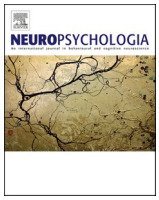
Neuropsychologia 188 (2023) 108655

Contents lists available at ScienceDirect

Neuropsychologia

journal homepage: www.elsevier.com/locate/neuropsychologia



Openness to experience and cognitive functioning and decline in older adults: The mediating role of cognitive reserve

Teresa Montoliu [a], Mariola Zapater-Fajarí [a], Vanesa Hidalgo [a,b,*], Alicia Salvador [a,c]

[a] Department Psychobiology-IDOCAL, University of Valencia, Valencia, Spain
[b] Department of Psychology and Sociology, University of Zaragoza, Teruel, Spain
[c] Spanish National Network for Research in Mental Health CIBERSAM, 28029, Spain

ARTICLE INFO

Keywords:
Personality
Cognitive reserve
Cognition
Aging

ABSTRACT

Objective: Openness to experience has been consistently associated with better cognitive functioning in older people, but its association with cognitive decline is less clear. Cognitive reserve has been proposed as a mechanism underlying this relationship, but previous studies have reported mixed findings, possibly due to the different ways of conceptualizing cognitive reserve. We aimed to analyze the potential mediating role of cognitive reserve in the association between openness and cognitive functioning and decline in healthy older people.

Method: In Wave 1 and at the four-year follow-up (Wave 2), 87 healthy older people (49.4% women; M age = 65.08, SD = 4.54) completed a neuropsychological battery to assess cognitive functioning and a questionnaire to assess cognitive reserve. Openness was measured with the NEO- Five-Factor Inventory. Mediation models were proposed to investigate the relationship between openness and cognitive function or decline through cognitive reserve or its change.

Results: Cognitive reserve mediated the openness-cognitive functioning association. Thus, individuals with higher openness showed greater cognitive reserve, and this greater cognitive reserve was associated with better cognitive functioning. Moreover, greater cognitive reserve at baseline also mediated the association between higher openness and slower cognitive decline. However, change in cognitive reserve did not mediate the association between openness and change in cognitive functioning.

Conclusions: Cognitive reserve is a mechanism underlying the association between openness and cognitive functioning and decline. These findings support the differential preservation hypothesis, suggesting that healthy older adults who engage in more cognitively stimulating activities would show less age-related cognitive decline.

1. Introduction

With global populations aging rapidly, the prevalence of cognitive decline and dementia has become a public health priority (World Health Organization [WHO], 2019). However, there is great heterogeneity in the trajectories of cognitive change in older people (Qiu et al., 2020), and so it is important to identify factors that might explain these individual differences. In recent years, a growing number of studies have analyzed personality traits as possible predictors of this variability in cognitive aging (see review: Curtis et al., 2015).

The big five personality traits (neuroticism, extraversion, openness to experience, agreeableness, and conscientiousness) measure individual differences in relatively enduring patterns of thoughts, feelings, and behaviors, with little meaningful change after the age of 30 (Costa and McCrae, 1992, 1997; Costa et al., 2000). Of these five personality traits, openness to experience (hereinafter, openness) (i.e., tendency to be creative, curious, sensitive to aesthetics, and open to new ideas and experiences) (Costa and McCrae, 1992; McCrae and John, 1992) has consistently been related to cognitive performance (see review: Curtis et al., 2015). Most cross-sectional studies have observed an association between higher levels of openness and better cognitive performance (Aiken-Morgan et al., 2012; Austin et al., 2002; Graham and Lachman, 2012; Sharp et al., 2010; Simon et al., 2020; Sutin et al., 2011). However, whereas some longitudinal studies have reported an

* Corresponding author. Department of Psychology and Sociology (area of Psychobiology), University of Zaragoza, Campus Ciudad Escolar, s/n 44003, Teruel, Spain.
E-mail address: vhidalgo@unizar.es (V. Hidalgo).

https://doi.org/10.1016/j.neuropsychologia.2023.108655
Received 17 October 2022; Received in revised form 13 June 2023; Accepted 25 July 2023
Available online 26 July 2023

association between higher openness and slower rates of cognitive decline (Luchetti et al., 2016; Nishita et al., 2019; Williams et al., 2013), others have failed to observe this relationship (Chapman et al., 2012; Hultsch et al., 1999; Sharp et al., 2010). Therefore, the openness-cognition association remains unclear, and analyzing the mechanisms underlying these associations could help to heighten our understanding of this question. Because individuals who are higher in openness tend to engage in cognitively stimulating activities (McCrae, 1994), cognitive reserve has been proposed as one of the mechanisms that might explain the openness-cognition relationship (Curtis et al., 2015).

Cognitive reserve is a construct that is usually measured indirectly through socio-behavioral proxy indexes (see review: Kartschmit et al., 2019), with education level, occupational status, and engaging in cognitively stimulating activities being the most common (see meta-analysis: Opdebeeck et al., 2016). The construct of cognitive reserve proposes that greater lifetime engagement in cognitively stimulating activities may provide a buffer against the effects of brain damage or pathology and help to cope with age-related changes in the brain (Stern, 2009). Some authors have argued that the influence of activity engagement on cognitive ability could follow two patterns: differential preservation (suggesting that individuals who engage in more cognitively stimulating activities would show less age-related cognitive decline) versus preserved differentiation (suggesting that individuals who engage in more cognitively stimulating activities would show higher levels of cognitive functioning throughout life, but without affecting the rate of cognitive change) (Salthouse, 2006). In their recent review, Pettigrew and Soldan (2019) reported that, although higher cognitive reserve is associated with better cognitive performance, its impact on longitudinal cognitive trajectories is unclear and needs more research.

Only a few cross-sectional studies have assessed the mediation role of cognitive reserve in the openness-cognitive function link in samples with both young and older (Soubelet and Salthouse, 2010) or only older (Ihle et al., 2016; Jackson et al., 2020) adults. These studies reported mixed findings, possibly due to different ways of conceptualizing and measuring cognitive reserve. Two studies assessed cognitive reserve with a list of activities, and they observed that time spent on activity engagement did not mediate the openness-cognition association (Jackson et al., 2020; Soubelet and Salthouse, 2010). However, Jackson et al. (2020) reported that the positive association between openness and cognition was mediated by activity diversity. In addition, Ihle et al. (2016) observed that cognitive reserve measured with three different indexes (educational attainment, cognitive level of job, and engaging in different leisure activities) mediated the positive association between openness and both verbal activity and executive functioning.

Furthermore, Ihle et al. (2019) carried out the only longitudinal study, and they reported that the relationship between higher openness and a smaller decline in executive functioning (measured with the Trail-Making Test [TMT]) was mediated by a higher frequency of leisure activities in Wave 1. However, the mediating role of cognitive reserve in the association between openness and cognitive decline, including a broader range of cognitive domains, has not been analyzed. Moreover, because cognitive reserve is a dynamic construct, a recent study highlighted that changes in cognitive reserve may have important implications for individual differences in cognitive aging trajectories (Bettcher et al., 2019).

Furthermore, it is worth noting that most of the aforementioned studies measured cognitive reserve by using activity engagement as a single proxy indicator (Ihle et al., 2019; Jackson et al., 2020; Soubelet and Salthouse, 2010). Only one study included three proxy indicators separately (educational attainment, cognitive level of job, and leisure activities) (Ihle et al., 2016). However, none of them assessed cognitive reserve with a standardized questionnaire combining multiple proxy indexes, which would better reflect the concept of cognitive reserve (Kartschmit et al., 2019), in order to more comprehensively investigate its relationship with cognitive functioning (Opdebeeck et al., 2016).

Therefore, the main purpose of this study was to analyze the mediating role of cognitive reserve, measured with a standardized questionnaire containing multiple proxy indexes, in the association between openness and global cognitive functioning, considering declarative and working memory and executive functions in healthy older people. To do so, we studied this mediation with both cross-sectional and longitudinal approaches. First, using a cross-sectional approach, we analyzed these relationships in each of two temporal points (Waves 1 and 2) separated by four years. Second, using a longitudinal approach, we also aimed to find out whether the association between openness and cognitive change was mediated by baseline levels or changes in cognitive reserve. We hypothesized that, in cross-sectional models, higher cognitive reserve would mediate the association between higher openness and better cognitive functioning. Regarding the follow-up, we hypothesized that higher cognitive reserve at baseline or an increase in cognitive reserve would mediate the association between higher openness and less cognitive decline.

2. Methods

2.1. Participants

The sample consisted of healthy older individuals recruited from a study program at the University of Valencia for people over 55 years of age. All participants were native Spanish speakers and residents of the province where the study was carried out. None of the participants scored less than 27 on the Spanish version of the Mini-Mental State Examination (MMSE) (Lobo et al., 1999) in Wave 1 or 2, indicating the absence of cognitive impairment. At baseline (Wave 1, 2011-2012), 128 participants from 55 to 77 years old ($M = 65.08$, $SD = 4.54$) participated in the study. The data for the present study are part of a larger research project where we collected saliva samples to assess cortisol levels. Therefore, we considered both physical (Duclos and Tabarin, 2016) and cognitive (Sáez de Asteasu et al., 2017) activity variables that could influence hypothalamic-pituitary-adrenal axis functioning. Hence, the exclusion criteria at baseline were: smoking more than 10 cigarettes a day, alcohol or other drug abuse, visual or hearing problems, diabetes, neurological or psychiatric disease, using any medication directly related to emotional or cognitive functioning or able to influence hormonal levels, such as glucocorticoids, psychotropic substances, or sleep medications, having been under general anesthesia once or more than once in the past year, and the presence of a stressful life event (e.g. death of a relative, divorce or separation, having been fired, serious personal illness, serious personal accident or injury, serious illness in the family) in the past year and, more specifically, its duration and intensity and how long ago it happened. Four years later (Wave 2, 2015-2016), participants were contacted by telephone and invited to take part in a follow-up study, and 87 individuals agreed to participate (44 men and 43 women). In Wave 2, they were asked if they had diabetes or a neurological or psychiatric disease, or if they were taking any medication directly related to emotional or cognitive functioning or able to influence hormonal levels, such as glucocorticoids, psychotropic substances, or sleep medications. In the Wave 2 sample, eight participants had been diagnosed with type II diabetes and were being medically treated, 15 were taking medication directly related to the central nervous system (i.e., sleep medication), and four participants were taking beta-blockers. Thus, medication/disease was included as covariate in the analyses to control it.

Forty-one participants (16 men and 25 women) from 56 to 78 years old ($M = 65.16$, $SD = 4.96$) were eliminated from Wave 1 because they did not agree to participate in Wave 2. They declined our invitation to participate in Wave 2 for several reasons: two were caring for a sick relative, two were caring for grandchildren, three had health problems, five were very busy, one had restricted calls, and the rest, 28, simply did not feel like participating, without providing any reason. Therefore, the

final sample was composed of 87 participants (44 men and 43 women) from 55 to 77 years old (M = 65.08, SD = 4.54) in Wave 1, and from 59 to 81 years old (M = 69.20, SD = 4.50) in Wave 2. Of this sample, 53% had an educational level above secondary school, whereas the percentage in the group that declined to participate was 43.2%.

2.2. Procedure

At baseline (Wave 1) and the four-year follow-up (Wave 2), participants were asked to attend a neuropsychological session that took place at 10:00 or 12:00 h in our laboratory. Before the session, participants were interviewed by phone to obtain information about their general habits (e.g., alcohol consumption, smoking), including information about their medication, among other things, in order to find out whether they met the inclusion criteria (see Participants section). Moreover, to avoid altering their cognitive performance during the session, participants were asked to maintain their general habits, that is, sleep as much as usual, refrain from heavy physical activity the day before the session, and not consume alcohol from the night before the session. They were also instructed to drink only water, and not eat, smoke, or take any stimulants (such as coffee, cola, caffeine, tea, or chocolate) at least 1 h prior to the session. In addition, participants were also asked to fill out the Cognitive Reserve Questionnaire (CRQ) (Rami et al., 2011) in Waves 1 and 2, and the NEO-Five Factor Inventory to assess the openness trait (Costa and McCrae, 1992) in Wave 2.

All the participants provided their written informed consent to participate in the study, which was conducted in accordance with the Declaration of Helsinki. The protocol was approved by the Research Ethics Committee of the University of Valencia.

2.2.1. Openness

The Spanish version (Costa and McCrae, 1999) of the NEO-Five Factor Inventory (NEO-FFI) (Costa and McCrae, 1992) was administered. The NEO-FFI consists of 60 items that measure the Big Five personality traits (neuroticism, conscientiousness, extraversion, openness, and agreeableness), with 12 items for each trait. The items are answered on 5-point scales, and higher scores indicate a higher degree of the trait. In the present study, the mean score was 29.80 (SD = 5.53), and the Cronbach's alpha was .70, which indicates acceptable internal consistency. In this study, only the Openness subscale has been employed.

2.2.2. Cognitive reserve

Cognitive reserve was assessed with the CRQ (Rami et al., 2011) in Wave 1 (CR1) and in Wave 2 (CR2). The CRQ consists of eight items that assess different aspects of intellectual activity: educational level, parents' educational level, attending training courses, occupational status, musical training, languages, reading activity, and intellectual games (chess, puzzles, crosswords). Furthermore, it also considers the approximate frequency with which cognitively stimulating activities have been carried out, such as reading and playing intellectual games. Scores range from 0 to 25, and higher scores indicate greater cognitive reserve. In the present study, the mean score was 16.19 (SD = 3.88) and 16.23 (SD = 4.01) for Wave 1 and Wave 2, respectively. The internal reliability (Cronbach's alpha) for the cognitive reserve questionnaire in the present study was acceptable, with a value of 0.71.

2.2.3. Cognitive functioning

In Waves 1 and 2, each participant completed a neuropsychological battery consisting of six standard neuropsychological tests that assess different cognitive domains. These tests have previously been described in detail (Montoliu et al., 2018). Declarative memory was assessed with the Spanish version of the Rey Auditory Verbal Learning Test (RAVLT) (Miranda and Valencia, 1997), and three indexes were obtained: (i) total learning: total number of words recalled on the first five trials, (ii) immediate recall: percentage of total number of words recalled after the interference trial compared to the number of words recalled on trial V (trial VI/trial V x 100), and (iii) delayed recall: percentage of total number of words recalled after the 20-min delay compared to the number of words recalled on the immediate recall trial (trial VII/trial VI x 100). Working memory was assessed with the Digit Span (DS) (iv) forward and (v) backward and the (vi) Letter-number sequencing (LNS) tests from the Spanish version of the Wechsler Memory Scale III (Wechsler, 1997). Finally, executive functioning was assessed with the Trail-Making Test (TMT) (Reitan, 1992), (vii) A and (viii) B, and the (ix) Stroop Color-Word Interference Test (Golden, 1978). TMT-A and –B raw scores were reversed before converting them to z-scores, given that higher scores indicated worse performance (longer times performing the test).

For the mediational analyses, raw scores on the nine cognitive indexes were converted to z-scores and averaged to create a composite *cognitive functioning* index for both Wave 1 (CF1) and Wave 2 (CF2), as in similar studies (Aggarwal et al., 2014; Lee et al., 2008; Turner et al., 2017). We used the composite variable to reduce the number of variables because, due to the size of the sample, performing all the analyses independently would have reduced the statistical power. In the final sample, CF1 ranged from −1.35 to 1.19 ($M = 0.002$, $SD = 0.541$), and CF2 ranged from −1.25 to 1.10 ($M = -0.002$, $SD = 0.501$), with higher scores indicating better performance.

2.3. Statistical analyses

Pearson's correlation analyses were performed to analyze the associations between all the variables (see Supplementary material).

Repeated-measures ANOVAs were performed to assess change in cognitive reserve, and multiple repeated-measures ANOVAs were performed on all the cognitive tests to assess change in cognitive functioning between Wave 1 and Wave 2.

First, in the mediation models, we investigated whether cognitive reserve mediated the relationship between openness and cognitive functioning in the cross-sectional study (Waves 1 and 2) using the PROCESS macro in SPSS (v3.4) (Model 4) with 5000 bootstrapped samples. The bootstrap technique draws random samples of a fixed sample size with replacements from the dataset, which increases the statistical power. This type of statistical approach takes the real sample size into consideration and controls for this factor in the analyses (Hayes, 2017). Therefore, the use of bootstrap-corrected confidence intervals solves the issues related to a relatively small sample size. We conducted separate mediation models, including the composite cognitive functioning index (CF1 or CF2) as the dependent variable, openness as the independent variable, and cognitive reserve (CR1 or CR2) as the mediator variable, and controlling for the covariates (age, gender, and medication/disease). Following Hayes (2017) and Zhao et al. (2010), only one requirement had to be met to establish mediation; that is, the indirect effect (ab) had to be significant. Thus, the relationship between the independent and dependent variables is explained by a mediator, and a significant direct effect is not needed. The sign of the indirect effect (*path ab*) is the product of path a x path b, which is the relationship (*path* a) between the independent variable and the mediator, controlling for the direct effect of the independent variable on the dependent variable, and the relationship (*path b*) between the mediator and the dependent variable, controlling for the independent variable. The direct effect (*path c'*) is the relationship between independent and dependent variables, controlling for the mediator. The total effect (*path c*) represents the sum of the indirect and direct effects (Hayes, 2017). Analyses controlling for age, gender, and medication/disease were performed because several studies have related these variables to cognitive function (Campbell et al., 2009; Silver et al., 2012; Tervo et al., 2004; Tilvis et al., 2004) and cognitive reserve (Clare et al., 2017). Additionally, most of the studies on openness-cognitive function through cognitive reserve have included age and gender (Ihle et al., 2019) or age (Soubelet and Salthouse, 2010) as covariates.

Second, to investigate cognitive functioning or reserve

longitudinally, we included the CF1 or CR1 as covariates and CF2 or CR2 as dependent variables. Thus, to assess whether cognitive reserve at baseline mediated the association between openness and change in cognitive functioning longitudinally (change), we conducted another mediation model that included CF2 as the dependent variable, openness as the independent variable, and CR1 as the mediator variable, controlling for the covariates and CF1. Finally, to assess whether change in cognitive reserve mediated the association between openness and change in cognitive functioning, we again conducted a mediation model that included CF2 as the dependent variable, openness as the independent variable, and CR2 as the mediator variable, controlling for the covariates and CF1 and CR1. Regarding changes in cognitive functioning and cognitive reserve, when Wave 2 is compared to Wave 1, positive values reflect increased performance (i.e., less cognitive decline or increased cognitive reserve), whereas negative values suggest decreased performance (i.e., a greater decline or decreased cognitive reserve). All the mediation analyses were performed using z-values, and all the Betas reported represent standardized values.

All the participants completed the neuropsychological assessment and the CRQ in Wave 2, but there were ten missing values for the CRQ in Wave 1 (CR1: N = 77) and one missing value for the NEO-FFI openness subscale (N = 86). Before performing the statistical analyses, participants who scored ±3 SD from the mean were identified, and z scores were winsorized by replacing extreme values that differed by more than three standard deviations (SD) from the mean with values ±3SD (Liao et al., 2016).

To perform these statistical analyses, version 26.0 of SPSS was used. All *p* values were two-tailed, and the level of significance was taken as $p = .05$.

3. Results

3.1. Differences in cognitive reserve and the cognitive indexes between waves 1 and 2

There was no significant change in cognitive reserve between Wave 1 (CR1; M = 16.19, SD = 3.88) and Wave 2 (CR2: M = 16.23, SD = 4.01), F (76) = 0.15, $p = .903$).

Overall, when analyzing the nine cognitive indexes separately, there was no significant change in cognitive functioning between Waves 1 and 2 (F (9, 68) = 1.88, $p = .069$). A statistically significant decline was observed only on RAVLT immediate recall (F (1, 76) = 9.28, $p = .003$) (Table 1).

Table 1
Means (M), standard deviations (SD), and repeated-measures ANOVAs for cognitive tests in Wave 1 and Wave 2.

	Wave 1 M (SD)	Wave 2 M (SD)	F	df	df (error)	*p*	η_p^2
RAVLT total learning	51.15 (8.04)	50.05 (9.10)	2.73	1	76	.103	.035
RAVLT immediate recall (%)	87.90 (16.35)	81.85 (18.54)	9.28	1	76	.003	.109
RAVLT delayed recall (%)	98.66 (10.59)	103.50 (18.68)	3.65	1	76	.060	.046
DS-Forward	8.91 (2.27)	8.62 (1.98)	2.39	1	76	.126	.030
DS-Backward	6.02 (1.98)	6.19 (2.00)	0.28	1	76	.595	.004
LNS	9.97 (2.27)	10.15 (2.34)	0.43	1	76	.516	.006
TMT-A	39.23 (12.46)	40.27 (15.13)	0.12	1	76	.726	.002
TMT-B	98.78 (43.33)	91.81 (37.52)	1.84	1	76	.178	.024
Stroop	−1.89 (7.33)	−2.02 (7.42)	0.40	1	76	.904	.000

Note: M = mean; SD = standard deviation; RAVLT = Rey Auditory Verbal Learning Test; DS = Digit Span; LNS = Letter-number sequencing; TMT = Trail-Making Test.

3.2. Mediating effect of cognitive reserve on the association between openness and cognitive functioning

Results showed that openness was positively associated with CR1 and CR2 (*path a*: $B = 0.27$, SE = 0.11, CI 95%: 0.052, 0.479, and $B = 0.33$, SE = 0.10, CI 95%: 0.129, 0.534, respectively). Moreover, CR1 and CR2 were positively related to CF1 and CF2, respectively (*path b:* $B = 0.41$, SE = 0.11, CI 95%: 0.195, 0.618, *and* $B = 0.36$, SE = 0.10, CI 95%: 0.129, 0.534, respectively). Furthermore, openness was positively associated with CF1 and CF2 via CR1 and CR2, respectively (*path ab:* $B = 0.11$, SE = 0.07, CI 95%: 0.012, 0.264, *and* $B = 0.12$, SE = 0.05, CI 95%: 0.025, 0.227, respectively). Finally, a direct effect of openness on CF1 or CF2 was not found (*path c'*: B = -0.15, SE = 0.10, CI 95%: −0.345,0.054, *and* $B = -0.08$, SE = 0.10, CI 95%: −0.277,0.115, respectively) (Fig. 1) (Table 2).

3.3. Mediating effect of cognitive reserve at baseline on the association between openness and cognitive change

Again, results showed that openness was positively associated with CR1 (*path a*: $B = 0.30$, SE = 0.10, CI 95%: 0.106, 0.497). Moreover, CR1 was positively related to CF2, controlling for CF1 (*path b:* $B = 0.36$, SE = 0.10, CI 95%: 0.163, 0.565); that is, greater cognitive reserve was related to better cognitive functioning change (i.e., less decline). Furthermore, openness was positively associated with CF2, controlling for CF1, via cognitive reserve in Wave 1 (*path ab*: B = 0.12, SE = 0.05, CI 95%: 0.025, 0.227). However, a direct effect of openness on CF2, controlling for CF1, was not found (*path c'*: B = -0.02, SE = 0.06, CI 95%: −0.146,0.105) (Fig. 2 left) (Table 3).

3.4. Mediating effect of change in cognitive reserve on the association between openness and cognitive change

Openness was positively associated with CR2, controlling for CR1 (*path a*: $B = 0.17$, SE = 0.08, CI 95%: 0.19, 0.325). However, CR2, controlling for CR1, was not related to CF2, controlling for CF1 (*path b:* B = -0.06, SE = 0.10, CI 95%: −0.216, 0.133). Moreover, a direct or indirect effect of openness on cognitive change was not found (*paths c' and ab*: B = -0.01, SE = 0.07, CI 95%: −0.140, 0.121, *and* $B = -0.01$, SE = 0.02, CI 95%: −0.062, 0.022, respectively) (Fig. 2 right) (Table 3).

4. Discussion

The aim of this research was to analyze the potential role of cognitive reserve in the association between openness and cognitive functioning and the expected decline in older people. Our results showed that, in cross-sectional models, cognitive reserve mediated the association between openness and cognitive functioning. Moreover, higher cognitive reserve at baseline also mediated the association between openness and cognitive change. However, although greater openness was related to an increase in cognitive reserve over four years, this increase did not mediate the openness-cognitive change relationship.

It is worth noting that, despite expecting poorer cognitive performance in Wave 2 compared to Wave 1, overall, we did not find this decline. We only found an opposite pattern of performance between RAVLT immediate (impairment) and delayed (enhancement) recall. This result could be explained by a different susceptibility of the different types of memory and phases to aging (Salthouse, 2010; Tucker-Drob, 2021). Thus, with aging, the working memory is further altered. This coincides with the impairment found on RAVLT immediate recall. Although the RAVLT is a declarative memory task, the immediate recall outcome appears to lie within the domain of working memory, given

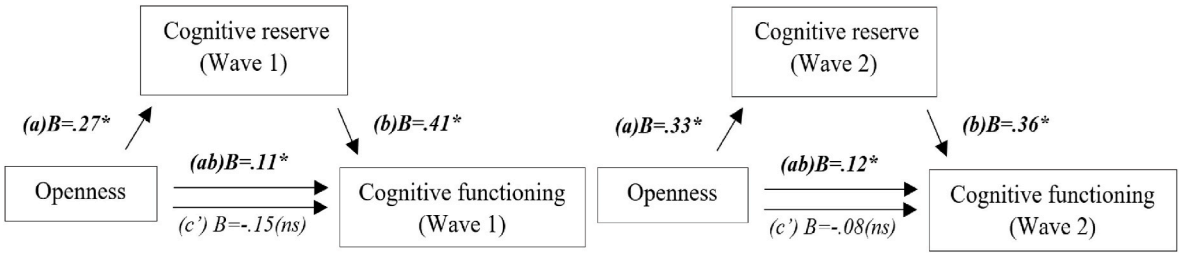


Fig. 1. Cross-sectional mediation models to test the indirect effect of openness on cognitive functioning (Waves 1 and 2) via cognitive reserve in Waves 1 and 2. *Note.* Values in bold represent significant values (*CI 95% did not include zero). Beta represent standardized values. Analyses with age, gender, and medication/disease as covariates. Letters represent the relationship between openness and cognitive reserve *(path a),* cognitive reserve and cognitive functioning (*path b*), the direct effect between openness and cognitive functioning controlling for cognitive reserve *(path c'),* and the indirect effect of the relationship between openness and cognitive functioning through cognitive reserve *(path ab).*

Table 2
Cross-sectional relationship between openness and cognitive function (Waves 1 or 2) through cognitive reserve (Waves 1 or 2).

Mediator variable (M): Cognitive Reserve (Wave 1)						
Independent variable (X): openness Dependent variable (Y): Cognitive Functioning (Wave 1)						
	Effect	SE	*t*	*p*	LLCI	ULCI
Effect of openness on CRQ (Wave 1) *(path a)*	.27	.11	2.47	.016	.052	.479
Effect of CRQ on cognitive functioning (Wave 1) *(path b)*	.41	.11	3.82	≤.001	.195	.618
Total effect of openness on cognitive functioning (Wave 1) *(path c)*	−.04	.10	−0.36	.720	−.246	.171
Direct effect of openness on cognitive functioning (Wave 1) *(path c')*	−.15	.10	−1.45	.150	−.345	.054
Indirect effect: openness →CRQ→ cognitive functioning (Wave 1) *(path ab)*	.11	.07			.012	.264
Mediator variable (M): Cognitive Reserve (Wave 2)						
Independent variable (X): openness Dependent variable (Y): Cognitive Functioning (Wave 2)						
	Effect	SE	*t*	*p*	LLCI	ULCI
Effect of openness on CRQ (Wave 2) *(path a)*	.33	.10	3.26	.002	.129	.534
Effect of CRQ on cognitive functioning (Wave 2) *(path b)*	.36	.10	3.61	.001	.163	.565
Total effect of openness on cognitive functioning (Wave 2) *(path c)*	.04	.10	0.40	.689	−.158	.237
Direct effect of openness on cognitive functioning (Wave 2) *(path c')*	−.08	.10	−0.82	.414	−.277	.115
Indirect effect: openness → CRQ→ cognitive functioning (Wave 2) *(path ab)*	.12	.05			.025	.227

Notes. Beta represent standardized values. CRQ= Cognitive Reserve Questionnaire. Values in bold represent significant (CI 95% not including zero) values. Letters represent the relationship between openness and cognitive reserve *(path a),* cognitive reserve and cognitive functioning *(path b),* the direct effect between openness and cognitive functioning controlling for cognitive reserve *(path c'),* and the indirect effect of the relationship between openness and cognitive functioning through cognitive reserve *(path ab).* Path c represents the total effect.

that participants had to recall without the target list being presented immediately before the onset of the trial and after the presentation of an interference list. Thus, RAVLT immediate recall requires storage and executive processes because the interference list has to be inhibited while the target list is recalled. However, we failed to find this aging effect on other working memory (i.e., Digit Span and Letter-Number Sequencing) and executive function (i.e., Trail Making Test and Stroop test) tests. In addition, at the same time, semantic memory, which involves storing facts and information, may improve with age. This is coherent with the marginal enhancement we found in Wave 2, compared to Wave 1, on RAVLT delayed recall.

We observed that higher openness was related to greater cognitive reserve, as found in other studies (Ihle et al., 2016, 2019; Jackson et al., 2020). Moreover, greater cognitive reserve was associated with better cognitive functioning, as expected (Pettigrew and Soldan, 2019). Therefore, as hypothesized, our results showed that cognitive reserve mediated the association between openness and cognitive functioning. Thus, individuals with higher openness showed greater cognitive reserve, and this greater cognitive reserve resulted in better cognitive performance. Our results are in line with other studies with healthy older adults that analyzed the association between openness and cognitive performance via diversity in activity engagement (Jackson et al., 2020) and measured cognitive reserve with three indexes (educational, occupation, and leisure activities) (Ihle et al., 2016). However, two studies found that time spent on activity engagement did not mediate the openness-cognition association (Jackson et al., 2020; Soubelet and Salthouse, 2010). Therefore, the different ways cognitive reserve is measured could account for these mixed findings. The standardized questionnaire we employed allows us to integrate eight proxy indexes (educational level, parents' educational level, training courses, occupational status, musical training, languages, reading activity, and intellectual games), and it also considers the frequency with which some of these activities are carried out. Therefore, this procedure may allow a more comprehensive evaluation of cognitive reserve and its association with cognitive functioning (see meta-analysis: Opdebeeck et al., 2016).

To our knowledge, only one study carried out a follow-up in a sample of cognitively healthy older adults, as in our study, although there are some important methodological differences between this study (Ihle et al., 2019) and ours. As our results also showed, Ihle et al. (2019) found that higher openness (assessed with two items from the short version of the Big Five Inventory (Rammstedt and John, 2007) was related to higher cognitive reserve assessed with a single index (frequency of leisure activities). In turn, Ihle and colleagues also reported that higher frequency of leisure activities was related to a smaller decline in executive functioning measured with the TMT. We also observed that higher cognitive reserve measured with a standardized questionnaire was associated with lower cognitive decline, measured as a global composite score that includes executive function (TMT and Stroop), working memory (DS and LNS), and declarative memory (RAVLT) domains. Moreover, as we hypothesized, higher cognitive reserve at baseline mediated the association between higher openness and less overall cognitive decline, as Ihle et al. (2019) observed when considering executive functioning.

Although higher cognitive reserve has been consistently associated with better cognitive performance, in a recent review, Pettigrew and

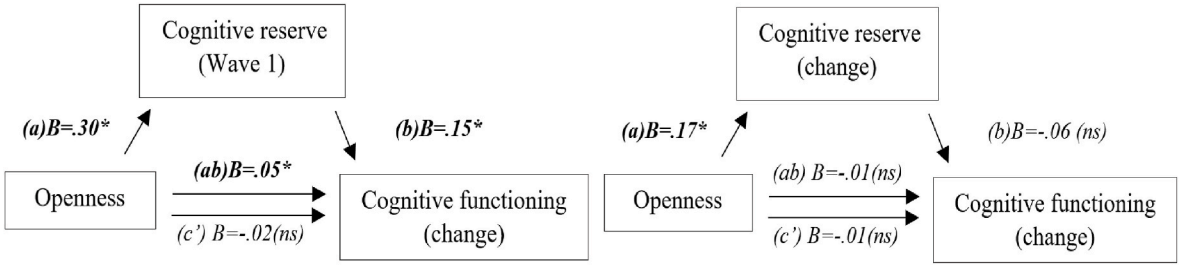


Fig. 2. Longitudinal mediation models to test the indirect effect of openness on cognitive change via cognitive reserve in Wave 1 or change.
Note. Values in bold represent significant values (*CI 95% did not include zero). Beta represent standardized values. Analyses with age, gender, medication/disease as covariates, cognitive functioning in Wave 1 (left), and cognitive functioning and reserve in Wave 1 (right). Letters represent the relationship between openness and cognitive reserve or cognitive change *(path a),* cognitive reserve and cognitive functioning change (*path b*), the direct effect between openness and cognitive functioning change controlling for cognitive reserve or change *(path c'),* and the indirect effect of the relationship between openness and cognitive functioning change through cognitive reserve *(path ab).*

Table 3
Longitudinal relationship between openness and cognitive change through cognitive reserve (Wave 1 or change).

Mediator variable (M): Cognitive Reserve (Wave 1)						
Independent variable (X): openness Dependent variable (Y): Cognitive Change						
	Effect	SE	*t*	*p*	LLCI	ULCI
Effect of openness on CRQ (Wave 1) (*path a*)	.30	.10	3.08	.003	.106	.497
Effect of CRQ (Wave 1) on cognitive change (*path b*)	.15	.07	2.13	.037	.010	.297
Total effect of openness on cognitive change (*path c*)	.03	.06	0.42	.677	−.095	.146
Direct effect of openness on cognitive change (*path c'*)	−.02	.06	−0.33	.741	−.146	.105
Indirect effect: openness → CRQ (Wave 1) → cognitive change (*path ab*)	.05	.02			.002	.097
Mediator variable (M): Cognitive Reserve Change						
Independent variable (X): openness Dependent variable (Y): Cognitive change						
	Effect	SE	*t*	*p*	LLCI	ULCI
Effect of openness on CRQ change (*path a*)	.17	.08	2.24	.029	.019	.325
Effect of CRQ change on cognitive change (*path b*)	−.06	.10	−0.65	.519	−.216	.133
Total effect of openness on cognitive change (*path c*)	−.02	.06	−0.33	.741	−.146	.105
Direct effect of openness on cognitive change (*path c'*)	−.01	.07	−0.15	.881	−.140	.121
Indirect effect: openness → CRQ change → cognitive change (*path ab*)	−.01	.02			−.062	.022

Notes. Beta represent standardized values. CRQ= Cognitive Reserve Questionnaire. Values in bold represent significant (CI 95% not including zero) values. Letters represent the relationship between openness and cognitive reserve in Wave 1 or change *(path a),* cognitive reserve and cognitive change *(path b),* the direct effect between openness and cognitive change, controlling for cognitive reserve, in Wave 1 or change *(path c'),* and the indirect effect of the relationship between openness and cognitive change through cognitive reserve in Wave 1 or change *(path ab).* Path c represents the total effect.

Soldan (2019) reported that higher cognitive reserve has been associated with reduced, greater, or no differences in rates of cognitive decline. Thus, these authors warned that the impact of cognitive reserve on longitudinal cognitive trajectories is unclear and may be influenced by a number of factors. Our results could explain why, although most studies observed that higher openness was associated with better cognitive functioning, its association with cognitive decline is unclear (Curtis et al., 2015). Therefore, our study shows that, at least in a sample of healthy older adults, cognitive reserve assessed with multiple indexes is related to lower global cognitive decline in a four-year follow up, which could at least partly explain the protective influence of openness on cognitive decline. Hence, our study would support the differential preservation hypothesis, suggesting that healthy older adults who engage in more cognitively stimulating activities would show less age-related cognitive decline (Salthouse, 2006). However, it is also important to note that, although our results showed that openness was related to better cognitive functioning and less decline via cognitive reserve, we did not find that higher openness was directly related to better cognitive functioning or change. In fact, our results reflect a partial mediation, which occurs when there is an indirect effect but not a direct effect, pointing out that a mediator has been identified correctly and could explain the direct association per se (Zhao et al., 2010). Thus, in our study, the relationship between openness and cognitive functioning is explained by cognitive reserve. This result highlights the importance of considering the mechanisms involved in order to better understand this relationship. More studies are needed to explore other mediators that could also contribute to explaining this relationship.

Contrary to what we hypothesized, we failed to observe that change in cognitive reserve (understood as cognitive reserve in Wave 2, controlling for Wave 1) mediated the association between openness and cognitive change. Although ANOVA for repeated measures showed no effect of time on cognitive reserve between Wave 1 and Wave 2, we observed that higher openness was related to an increase in cognitive reserve (greater change in cognitive reserve), but we failed to observe that an increase in cognitive reserve was related to less cognitive decline. This latter result was unexpected because it has been suggested that cognitive reserve is a dynamic construct, and that more rapid depletion of cognitive reserve would be associated with faster cognitive decline (Bettcher et al., 2019). However, in contrast to our study, these authors measured cognitive reserve using a psychometric approach incorporating brain and demographic variables, and they included individuals with Mild Cognitive Impairment and dementia (Bettcher et al., 2019). Moreover, as we mentioned above, no differences in cognitive reserve were found between Waves 1 and 2, and so the change in cognitive reserve was small, and higher scores would show different results.

Some limitations should be considered. First, given that this paper belongs to a larger study that includes a large number of variables, openness was only assessed in Wave 2. Although this personality trait has not shown a meaningful mean level of change after the age of 30 (Costa & McCrae, 1997; Costa et al., 2000), specifically in older people (Möttus et al., 2012), future research should replicate this study but measuring openness in both Wave 1 and Wave 2. Longitudinal studies should focus on whether cognitive decline is related to a decline in openness in older adults, as previously suggested (Curtis et al., 2015). In addition, participants were recruited from a University study program, yielding a sample with a cognitively stimulating lifestyle, and the strict exclusion criteria made it possible to obtain a healthy older sample and control the effect of confounding variables. Therefore, the results cannot

be generalized to all older people. Moreover, we performed many analyses for the small sample size. Although the bootstrap-corrected confidence intervals in the mediation analyses partially solve the issues related to a relatively small sample size, future studies should include a longer follow-up and a larger sample in order to increase the statistical power and explore gender differences in these associations. In addition, more waves across several years would help to better understand the mechanisms of long-term development and capture longitudinal changes throughout the aging process. However, it is worth noting that our analyses showed good statistical power in both the cross-sectional (.85- .99) and longitudinal (0.99–1.0) models. Our study also has other important methodological strengths. This is a longitudinal study that measured cognitive reserve and cognitive functioning in Wave 1 and Wave 2. Moreover, cognitive reserve was assessed with a questionnaire that included multiple markers, which is considered necessary in order to more comprehensively investigate the relationship between this construct and cognitive functioning (see Opdebeeck et al., 2016). Finally, we used a composite measure of global cognitive functioning, based on several individual tests that include different cognitive domains, in order to minimize measurement error in general and floor and ceiling artifacts (Wilson et al., 2007).

In conclusion, our results confirm that cognitive reserve is a mechanism underlying the association between openness and cognitive functioning and decline. This is the first longitudinal study to investigate the mediating role of cognitive reserve, using a standardized questionnaire, in the relationship between openness and cognitive decline, assessing a broad range of cognitive domains. Only one previous study, Ihle et al. (2019) investigated this mediating role longitudinally, but using only one proxy for cognitive reserve, leisure activities, and only one cognitive domain, executive function. Our findings support the differential preservation hypothesis, suggesting that healthy older adults who engage in more cognitively stimulating activities would show less age-related cognitive decline. It would be beneficial for interventions to take into account the impact of factors such as openness and cognitive reserve in promoting the well-being of older adults by mitigating cognitive decline. Specifically, interventions should promote openness and prioritize any activities, such as reading, painting, dancing, or exercise, among others, that increase cognitive reserve, in order to enhance the quality of life of older individuals.

Credit author statement

Teresa Montoliu: Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Writing – Original Draft Preparation, Mariola Zapater-Fajarí: Formal Analysis, Investigation, Writing – Original Draft Preparation, Vanesa Hidalgo: Conceptualization, Project Administration, Supervision, Writing – Review & Editing, Alicia Salvador: Conceptualization, Funding Acquisition, Project Administration, Supervision, Writing – Review & Editing.

Declaration of competing interest

None.

Data availability

Data will be made available on request.

Acknowledgments

This work was supported by the Spanish Innovation and Science Ministry (grant number PSI2016-78763-P; PID2020-119406 GB-I00/AEI/10.13039/501100011033); and the Universitat de València (grant number UVPREDOC16F1-383576). Moreover, the contribution of V. Hidalgo was supported by the Gobierno de Aragón (Department of Innovation, Research and University) under the research group S31_23R, and the Universities Ministry and European Union (European Union Next Generation EU, grant for the requalification of the Spanish University System).

The authors wish to thank Ms. Cindy DePoy for the revision of the English text.

References

Aggarwal, N.T., Wilson, R.S., Beck, T.L., Rajan, K.B., De Leon, C.F.M., Evans, D.A., Everson-Rose, S.A., 2014. Perceived stress and change in cognitive function among adults aged 65 and older. Psychosom. Med. 76 (1), 80–85. https://doi.org/10.1097/PSY.0000000000000016.

Aiken-Morgan, A.T., Bichsel, J., Allaire, J.C., Savla, J., Edwards, C.L., Whitfield, K.E., 2012. Personality as a source of individual differences in cognition among older African Americans. J. Res. Pers. 46 (5), 465–471. https://doi.org/10.1016/j.jrp.2012.04.006.

Austin, E.J., Deary, I.J., Whiteman, M.C., Fowkes, F.G.R., Pedersen, N.L., Rabbitt, P., McInnes, L., 2002. Relationships between ability and personality: does intelligence contribute positively to personal and social adjustment. Pers. Indiv. Differ. 32, 1391–1411. https://doi.org/10.1016/S0191-8869(01)00129-5.

Bettcher, B.M., Gross, A.L., Gavett, B.E., Widaman, K.F., Fletcher, E., Dowling, N.M., et al., 2019. Dynamic change of cognitive reserve: associations with changes in brain, cognition, and diagnosis. Neurobiol. Aging 83, 95–104. https://doi.org/10.1016/j.neurobiolaging.2019.08.016.

Campbell, N., Boustani, M., Limbil, T., Ott, C., Fox, C., Maidment, I., et al., 2009. The cognitive impact of anticholinergics: a clinical review. Clin. Interv. Aging 225–233. https://doi.org/10.2147/cia.s5358.

Chapman, B., Duberstein, P., Tindle, H.A., Sink, K.M., Robbins, J., Tancredi, D.J., Gingko Evaluation of Memory Study Investigators, 2012. Personality predicts cognitive function over 7 years in older persons. Am. J. Geriatr. Psychiatr. 20 (7), 612–621. https://doi.org/10.1097/JGP.0b013e31822cc9cb.

Clare, L., Wu, Y.T., Teale, J.C., MacLeod, C., Matthews, F., Brayne, C., Woods, B., CFAS-Wales study team, 2017. Potentially modifiable lifestyle factors, cognitive reserve, and cognitive function in later life: a cross-sectional study. PLoS Med. 14 (3), e1002259 https://doi.org/10.1371/journal.pmed.1002259.

Costa Jr., P.T., Herbst, J.H., McCrae, R.R., Siegler, I.C., 2000. Personality at midlife: stability, intrinsic maturation, and response to life events. Assessment 7 (4), 365–378. https://doi.org/10.1177/107319110000700405.

Costa, P.T., McCrae, R.R., 1992. Revised NEO Personality Inventory (NEO-PIR) and NEO Five Factor Inventory (NEO-FFI) Professional Manual. Psychological Assessment Resources, Odessa, FL.

Costa, P.T., McCrae, R.R., 1997. Longitudinal stability of adult personality. In: Hogan, R., Johnson, J., Briggs, S. (Eds.), Handbook of Personality Psychology, pp. 269–292.

Costa, P.T., McCrae, R.R., 1999. NEO PI-R, Inventario de Personalidad NEO Revisado. NEO-FFI, Inventario NEO reducido de Cinco Factores [Revised NEO Personality Inventory (NEO-PIR) and NEO Five Factor Inventory (NEO-FFI)]. Manual. TEA Ediciones, Madrid.

Curtis, R.G., Windsor, T.D., Soubelet, A., 2015. The relationship between Big-5 personality traits and cognitive ability in older adults–a review. Aging Neuropsychol. Cognit. 22 (1), 42–71. https://doi.org/10.1080/13825585.2014.888392.

Duclos, M., Tabarin, A., 2016. Exercise and the hypothalamo-pituitary-adrenal Axis. Front. Horm. Res. 47, 12–26. https://doi.org/10.1159/000445149.

Golden, C.J., 1978. A Manual for the Clinical and Experimental use of the Stroop Color and Word Test. Stoelting, Wood Dale, IL.

Graham, E.K., Lachman, M.E., 2012. Personality stability is associated with better cognitive performance in adulthood: are the stable more able? J. Gerontol. B Psychol. Sci. Soc. Sci. 67 (5), 545–554. https://doi.org/10.1093/geronb/gbr149.

Hayes, A.F., 2017. Introduction to Mediation, Moderation, and Conditional Process Analysis: A Regression-Based Approach. Guilford publications.

Hultsch, D.F., Hertzog, C., Small, B.J., Dixon, R.A., 1999. Use it or lose it: engaged lifestyle as a buffer of cognitive decline in aging? Psychol. Aging 14 (2), 245. https://doi.org/10.1037/0882-7974.14.2.245.

Ihle, A., Oris, M., Fagot, D., Maggiori, C., Kliegel, M., 2016. The association of educational attainment, cognitive level of job, and leisure activities during the course of adulthood with cognitive performance in old age: the role of openness to experience. Int. Psychogeriatr. 28 (5), 733–740. https://doi.org/10.1017/S1041610215001933.

Ihle, A., Zuber, S., Gouveia, É.R., Gouveia, B.R., Mella, N., Desrichard, O., et al., 2019. Cognitive reserve mediates the relation between openness to experience and smaller decline in executive functioning. Dement. Geriatr. Cognit. Disord. 48 (1–2), 39–44. https://doi.org/10.1159/000501822.

Jackson, J.J., Hill, P.L., Payne, B.R., Parisi, J.M., Stine-Morrow, E.A., 2020. Linking openness to cognitive ability in older adulthood: the role of activity diversity. Aging Ment. Health 24 (7), 1079–1087. https://doi.org/10.1080/13607863.2019.1655705.

Kartschmit, N., Mikolajczyk, R., Schubert, T., Lacruz, M.E., 2019. Measuring Cognitive Reserve (CR)–A systematic review of measurement properties of CR questionnaires for the adult population. PLoS One 14 (8), e0219851. https://doi.org/10.1371/journal.pone.0219851.

Lee, B.K., Glass, T.A., Wand, G.S., McAtee, M.J., Bandeen-Roche, K., Bolla, K.I., Schwartz, B.S., 2008. Apolipoprotein e genotype, cortisol, and cognitive function in community-dwelling older adults. Am. J. Psychiatr. 165 (11), 1456–1464. https://doi.org/10.1176/appi.ajp.2008.07091532.

Liao, H., Li, Y., Brooks, G., 2016. Outlier impact and accommodation methods: multiple comparisons of Type I error rates. J. Mod. Appl. Stat. Methods 15 (1), 23. https://doi.org/10.22237/jmasm/1462076520.

Lobo, A., Saz, P., Marcos, G., Día, J.L., de la Cámara, C., Ventura, T., et al., 1999. Revalidación y normalización del mini-examen cognoscitivo (primera versión en castellano del Mini-Mental Status Examination) en la población general geriátrica. Med. Clínica 112 (20), 767–774.

Luchetti, M., Terracciano, A., Stephan, Y., Sutin, A.R., 2016. Personality and cognitive decline in older adults: data from a longitudinal sample and meta-analysis. J. Gerontol. B Psychol. Sci. Soc. Sci. 71 (4), 591–601. https://doi.org/10.1093/geronb/gbu184.

McCrae, R.R., 1994. Openness to experience: expanding the boundaries of factor V. Eur. J. Pers. 8 (4), 251–272. https://doi.org/10.1002/per.2410080404.

McCrae, R.R., John, O.P., 1992. An introduction to the five-factor model and its applications. J. Pers. 60 (2), 175–215. https://doi.org/10.1111/j.1467-6494.1992.tb00970.x.

Miranda, J.P., Valencia, R.R., 1997. English and Spanish versions of a memory test: word-length effects versus spoken-duration effects. Hisp. J. Behav. Sci. 19 (2), 171–181.

Montoliu, T., Hidalgo, V., Pulopulos, M.M., Ivorra, J.L., Martínez, M.J., Salvador, A., 2018. The relationship between cortisol and cognitive function in healthy older people: the moderating role of Apolipoprotein E polymorphism. Neurobiol. Learn. Mem. 155, 297–305. https://doi.org/10.1016/j.nlm.2018.08.013.

Mõttus, R., Johnson, W., Deary, I.J., 2012. Personality traits in old age: measurement and rank-order stability and some mean-level change. Psychol. Aging 27 (1), 243. https://doi.org/10.1037/a0023690.

Nishita, Y., Tange, C., Tomida, M., Otsuka, R., Ando, F., Shimokata, H., 2019. Positive effects of openness on cognitive aging in middle-aged and older adults: a 13-year longitudinal study. Int. J. Environ. Res. Publ. Health 16 (12), 2072. https://doi.org/10.3390/ijerph16122072.

Opdebeeck, C., Martyr, A., Clare, L., 2016. Cognitive reserve and cognitive function in healthy older people: a meta-analysis. Aging Neuropsychol. Cognit. 23 (1), 40–60. https://doi.org/10.1080/13825585.2015.1041450.

Pettigrew, C., Soldan, A., 2019. Defining cognitive reserve and implications for cognitive aging. Curr. Neurol. Neurosci. Rep. 19 (1), 1. https://doi.org/10.1007/s11910-019-0917-z.

Qiu, P., Zeng, M., Kuang, W., Meng, S.S., Cai, Y., Wang, H., Wan, Y., 2020. Heterogeneity in the dynamic change of cognitive function among older Chinese people: a growth mixture model. Int. J. Geriatr. Psychiatr. 35 (10), 1123–1133. https://doi.org/10.1002/gps.5334.

Rami, L., Valls-Pedret, C., Bartres-Faz, D., Caprile, C., Sole-Padulles, C., Castellvi, M., et al., 2011. Cognitive reserve questionnaire. Scores obtained in a healthy elderly population and in one with Alzheimer's disease. Rev. Neurol. 52 (4), 195–201.

Rammstedt, B., John, O.P., 2007. Measuring personality in one minute or less: a 10-item short version of the Big Five Inventory in English and German. J. Res. Pers. 41 (1), 203–212.

Reitan, R.M., 1992. Trail Making Test: Manual for Administration and Scoring. Reitan Neuropsychology Laboratory, Tucson, AZ.

Sáez de Asteasu, M.L., Martínez-Velilla, N., Zambom-Ferraresi, F., Casas-Herrero, Á., Izquierdo, M., 2017. Role of physical exercise on cognitive function in healthy older adults: a systematic review of randomized clinical trials. Ageing Res. Rev. 37, 117–134. https://doi.org/10.1016/j.arr.2017.05.007.

Salthouse, T., 2010. Selective review of cognitive aging. J Int Int Neuropsychol. Soc. 16 (5), 754–760. https://doi.org/10.1017/S1355617710000706.

Salthouse, T.A., 2006. Mental exercise and mental aging: evaluating the validity of the "use it or lose it" hypothesis. Perspect. Psychol. Sci. 1 (1), 68–87. https://doi.org/10.1111/j.1745-6916.2006.00005.x.

Sharp, E.S., Reynolds, C.A., Pedersen, N.L., Gatz, M., 2010. Cognitive engagement and cognitive aging: is openness protective? Psychol. Aging 25 (1), 60–73. https://doi.org/10.1037/a0018748.

Silver, H., Goodman, C., Bilker, W.B., 2012. Impairment in associative memory in healthy aging is distinct from that in other types of episodic memory. Psychiatr. Res. 197 (1–2), 135–139. https://doi.org/10.1016/j.psychres.2012.01.025.

Simon, S.S., Lee, S., Stern, Y., 2020. Personality-cognition associations across the adult life span and potential moderators: results from two cohorts. J. Pers. 88 (5), 1025–1039. https://doi.org/10.1111/jopy.12548.

Soubelet, A., Salthouse, T.A., 2010. The role of activity engagement in the relations between Openness/Intellect and cognition. Pers. Indiv. Differ. 49 (8), 896–901. https://doi.org/10.1016/j.paid.2010.07.026.

Stern, Y., 2009. Cognitive reserve. Neuropsychologia 47 (10), 2015–2028. https://doi.org/10.1016/j.neuropsychologia.2009.03.004.

Sutin, A.R., Terracciano, A., Kitner-Triolo, M.H., Uda, M., Schlessinger, D., Zonderman, A.B., 2011. Personality traits prospectively predict verbal fluency in a lifespan sample. Psychol. Aging 26 (4), 994–999. https://doi.org/10.1037/a0024276.

Tervo, S., Kivipelto, M., Hänninen, T., Vanhanen, M., Hallikainen, M., Mannermaa, A., Soininen, H., 2004. Incidence and risk factors for mild cognitive impairment: a population-based three-year follow-up study of cognitively healthy elderly subjects. Dement. Geriatr. Cognit. Disord. 17 (3), 196–203. https://doi.org/10.1159/000076356.

Tilvis, R.S., Kähönen-Väre, M.H., Jolkkonen, J., Valvanne, J., Pitkala, K.H., Strandberg, T.E., 2004. Predictors of cognitive decline and mortality of aged people over a 10-year period. The journals of gerontology. Series A, Biological sciences and medical sciences 59 (3), 268–274. https://doi.org/10.1093/gerona/59.3.m268.

Tucker-Drob, E.M., 2021. Cognitive aging and dementia: a life-span perspective. Annu. Rev. Dev. Psychol. 1, 177–196. https://doi.org/10.1146/annurev-devpsych-121318-085204, 2019.

Turner, A.D., James, B.D., Capuano, A.W., Aggarwal, N.T., Barnes, L.L., 2017. Perceived stress and cognitive decline in different cognitive domains in a cohort of older African Americans. Am. J. Geriatr. Psychiatr. 25 (1), 25–34. https://doi.org/10.1016/j.jagp.2016.10.003.

Wechsler, D., 1997. WMS-III Administration and Scoring Manual. The Psychological Corporation, Harcourt Brace & Company, San Antonio.

WHO, 2019. Dementia. Retrieved from. https://www.who.int/news-room/fact-sheets/detail/dementia.

Williams, P.G., Suchy, Y., Kraybill, M.L., 2013. Preliminary evidence for low openness to experience as a pre-clinical marker of incipient cognitive decline in older adults. J. Res. Pers. 47 (6), 945–951. https://doi.org/10.1016/j.jrp.2013.09.006.

Wilson, R.S., Schneider, J.A., Boyle, P.A., Arnold, S.E., Tang, Y., Bennett, D.A., 2007. Chronic distress and incidence of mild cognitive impairment. Neurology 68 (24), 2085–2092. https://doi.org/10.1212/01.wnl.0000264930.97061.82.

Zhao, X., Lynch Jr., J.G., Chen, Q., 2010. Reconsidering baron and Kenny: Myths and truths about mediation analysis. J. Consum. Res. 37 (2), 197–206.