The effects of different proxies of cognitive reserve on episodic memory performance: aging study in Iran

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ABSTRACT

Objective: The main aim of the present study is to investigate the association between different measures of cognitive reserve including bilingualism, mental activities, type of education (continuous versus distributed), age, educational level, and episodic memory in a healthy aging sample.

Methods: Four hundred and fifteen participants aged between 50 and 83 years participated in this cross-sectional study and were assessed with the Psychology Experimental Building Language Test battery tapping episodic memory. Demographic variables were collected from a questionnaire designed by the research team.

Results: Compared to participants with continuous type of education, those with distributed type performed better in tests of episodic memory, while no differences were found between bilingual and monolingual participants. We additionally found that age negatively predicts episodic memory, whereas playing mind teasers and educational level have positive relationships with episodic memory.

Conclusions: Our results indicate that higher cognitive reserve, as measured by distributed educational training, higher level of education, and doing regular mental activities, is associated with better performance on episodic memory tasks in older adults. These results were discussed in connection with successful aging and protection against memory decline with aging.

Key words: episodic memory, cognitive reserve, bilingualism, mental activities

Introduction

Successful aging is a term that is frequently heard in the modern era due to the significant transition of societies from young to an aging population structure. By this demographic shifting, many concerns have been raised for age-related pathologies (e.g. dementia, Alzheimer’s disease) that affect brain structures and functions in older adults.

Over the past few years, many attempts have been dedicated to brain health promotion in aging population. As a result of these efforts, a new concept termed as “Cognitive Reserve” (CR) has been proposed as one of the protective barriers against the clinical presentation of brain-related pathologies and a key component of successful cognitive aging (Caffo et al., 2016; Daffner, 2010; Vance, 2012). In a recent study with normal older adults aged 50–65 years, CR has been indicated to have a positive association with quality of life (Lara et al., 2017). As a brain capacity, CR engages different cognitive processes and neural networks to cope with brain damages. As an individual characteristic, people have different susceptibility to cognitive decline (because of brain aging, pathology, or insult) due to their CR (Stern, 2002; 2009; Stern et al., 2018). For example, studies considering the association between CR and the onset of dementia and Alzheimer’s disease indicate that CR can delay the onset of their clinical manifestation by about 4 to 5 years (Bialystok et al., 2007; Craik et al., 2010; Woumans et al., 2014). Another important role of CR in successful aging has been suggested by a series of studies examining the association between CR and cognitive functions including episodic memory. While there is a consensus on age-related changes in episodic memory (memories for events) and its vulnerability to multiple age-related brain disorders, there are evidences supporting the moderating role
of CR in these changes (Nilsson et al., 2004; Nystrom et al., 2017; Zahodne et al., 2013). For example, Giogkaraki and colleagues applied structural equation modeling to study how CR was related to age and cognitive functions in healthy older adults and indicated that CR decreases the direct negative effect of age on episodic memory (Giogkaraki et al., 2013). Similar results has also been reported by Vuoksimaa et al. (2013). Other studies also demonstrated that higher level of CR is directly associated with better performance in episodic memory (Dias et al., 2015; Fyffe et al., 2011; Opdebeeck et al., 2016).

In all these studies, CR has been indirectly measured by different factors referred as proxy. Educational level (Jefferson et al., 2011), bilingualism (Bak et al., 2014; Ossher et al., 2013), and doing mental activities (Scarmeas et al., 2001) are commonly used indicators for CR measurement.

Although the potential contribution of these indicators has been investigated in several studies, there are some inconsistencies between the reported results. For example, some studies indicated that bilingualism is associated with better memory performance and delays the onset of memory loss symptoms in healthy and Alzheimer’s disease (AD) adults (Bialystok et al., 2007; Craik et al., 2010; Ljungberg et al., 2013). While Zahodne et al. (2014) did not support this result and indicated that bilingualism was not related to the rate of change in episodic memory (Zahodne et al., 2014).

Another arguable proxy indicator is mental activities that may affect memory performance. Some studies have shown that frequent participation in mentally stimulating activities (e.g. reading books/newspapers/magazines, doing crossword puzzles) is associated with better memory performance and lower risk of AD or mild cognitive impairment (MCI) development in older population (Sattler et al., 2012; Scarmeas et al., 2001; Wilson et al., 2007; 2013; Yates et al., 2016). However, it has been found that writing and taking part in group discussions as mental activities may not prevent memory loss and risk of AD (Gottlieb, 2003). One possibility is likely due to the different natures of these activities in terms of their mental stimulation properties (Cheng, 2016).

Although educational level is another proposed indicator of CR, some studies have not supported the moderating effect of educational level on age-related decline in episodic memory (Wilson et al., 2009; Zahodne et al., 2011).

Therefore, by lack of sufficient evidence in different aspects of this field of research and the importance of CR in successful aging, the present study is conducted to examine whether there is an association between CR proxies (bilingualism, mental activity, type of educational training and educational level) and episodic memory performance in older adults. We assumed that having higher level of education, being bilingual, and doing regular mental activities are associated with better episodic memory. We also sought to answer this question that if there is difference between participants who had continuous training and those who had distributed training throughout ones’ educational life on the measures of episodic memory.

Method

Participants

Four hundred and fifteen participants (292 female, 123 male) aged between 50 and 83 years who were living in Tehran, recruited through advertisements in social networks and flyers distributed in the residential areas in the neighbourhood of the university campus (Tehran University). It should be noted that the participants included in this project are a subgroup recruited into the project of “Sepidar” that is a long-term project at the University of Tehran. Free assessment of memory with a complete report of memory performance was presented in the advertisements to invite people to participate. The recruited participants completed the Mini Mental State Examination (MMSE), the short version of the Depression Anxiety Stress Scale-21 (DASS-21), as well as a demographic questionnaire. Episodic memory was assessed with a set of computerized tests from the Psychology Experimental Building Language (PEBL) battery (Nilsson et al., 1997). All tests and questionnaires were performed by an experienced psychologist from the research team (Mottaghi Ghamsari, A). Data were collected between September 2014 and September 2017. The inclusion criteria for participants were age between 50 and 83 years and had a minimum educational level of elementary school (being able to read and write in Farsi). Participants were excluded if they had dementia according to score on MMSE (<23) (Ansari et al., 2010), had mild to extremely severe levels of psychological distress according to score on DASS-21 (depression > 7 or anxiety > 6 or stress > 10) (Jafari et al., 2017), and reported history of brain disorders (e.g. stroke, traumatic brain disorder) as well as visual and auditory impairments. All selected participants were informed of the study objectives and procedures involved and were required to sign an approved informed consent before assessments.

Assessments

Demographic questionnaire

Demographic information was collected using a questionnaire developed by the research team. The
questionnaire had six main sections concerned with information related to basic demographic data (including age, gender, and marital status), health status (including history of brain disorders and visual and auditory impairments), language background (monolingual or bilingual), mental activities, educational level, and type of education (distributed or continuous types). The criteria for being bilingual were considered as speaking/writing two different languages fluently (Farsi and the second language) in their everyday life. The measure of mental activity was obtained by the average time that the participants spend on doing mental activities (including reading news or books, playing crosswords and mind teasers (e.g. Sudoku, video games), writing, doing calculation, watching television programs (e.g. documentary, sport, news, movie or TV serial drama), web searching, and social networking) per week. For educational level, participants were divided into four groups of high school (those with less than 12 years of schooling), associate degree (those with 12 years of schooling), bachelor’s degree (those with 16 years of schooling), and master’s/doctoral degree (those with more than 16 years of schooling). In Iran, classical education begins at age of 6–7 years with the elementary schools and proceeds to the secondary and then high schools. Students earn their associate degree at age of 18 years and then bachelor’s degree at age of 22 years. Postgraduate education normally takes around 2–6 years, and so without any gap, students earn their doctoral degree at age of 28 years (22 years of schooling). But for most of students, this process takes longer and extends beyond 22 years of schooling. Since in our sample the latest age at which participants finished their schooling continuously was 35, we categorized participants into two groups based on this cut-off point. Those who graduated before the age of 35 were categorized in the group with continuous educational training, while those who graduated after the age of 35 were categorized in the group with distributed educational training.

The depression, anxiety, and stress scale
It is a questionnaire with 21 self-report items developed to measure psychological distress in terms of three subscales (depression, anxiety, and stress). All the items are measured on a four-point scale (0 = did not apply to me at all, 3 = applied to me very much, or most of the time). Higher scores indicated higher depression, anxiety, and stress. Reliability and validity of Farsi version of DASS-21 have been reported by Asghari et al. (2008).

Mini mental state exam
MMSE is a 11-item screening tool for cognitive impairments in various dimensions including orientation, attention, recall, naming, and comprehension. The total score is 30 and a higher score indicates better performance. The Farsi version of MMSE that has been validated among Iranian population (Ansari et al., 2010) was used in the present study.

Episodic memory evaluation
The present study used computerized tests of episodic memory from the PEBL Test battery (Nilsson et al., 1997). The battery has been originally developed by Nilsson and colleagues (1997) and translated into Farsi by Hatami and colleagues (Hatami et al., In press; Nilsson et al., 1997). PEBL is a free, open-source software system with a set of approximately 70 behavioral tests that has been used in different fields of studies including cognitive psychology and cognitive neuroscience (Mueller and Piper, 2014). In the present study, six tests have been selected for episodic memory assessment. The brief description of each test has been provided in the following.

1. Memorizing of children’s names and faces: Participants were randomly presented with 16 pictures of children identified with the first and last names. They were asked to memorize the pictures and the relevant information to recall them later.

2. Recalling of sentences and actions: This test consists of memorizing and recalling the two lists of 16 sentences with/without enactment. For the list of enactment sentences (e.g. give me the pencil, put the paper on the table), participants were asked to learn the sentences by performing the actions indicated in these sentences and recall them after a short delay (2 minutes). While for the second list, they were just asked to verbalize the sentences by repeating them verbally and recall them after a 2-minute delay.

3. Cued recall of nouns: In this test, participants were asked to recall the nouns from the previously presented sentences in test 2 (Recalling of sentences and actions). The participants were presented incomplete sentences with eight words. The task was to choose the correct word to complete the sentence based on what they had been presented previously.

4. Free choice recognition of children’s faces: In this test, 12 of 16 pictures that had been presented in test 1 (Memorizing of children’s names and faces) were displayed together with 12 new pictures. The participants were asked to recognize the familiar (old) images from the novel (new) ones.

5. Force choice recognition of children’s names: In this test, 16 pictures of children presented in test 1 (Memorizing of children’s names and faces) were shown to the participants. For each picture, the participants were provided with four options for names and four options for last names including one correct item (target) and three wrong items (distractors). Participants were asked to recognize the correct ones (targets).
Table 1. Characteristics of the study participants

<table>
<thead>
<tr>
<th>Age range (n(%))</th>
<th>Participants (N = 415)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50–59</td>
<td>225 (54.2)</td>
</tr>
<tr>
<td>60–69</td>
<td>158 (38.9)</td>
</tr>
<tr>
<td>70–79</td>
<td>28 (6.7)</td>
</tr>
<tr>
<td>80–83</td>
<td>4 (0.2)</td>
</tr>
<tr>
<td>Gender (n(%))</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>292 (70.4)</td>
</tr>
<tr>
<td>Male</td>
<td>123 (29.6)</td>
</tr>
<tr>
<td>Language background (n(%))</td>
<td></td>
</tr>
<tr>
<td>Monolingual</td>
<td>342 (82.4)</td>
</tr>
<tr>
<td>Bilingual</td>
<td>73 (17.6)</td>
</tr>
<tr>
<td>Educational level (n(%)): (Years of schooling)</td>
<td></td>
</tr>
<tr>
<td>High school: (&lt;12 years)</td>
<td>33 (7.9)</td>
</tr>
<tr>
<td>Associate degree: (=12 years)</td>
<td>155 (37.4)</td>
</tr>
<tr>
<td>Bachelor’s degree: (=16 years)</td>
<td>163 (39.2)</td>
</tr>
<tr>
<td>Master’s/Doctoral degree: (16+ years)</td>
<td>64 (15.3)</td>
</tr>
<tr>
<td>Type of educational training (n(%))</td>
<td></td>
</tr>
<tr>
<td>Continuousa</td>
<td>322 (77.6)</td>
</tr>
<tr>
<td>Distributedb</td>
<td>93 (22.4)</td>
</tr>
</tbody>
</table>

a Age of schooling onset and graduation: 6–7 to 35 years.
b Age of schooling onset and graduation: 6–7 to 50 years.

6. Recognition and cued recall of nouns: These two tests were related to the sentences that were presented in test 2 (Recalling of sentences and actions). In this test, participants were first asked to complete the sentences that they had been presented in test 2 (Recalling of verbs or nouns) and then determined whether the sentences were enacted or not.

Statistical analysis

Descriptive statistics were used to describe the demographic characteristics. Kolmogorov–Smirnov test was used to verify the assumption of normality of data. To reduce the number of variables, exploratory factor analysis using the principal component analysis method with varimax rotation was used and those factors with Eigenvalues > 1 were selected for the main analysis. Standardized z-scores were used to develop a composite score for episodic memory. Independent t-test was applied to test whether there is a difference in the means of memory performance between bilingual and monolingual as well as distributed and continuous types of educational training groups. To measure the correlation between variables, Spearman’s correlation coefficient was used. Backward regression was used to identify variables that independently contributed to the prediction of memory performance. Data were analyzed using SPSS (version 22; IBM, Armonk, NY, USA). Data for this project have been preregistered and are accessible on the Open Science Framework, titled “The role of bilingualism, mental activities and education in memory performance of older adults.”

Results

Descriptive data

Of the 415 participants in the sample (mean age = 59.46 ± 6.59), 292 (70.4%) were females and 123 (29.6%) were males. Participant characteristics including age, gender, language background, educational level and type of education are shown in Table 1.

The factor analysis yielded four factors explaining 44.4% of the variance in the correlation matrix. These factors were labeled in line with our previous published study (Hatami et al., In press) including Sentence Memory (SM), Recall-Attention (RA), Action Memory (AM), and Name Recognition (NR) measures. Following factor analysis, we created a factor-based composite score for the Episodic Memory (EM) Score using SM, RA, AM, and NR factors.

Pearson (r) and Spearman’s rank (ρ) correlation coefficient were used to test the correlation between demographic characteristic and memory performance. Spearman’s correlation indicated that there was a significant correlation between age and SM, RA, AM, NR, and EM measures (r = −0.36, p = 0.000; r = −0.41, p = 0.000; r = −0.35, p = 0.000; r = −0.27, p = 0.000; r = −0.45, p = 0.000, respectively), as well as between educational level and all the memory measures (r = 0.22, p = 0.000; r = 0.28, p = 0.000; r = 0.16, p = 0.001; r = 0.18, p = 0.000; r = 0.26, p = 0.000, respectively). In addition, Pearson’s correlation showed that gender was negatively correlated with all memory measures including SM, RA, AM, NR, and EM (r = −0.28, p = 0.000; r = −0.33, p = 0.000; r = −0.32, p = 0.000; r = −0.24, p = 0.000; r = −0.38, p = 0.000, respectively). In other words, women performed better than men. While type of educational training was positively correlated with NR (r = 0.15, p = 0.005) and EM (r = 0.10, p = 0.04), no correlation was found between language background and different measures of memory (Table 2).

Table 3 indicates the analysis results by t-test between the groups. There was no significant difference in all measures of memory performance including SM, RA, AM, NR as well as EM between the bilingual and monolingual groups (p = 0.81, p = 0.20, p = 0.42, p = 0.45, p = 0.58, respectively), while differences between participants with distributed and continuous education were only significant in the measures of NR (p = 0.005) and...
EM ($p = 0.04$) and those with distributed education outperformed the other groups (Table 3).

Spearman's correlation test between mental activities and memory measures showed that there is a significant correlation between reading and SM measure ($r = 0.15$, $p = 0.03$). Doing calculation is correlated with higher score in AM ($r = 0.22$, $p = 0.01$). Furthermore, writing has been found to be positively correlated with AM, NR, and EM measures ($r = 0.22$, $p = 0.01$; $r = 0.17$, $p = 0.04$; $r = 0.19$, $p = 0.02$, respectively). Playing mind teasers is positively associated with outperformance in SM and AM measures ($r = 0.20$, $p = 0.02$; $r = 0.22$, $p = 0.01$). Watching documentary is positively correlated with EM, SM, and RA measure ($r = 0.22$, $p = 0.01$; $r = 0.19$, $p = 0.01$; $r = 0.21$, $p = 0.01$, respectively). Web searching is positively correlated with SM, RA, and EM ($r = 0.20$, $p = 0.01$; $r = 0.32$, $p = 0.01$; $r = 0.23$, $p = 0.01$, respectively). Moreover, social networking is positively correlated with SM and RA ($r = 0.16$, $p = 0.03$; $r = 0.21$, $p = 0.01$, respectively).

Backward regression was used to determine whether independent variables predict EM performance. Independent variables that were not significantly correlated with EM were not included in the backward regression test. Table 4 presents the results from the analysis. SM had a significant correlation with age, educational level, web searching, playing mind teasers, watching documentary, and social networking. They all were included in the backward regression test. The results showed that age and educational level predict SM (adjusted $R^2 = 0.20$, $F (3, 62) = 6.59$, $p = 0.001$). RA had a significant correlation with age, educational level, web searching, watching documentary, and social networking. They were included in the backward regression test, and the results showed that age and playing mind teasers predict AM (adjusted $R^2 = 0.27$, $F (2, 88) = 18.29$, $p < 0.01$). AM had a significant correlation with age, educational level, playing

<table>
<thead>
<tr>
<th>Measures of memory</th>
<th>Age</th>
<th>Gender</th>
<th>Language background</th>
<th>Educational level</th>
<th>Type of educational training</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM</td>
<td>$-0.36^{**}$</td>
<td>$-0.28^{**}$</td>
<td>0.01</td>
<td>0.22**</td>
<td>0.09</td>
</tr>
<tr>
<td>RA</td>
<td>$-0.41^{**}$</td>
<td>$-0.33^{**}$</td>
<td>$-0.06$</td>
<td>0.28*</td>
<td>0.06</td>
</tr>
<tr>
<td>AM</td>
<td>$-0.35^{**}$</td>
<td>$-0.32^{**}$</td>
<td>$-0.03$</td>
<td>0.16**</td>
<td>0.07</td>
</tr>
<tr>
<td>NR</td>
<td>$-0.27^{**}$</td>
<td>$-0.24^{**}$</td>
<td>0.03</td>
<td>0.18**</td>
<td>0.15**</td>
</tr>
<tr>
<td>EM</td>
<td>$-0.45^{**}$</td>
<td>$-0.38^{**}$</td>
<td>$-0.02$</td>
<td>0.26**</td>
<td>0.10*</td>
</tr>
</tbody>
</table>

Abbreviations: SM, sentence memory; RA, recall-attention; AM, action memory; NR, name recognition; EM, episodic memory.

**$p < 0.001$, *$p < 0.05$.**

Discussion

In this study, we investigated the relationship between CR measures including bilingualism, educational level, type of education, mental activities, and memory performance in a sample of elderly adults.

Our study had several key findings. First, we found that participants with distributed type of educational training scored significantly higher on different measures of memory (NR and EM) than those with continuous educational training. Second, it has been found that mental activities such as reading, writing, doing calculation, playing cross-words and mind teasers, watching documentary, web searching, and social networking have a positive association with various measures of EM. Third, it has been found that demographic variables (age and the educational level) as well as mental activities (playing mind teasers) are significant predictors of EM performance.

To our knowledge, the finding of a relationship between the type of educational training and memory function had not been investigated before, and...
we found for the first time that people with the background of distributed type of education scored higher in NR and EM than those with continuous type of education. This result is in line with previous studies showing that education can contribute to higher level of CR (Armstrong et al., 2012). Previous researches investigating the effect of education on CR have repeatedly indicated that a longer term of education is associated with higher CR since participants can collect more compensatory skills to cope with neurocognitive impairments including recollection of EMs (Ljungberg et al., 2013). Consistent with previous studies, our result suggests that distributed educational training provides a longer term of opportunity for subject to be involved in learning process, and therefore, it is possible that EM, and specifically its function in terms of NR, has been mostly affected by the improved CR. Similar to what it has been reported in the previous studies, we found the positive correlation between educational level and all measures of memory (Ganguli et al., 2010; Lovden et al., 2004; Masel and Peek, 2009; Zahodne et al., 2011).

In accordance with previous studies, our study also demonstrated that engaging in regular mental activities such as reading, writing, playing crossword, doing calculation, watching documentary, web searching, and social networking is positively associated with higher scores in different measures of EM. The positive relationships have been found between reading and measure of SM, between doing calculation and AM, between writing and measures of AM, NR, and EM, between playing mind teasers and measures of SM and AM, between watching documentary and measures of EM, SM and RA, between web searching and measures of SM, RA, and EM as well as between social networking and measures of SM and RA. The effect of engaging in mental activities (e.g. reading newspapers, playing games like checkers, chess, cards, or crossword puzzles) on memory performance has been reported earlier in previous studies (Daffner, 2010). These mental stimulating activities increase the level of CR and reduce the risk of dementia in older adults (Gottlieb, 2003; Valenzuela and Sachdev, 2009).

Another important finding was the role of studied variables in predicting memory function. We found that all measures of EM were affected by age that is in line with findings from neuroimaging studies indicating the age-dependent decline in brain regions engaging in episodic encoding and retrieval (e.g. prefrontal cortex, medial temporal lobe (Fletcher and Henson, 2001; Maass et al., 2014; Nyberg, 2017; Zeineh et al., 2003). Educational level was the other significant predictor for all measures of EM (except AM) that is consistent with previous studies indicating that higher level of

Table 3. Results of the independent-samples t-test between the groups

<table>
<thead>
<tr>
<th>GROUPS BASED ON LANGUAGE BACKGROUND</th>
<th>MEAN (SD)</th>
<th>T</th>
<th>DF</th>
<th>P</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous education</td>
<td>0.34 (0.25)</td>
<td>0.24</td>
<td>413</td>
<td>0.24</td>
<td>0.59</td>
</tr>
<tr>
<td>Distributed education</td>
<td>0.34 (0.25)</td>
<td>0.24</td>
<td>413</td>
<td>0.81</td>
<td>0.59</td>
</tr>
<tr>
<td></td>
<td>Abbreviations: SM, sentence memory; RA, recall-attention; AM, action memory; NR, name recognition; EM, episodic memory.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: SM, sentence memory; RA, recall-attention; AM, action memory; NR, name recognition; EM, episodic memory.

p < 0.05.
information about the relationship between language and belonged to different groups of bilinguals (they were Turkish, Kurdish, and Arab) and had no academic training about their first language in school. This issue needs to be investigated if the homogeneity or diversity of bilingual groups can affect the results.

It should be noted that our study had some limitations. First, although our sample size was relatively large, it included predominantly women (70%) and men comprising significantly smaller proportion of the sample. So, we did not include gender in our analysis. This is an important issue, since there is evidence suggesting an obvious gender differences in memory function (Herlitz et al., 1997; Zelinski et al., 1993). The second limitation of the present study was the application of self-referral data that we gathered about regular mental activities, bilingualism status, and educational information. This approach has lower accuracy compared to objective measurements as it has been repeatedly addressed in various studies. Moreover, our participants were fully functional since they come to our laboratory independently. But we did not use any measure to screen this variable. Finally, participants participated in our study were a group of healthy and educated people who met the inclusion and exclusion criteria. Since this group forms just a proportion of community member, our results cannot be simply generalized to different groups of patients or people with lower education.

In conclusion, we found that passing formal educational training courses distributedly throughout life and doing regular mental activities such as social networking and playing mind teasers can

Table 4. Impact of age, education, and mental activities in the multiple linear regression analyses with backward variable selection

<table>
<thead>
<tr>
<th>Dependent variables</th>
<th>Independent variables</th>
<th>Unadjusted coefficients</th>
<th>Beta</th>
<th>t</th>
<th>p</th>
<th>Adjusted R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM</td>
<td>Age</td>
<td>-0.05</td>
<td>-0.31</td>
<td>-2.80</td>
<td>&lt;0.01</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td>Educational level</td>
<td>0.24</td>
<td>0.23</td>
<td>2.03</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mind teasers</td>
<td>0.08</td>
<td>0.21</td>
<td>1.87</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>RA</td>
<td>Age</td>
<td>-0.05</td>
<td>-0.44</td>
<td>-4.86</td>
<td>&lt;0.01</td>
<td>0.27</td>
</tr>
<tr>
<td></td>
<td>Educational level</td>
<td>0.17</td>
<td>0.24</td>
<td>2.72</td>
<td>&lt;0.01</td>
<td></td>
</tr>
<tr>
<td>AM</td>
<td>Age</td>
<td>-0.04</td>
<td>-0.32</td>
<td>3.54</td>
<td>&lt;0.01</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td>Calculation</td>
<td>0.02</td>
<td>0.16</td>
<td>1.78</td>
<td>0.07</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mind teasers</td>
<td>0.10</td>
<td>0.28</td>
<td>3.08</td>
<td>&lt;0.01</td>
<td></td>
</tr>
<tr>
<td>NR</td>
<td>Age</td>
<td>-0.02</td>
<td>-0.24</td>
<td>3.03</td>
<td>&lt;0.01</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td>Educational level</td>
<td>0.13</td>
<td>0.26</td>
<td>3.28</td>
<td>&lt;0.01</td>
<td></td>
</tr>
<tr>
<td>EM</td>
<td>Age</td>
<td>-0.03</td>
<td>-0.36</td>
<td>-4.08</td>
<td>&lt;0.01</td>
<td>0.28</td>
</tr>
<tr>
<td></td>
<td>Educational level</td>
<td>0.21</td>
<td>0.33</td>
<td>3.82</td>
<td>&lt;0.01</td>
<td></td>
</tr>
</tbody>
</table>

SM: F = 6.59, p < 0.01; RA: F = 18.29, p < 0.01; AM: F = 9.25, p < 0.01; NR: F = 10.00, p < 0.01; EM: F = 20.36, p < 0.01.

Abbreviations: SM, sentence memory; RA, recall-attention; AM, action memory; NR, name recognition; EM, episodic memory.

*Adjusted for age, education, and mind teasers survived after the backward variable selection.
influence different aspects of EM. These positive effects can be explained in terms of improved CR that may cope with age-related decline in EM. Although our results indicate a positive association between CR proxies and cognitive functions (EM), future studies will benefit from examining how these proxies are associated with brain structural/functional changes (using neuroimaging techniques) as well as clinical expression of age-related pathologies (using clinical biomarkers), particularly in the context of longitudinal studies (van Loenhoud et al., 2017).

To sum up, our results support the role of CR measures on successful aging, and hence these measures are closely related to lifestyle and they can be embedded in our everyday life.

Conflict of interest

None of the authors have any conflicted interest as defined by International Psychogeriatrics Publishing group, or other interests that might be perceived to influence the results and/or discussion reported in this paper. This study was funded by the Cognitive Science and Technologies Council (CSTC) of Iran (Grant number: 858).

Description of authors’ role

Mohammad and Rezapour wrote the paper, Hatami designed the procedure, Abdokhadaie and Mohammad contributed to analysis, Kormi-Nouri and Ehsan edited the paper, and Ghamarsi ran the participants. All authors contributed to the writing of the manuscript.

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