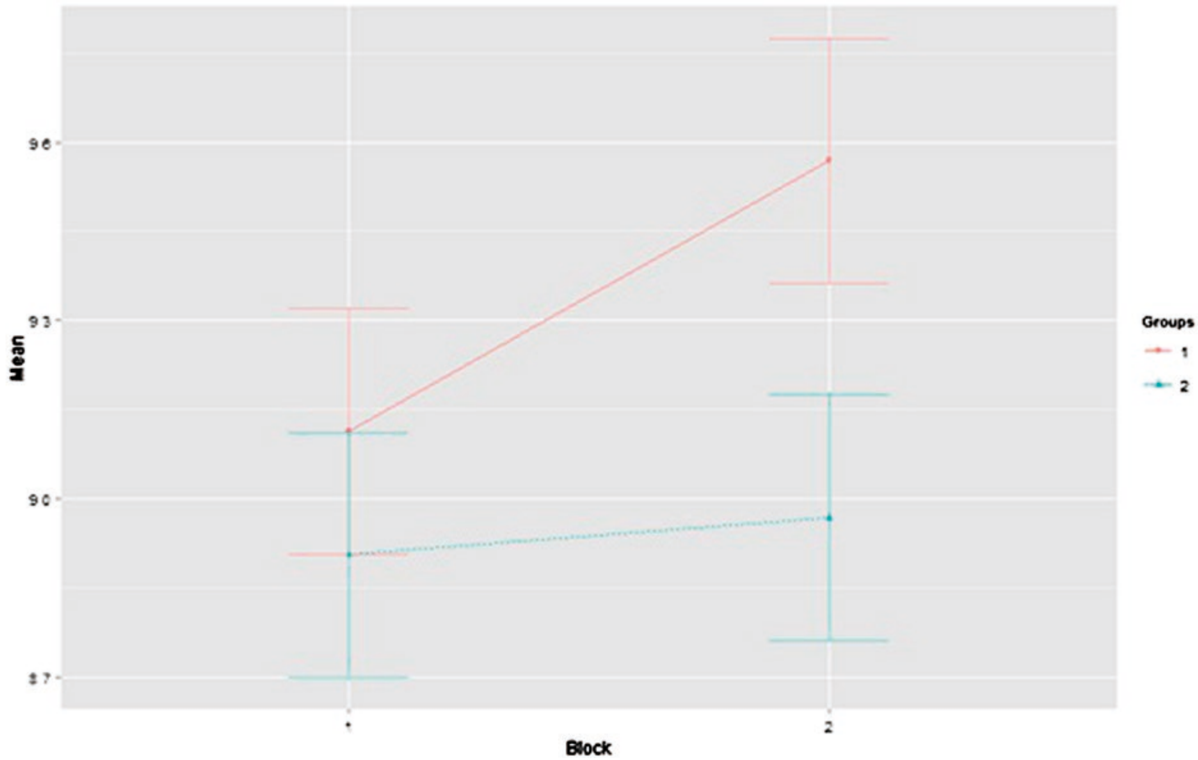

Figure 8. Arithmetic: rank transformation ANOVA.
Legend: Group 1 = EG (red line); Group 2 = CG (blue line); Block 1 = pre-test; Block 2 = post-test

effects for trained abilities were reported for: attention and processing speed (Bugos, Perlstein, McCrae, Brophy, & Bedenbaugh, 2007); episodic memory (association and imagination strategies trained) (Fabre, Chamari, Mucci, Masse-Biron, & Prefaut, 2002); reasoning and short-term memory (but no effect for some target abilities such as attention and mental rotation) (Basak, Boot, Voss, & Kramer, 2008); and episodic memory (Tranter & Koutstaal, 2008). For unimodal cognitive training with individual setting, near transfer effect for trained abilities was reported for: selective attention (training focused on visual and auditory selective attention) (Mozolic, Long, Morgan, Rawley-Payne, & Laurienti, 2011); visual perceptual skills (perceptual discrimination training) (Berry et al., 2010); episodic memory and metamemory (Fairchild & Scogin, 2010). Finally, an adaptive cognitive training to improve speed and accuracy of auditory information processing showed positive effect for experimental group for auditory memory, attention, digit span and processing speed (Smith et al., 2009).

The results for untrained abilities in this research non-target-abilities (Arithmetic and Matrix Reasoning) indicated no difference between groups, suggesting that intervention had no impact on solving numeral problems or spatial, logical and abstract reasoning. These results are also supported by literature, which demonstrates a substantial training effect for target-abilities and a restricted impact for those tasks that assessed untrained abilities (Kelly et al., 2014; Martin et al., 2011; Reijinders et al., 2013). A meta-analyze conducted by Karbach and Verhaeghen (2014) examined the effects of process-based executive –function and working memory training (49 articles) in older adults (>60 years) and found significant effects on performance on the trained tasks (near transfer). As expected, the far transfer effects were smaller than near transfer effects.

However, some experimental studies with individual setting reported far transfer effects for: metamemory in a training on visual and auditory selective attention (Mozolic et al., 2011) and in a training on working memory (Richmond, Morrison, Chein, & Olson, 2011); episodic memory (metacognitive skills training) (Bailey, Dunlosky, & Hertzog, 2010); spatial perceptual skills (multidomain training) (Tranter & Koutstaal, 2008). A verbal working memory training which aimed to observe transfer effect for untrained abilities showed far transfer effect for short-term memory and processing speed and near transfer effect for untrained abilities at the same domain (visuospatial working memory) (Borella, Carretti, Riboldi, & De Beni, 2010).

Interestingly, in the present results one of the trained abilities (Symbol Search) and two of untrained abilities (Arithmetic, Matrix Reasoning) of which no cognitive training effects were observed, are usually related to the core of intelligence, specifically to crystallized intelligence (Arithmetic) and fluid intelligence (Symbol Search, Matrix Reasoning). In this regard, there have been some strong doubts regarding the possibility of raising intelligence through cognitive training (Moody, 2009). If far transfer effects are difficult to detect, it would be more difficult to support the cognitive enrichment hypothesis. At best, partial cognitive enrichment may be suggested, considering the positive evidence found in several studies related to near transfer, including our own study.

Many studies which accept the cognitive enrichment hypothesis, based exclusively on positive results derived from near transfers, favor a confirmation bias (Hertzgov et al., 2008; Salthouse, 2006). Assuming that our criticism is correct (there would be only partial cognitive enrichment), we would argue that many intervention programs that have been transformed into business products, such as Brain Age (Nitendo), provide no scientific evidence to support the alleged training effects (for a description of such products, go to http://www.sharpbrains.com). The efficacy of these software/programs needs to be empirically verified and reported applying the same scientific standards that pertain to interventions created by researchers.

Considering the estimated worldwide proportion of people over 60 years (20% in 2050), according to the United Nations (http://www.un.org/esa/population/publications/worldageing19502050/), the next decades will be crucial for expanding knowledge on aging and cognition. The evidences accumulated since the 1970's do not reject the possibility preservation or enhancement of mental function during aging by cognitive training. However, this possibility is limited to the intervention period (as durability effects are rarely reported), to the trained abilities (as far transfer effects are less reported) and to specific abilities (see reviews: Bahar-Fuchs et al., 2013; Gates et al., 2011; Kelly et al., 2014; Martin et al., 2011; Papp et al., 2009; Tardif & Simard, 2011). The results presented in this paper are consistent with these general findings, since we demonstrated an observed gain effect related to specific and trained abilities.

Finally, the results presented in this study are relevant insofar as they present a new cognitive training protocol that was elaborated in the context of the Brazilian population, and it contributes by endorsing evidences regarding the immediate positive effects of cognitive training on the elderly population. In addition, target transfer effects abilities were presented.

However, some limitations should be acknowledged: the small sample size, which limited the use of more robust statistical techniques; screening for dementia and mild cognitive impairment based only on the MMSE and self-report, making possible the inclusion of individuals in very early stages of dementia in the sample; the not-blinded condition for those who administrated pre and post-test assessments, although this limitation has been reduced by the use of only objective measures; the semi-randomization of participant distribution, as some participants were assigned to alternative groups in order to balance age and educational level between EG and CG. This led to a compromised not-blinded condition of evaluators and researchers regarding the participants in the experimental condition. In future studies, we suggest that these methodological limitations can be removed by extending the present cognitive training protocol investigation to other samples.

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Appendix 1.

Brazilian Cognitive Studies with Elderly Revised

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