Cognitive reserve and emotional stimuli in older individuals: Level of education moderates the age-related positivity effect

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Abstract

Background - A frequently observed age-related effect is a preference in older individuals for positive stimuli. The cognitive control model proposes that this positivity effect may be mediated by executive functions. We propose that cognitive reserve, operationally defined as years of education, which tempers cognitive decline and has been linked to executive functions, should also influence the age-related positivity effect, especially as age advances.

Methods - We administered an emotional free recall test to a group of 84 cognitively-intact individuals aged 60-88, who varied in years of education. As part of a larger test battery, data were obtained on measures of executive functioning and depression.

Results - We performed multiple regression and moderation analyses controlling for general cognitive function, severity of depressive symptoms and executive function. In our data, years of education appeared to moderate the effect of age on the positivity effect; age was negatively associated with recall of positive words in participants with fewer years of education, whereas a non-significant positive correlation was observed between age and positivity in participants with more education.

Conclusion - Cognitive reserve appears to play a role in explaining individual differences in the positivity effect in healthy older individuals. Future studies should investigate whether cognitive reserve is also implicated in the ability to process a wide range of emotional stimuli and whether greater reserve is reflected in improved emotional regulation.

Keywords: Cognitive reserve; years of education; positivity effect; emotional recall; executive function.

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Introduction

There is substantial variability in the way in which individuals respond to brain damage and pathology. For instance, Katzman et al. (1988) demonstrated that it is possible to show no cognitive impairment in life, despite presenting clear signs of Alzheimer's disease pathology in *post-mortem* evaluations (also see, e.g.: Morris et al., 1996; Price & Morris, 1999). The notion of reserve was introduced to account for this variability. In abstract terms, the idea of reserve refers to the notion that individuals possess varying degrees of a certain *quantity*, which acts as a protective factor against dysfunction, slowing down both natural and pathological age-related decline. Cognitive reserve (Steffener & Stern, 2012), specifically, refers to individual differences in the ability to make flexible and efficient use of existing brain resources when engaged in a task. In more neurological terms, greater cognitive reserve in a healthy brain corresponds to greater *neural reserve*, which is reflected in more capacity or more flexibility in the brain networks that can be recruited to perform a task (Stern, 2009). Alternatively, greater cognitive reserve could also lead to better *neural compensation* in the face of pathology or decline, as the increased network flexibility would provide more opportunities to adapt to damage and dysfunction, and invoke alternative networks (Park & Reuter-Lorenz, 2009; Steffener & Stern, 2012; Stern, 2009).

In addition to cognitive and neural age-related changes, emotion processing also appears to change across the lifespan. Although limbic regions tend to be spared by increasing age (Kensinger, Brierley, Medford, Growdon & Corkin, 2002), changes in amygdalar function and connectivity are observed (St. Jacques, Dolcos & Cabeza, 2009), suggesting age-related differences in emotional processing. The amygdala comprises a series of subcortical nuclei in the medial-temporal lobe and is thought to exert a modulatory role on the hippocampus, which, in turn, enhances episodic memory performance for emotional stimuli (LaBar & Cabeza, 2006). The most commonly reported and debated age-related change in emotional regulation is the emergence of a positivity effect (Carstensen & Mikels, 2005; Mather & Carstensen, 2005; Reed & Carstensen, 2012), whereby older adults accentuate positive information and tend to de-emphasize or avoid negative information. Moreover, older adults are thought to receive a memory boost for positively valenced information. However, this latter finding has been disputed, with some reports confirming it (Addis, Leclerc, Muscatell & Kensinger, 2010; Charles, Mather & Carstensen, 2003; Grady, Hongwanishkul, Keightley, Lee & Hasher, 2007; Kensinger, Garoff-Eaton & Schacter, 2007), while others have not found supporting evidence, or have qualified it (Emery & Hess, 2008; Kapucu, Rotello, Ready & Seidl, 2008; Kensinger, 2008).

According to socioemotional selectivity theory (e.g., Carstensen, 2006), positivity effects are the result of a strategic shift, whereby older adults emphasize life goals that hold an emotional rather than experiential meaning. Older adults tend to become more actively involved in the regulation of emotions, generally reducing negative affect and emphasizing positive valence. In particular, as age advances, the motivation to shift from future-oriented goals to present-based goals becomes more prominent, as expected life perspectives diminish. Therefore, according to this perspective, age continues to play an important role in influencing the positivity effect even among the elderly.

Mather and colleagues (Kryla-Lighthall & Mather, 2009; Mather & Knight, 2005; Nashiro, Sakaki & Mather, 2012) have integrated socioemotional selectivity theory with the cognitive control model. According to this model the strategic shift proposed by socioemotional selectivity theory is only successful if older adults possess a certain availability of cognitive resources, or, in other words, if they have enough cognitive control. For example, Mather and Knight (2005; see also Mather, Knight & McCaffrey, 2005) showed that the positivity effect in older adults was more pronounced in those individuals who had higher scores in tests of executive function, which provide a measure of cognitive control (see also, Petrican, Moscovitch & Schimmack, 2008).

Importantly, executive function task performance has also been linked to cognitive reserve. Roldán-Tapia, García, Cánovas and León (2012) examined 160 healthy adults (aged between 20 and 65) for associations between indices of cognitive reserve and measures of executive function. Their results showed that, controlling for age, almost all tests of executive function they employed, including trail making A (TMA; see also Giordano et al., 2012) and B (TMB), were positively associated with cognitive reserve. These findings suggest a similarity, if not a conceptual overlap between executive functions and cognitive reserve. Addressing this issue, Tucker and Stern (2011) have proposed that cognitive reserve may be associated with fluid executive abilities, and Siedlecki, Stern, Reuben, Sacco, Elkind and Wright (2009) have argued that, although it "may be reasonable to refer to cognitive reserve as a distinct construct", it should be "acknowledged that the cognitive reserve variables are highly related to executive functioning" (p. 567). Moreover, both cognitive reserve and executive functions tend to be anatomically located in the frontal lobe (Stern, 2009).

These recent findings suggest two interconnected links. On the one hand, as proposed by Mather and colleagues (e.g., Kryla-Lighthall & Mather, 2009), the relationship between age and the positivity effects may depend upon executive function, and cognitive control. On the other hand, cognitive reserve is positively associated with executive function task performance. Therefore, it is possible to suggest that the age-related positivity effects may be affected also by cognitive reserve. In particular, we propose that the relationship between age and the positivity effects may depend on separate, independent contributions of both executive function and cognitive reserve; in other words, cognitive reserve may impact on the age-related positivity effect over and above the contribution of executive function. Based on our discussion above, individuals with greater cognitive reserve should possess greater neural reserve, which translates into high levels of efficiency and/or flexibility in usage of brain networks when performing a task. Consequently, individuals with greater reserve should also be facilitated in the task of shifting from future-oriented strategies to present-based goals, as age increases. Finally, as this shift is expected to favor the positivity effect, greater cognitive reserve would be associated with increased age-related positivity effects. Therefore, we aim to test whether cognitive reserve has an effect on the age-related positivity effect in memory independently of the effect of executive function.

To test our hypothesis that age-related positivity effects are associated with cognitive reserve, we recruited a sample of non-demented and cognitively intact adult volunteers, aged 60 or above. These participants underwent a series of routine examinations and assessments to establish their physical and mental health, including a measure of depression (Hamilton Depression Scale [HDS]; Hamilton, 2000). Afterwards, they took part in a free recall test comprising negative, positive and neutral words. The purpose of the latter test was to determine whether cognitive reserve affected recall performance for emotionally valenced stimuli and, as per our hypotheses, we predicted that participants with higher cognitive reserve would show greater free recall of positive words than participants with lower cognitive reserve.

Of note, a prior report from Schultz, de Castro & Bertolucci (2009) does not support our hypothesis. Schultz et al. tested non-demented participants, aged 50 or older, on a test of immediate free recall of emotional and neutral pictures. Ten of their participants had four or fewer years of total schooling, whereas 10 had five years or more. Although no formal comparison across education groups was performed, a glance at the results suggests that free recall for positive pictures was not affected by years of education, thus raising the possibility that the cognitive reserve may have no effect on immediate recall of positive stimuli. A caveat is, however, necessary; Schultz et al.'s cut-off point for education was very low (4-5 years), thus suggesting that within the higher education group there would still be participants whose level of education was relatively low. Therefore, it is possible that differences in cognitive reserve were obscured in this study, by having the higher cognitive reserve group include participants with lower education.

For the purpose of our study, a reliable measure of cognitive reserve was also required. Being that cognitive reserve is a hypothetical construct, a direct measure does not yet exist (Jones, Manly, Glymour, Rentz, Jefferson & Stern, 2011); the more common available methodologies are: years of education (e.g., Springer, McIntosh, Winocur & Grady, 2005; Stern, Alexander, Prohovnik & Mayeux, 1992), IQ (e.g., Alexander et al., 1997), reading skills (e.g., Fyffe, Mukherjee, Barnes, Manly, Bennett & Crane, 2011; Manly, Byrd, Touradji, Sanchez & Stern, 2004) and occupational status (e.g., Valenzuela & Sachdev, 2006), among others. In this paper, for reasons of availability, we will use self-reported years of education to define cognitive reserve (limits of this approach are discussed in the General Discussion); education has been associated with the generation of cognitive strategies (Manly et al., 2004), with synaptic growth (Katzman, 1993) and with reduced cognitive decline in the elderly (Yaffe et al., 2011), and should therefore provide a reliable measure of cognitive reserve.

Method

Participants. A total of 115 participants of the Memory Evaluation Research Initiative (MERI) program at the Geriatric Psychiatry Research Division of the Nathan S. Kline Institute for Psychiatric Research were recruited for this study. The MERI program was established in 2003 in collaboration with Rockland County, NY, to provide free memory and evaluations for people in the local community. All the participants were administered a series of tests that comprise the standard MERI battery including tests of memory, motor performance, language fluency and general cognitive ability. Out of all the administered tests, we are only reporting here those tests that are pertinent to addressing the question of whether cognitive reserve is associated with age-related positivity effects in memory performance.

Out of the total group, 105 volunteers, generally self-referred, were administered an immediate emotional free recall test for no compensation, and 84 participants fell within our selection criteria (i.e., non-demented, cognitively intact and aged 60 or over). These 84 participants were between the ages of 60 and 88 (*mean* = 75.1; *SD* = 6.6), had a Mini-Mental State Exam (MMSE; Folstein, Folstein & McHugh, 1975) score of 25 or higher (*range*: 25-30; *mean* = 29.1; *SD* = 1.2), and presented no major clinical condition, psychiatric illness, or symptoms of dementia, as established in an interview by a board-certified geriatric psychiatrist (*mean* HDS score = 7.1; *SD* = 7.2). Moreover, their level of education was between 10 and 21 years (*mean* = 16.4; *SD* = 2.4). Finally, 18 participants reported use of psychoactive medications (e.g., Zoloft, Lorazepam), at the time of testing.

Stimuli. Three sets of 27 words each were selected from the ANEW pool (Bradley & Lang, 1999). Each set included nine negatively arousing words (for three sets respectively: *mean* valence = 2.17, 2.07, 2.18; *mean* arousal = 6.34, 6.87, 6.77), nine positively arousing words (for three sets respectively: *mean* valence = 7.74, 7.69, 7.63; *mean* arousal = 6.58, 6.43, 6.32), and nine neutral non-arousing words (for three sets respectively: *mean* valence = 5.05, 5.29, 5.24; *mean* arousal = 3.85, 4.29, 4.32). Within each set, Francis and Kucera (1982) word frequencies were equated across emotion, and the semantic inter-relatedness among all classes of words was matched using latent semantic analysis (Landauer, Foltz, & Laham, 1998).

Procedure. After providing informed consent, participants' vitals (e.g., blood pressure, pulse) were examined and blood was drawn for general testing. The MMSE and HDS scores were collected at this stage. Afterwards, participants were interviewed for personal and family medical history, as well as for memory complaints. Tests of executive functions (TMA & TMB) were administered as part of a neuropsychological test battery, at the end of which the test of emotional recall was also administered. The instructions for the emotional recall test were adapted from Kensinger et al. (2002). At the beginning of the test, the experimenter informed the participants that they would be presented with a list of words, some of which would be negative, some would be positive and some would be neutral, and examples were given (e.g., "TABLE is neutral"). Participants were then read a list of 27 words, one at a time. For each word, participants were asked to rate whether the word was "neutral", "negative", or "positive", according to what they thought or felt about the words. Four buffer words were used to eliminate primacy and recency effects, two at the start and two at the end of the list. Nine words were neutral, nine were negative and nine were positive (see Stimuli). Three alternative lists of words were randomized three times each to generate nine total study lists, which were then rotated through the participants. After the study phase, participants were asked to recall as many words as possible, in any order. They were stopped after three minutes, if still engaged in the task.

Design and Analysis. To determine emotional memory performance, a proportion of correctly recalled items score was calculated by dividing the number of recalled items in each valence category by nine. A single-factor (Valence [within-subjects]: negative, neutral & positive) repeated-measures Analysis of Variance (ANOVA) was then employed to test for main effects of valence on free recall performance; Fisher's LSD method was used for post-hoc analyses. The TMA and TMB scores were highly correlated [$r = .714$, $p<.001$]. As a measure of executive function (EF), we used the residuals in the TMB score after regressing it on the TMA score. Of note, five participants did not complete the TMB test and, for this reason, were excluded from all subsequent analyses; the updated demographics for the 79-participant sample are identical to those reported above with the only exception being age (75.00, 6.80).

Second, we considered the option of mediation, assuming that the relationship between age and recall performance of positive items might be mediated by years of education. However, this option was rejected (Baron & Kenny, 1986; Robinson, Pearce, Engel & Wonderlich, 2009) as age and recall of positive words were not correlated [$r = -.099$, $p=.386$], nor were age and years of education [$r = .105$, $p=.359$], or years of education and recall of positive words [$r = .169$, $p=.138$].

Finally, we performed moderator analyses, using multiple linear regressions. The outcome variables were: total memory performance (i.e., total number of correctly recalled items, regardless of valence), recall of positive words and recall of negative words. The main predictor was age; as per our discussion above, growing older should increase the likelihood of a positivity effect, either via a mechanism similar to that described by socioemotional selectivity theory, or because age should negatively impact upon primary network's efficiency. Another predictor was years of education, used here as a proxy of cognitive reserve. EF, MMSE and HDS were included as control variables, representing executive function, general cognitive function and severity of depressive symptoms, respectively. Finally, the moderation term was the interaction between age and education. Therefore, two models were tested with all outcome variables; the initial model included age, MMSE, HDS, years of education and EF; and the second model included the interaction between age and years of education. All variables were standardized. Use of psychoactive medications was not included in the regression analyses as none of the outcome variables appeared to differ as a function of drug use (p's > .389).

Results

Free recall scores for the whole group are summarized in the Table. When we conducted the ANOVA on recall performance, a main effect of Valance was observed [$F(2,166)=10.334$, $MSe=.011$, $p<.001$]; LSD post-hoc comparisons indicated that there was no significant difference between recall performance with negative and neutral words [$p>.05$], whereas positive words recall was better than with both negative [$p<.001$] and neutral [$p<.001$] words.

Following the ANOVA, the regression analysis with a moderator term was performed. When we conducted the analysis on total memory performance, the best predictors of performance were MMSE [$\beta=.312$, $p=.006$] and years of education [$\beta=.298$, $p=.006$], suggesting, not surprisingly, that general cognitive ability and cognitive reserve are associated with better memory. Age was marginally significant [$\beta=-.208$, $p=.060$], showing that the memory ability becomes weaker with age, as typically expected. EF was not a significant predictor [$\beta=.007$, $p=.948$] and, similarly, the moderator term did not result in a significant increase of the variance explained [r^2change = .032, $p = .077$].

In contrast, when recall of positive words was examined, the interaction term provided a significant increase in the variance explained [r^2change =.078, $p = .010$]; the age X years of education interaction was correlated with recall of positive words [β=.291]. The simple slope analysis (Aiken & West, 1991; see Figure 1) for participants with fewer years of education (-1 *SD*) shows that increasing age is associated with a progressive decline of recall for positive words [t=2.223, p=.029, β=-.367]; in contrast, despite the upward trend depicted in Figure 1, increasing age is not related to a change in positive words recall for individuals with more years of education [t=1.457, p=.149, β=.221]. On its own, years of education did not reach significance [β=.207, p=.065], suggesting that the influence of cognitive reserve on the positivity effect in memory is indeed age-related. MMSE was also a significant predictor for recall of positive words [β=.352, p=.004]. Finally, recall of negative words was only affected by MMSE [β=.301, p=.012].

Insert Table and Figure here

General Discussion

This study aimed to examine whether cognitive reserve was associated with the age-related positivity effect in older adults. Cognitive reserve was introduced to account for individual differences in response to brain disease and damage, and cognitive decline. We have proposed that age-related positivity effects in healthy, cognitively intact, older adults can be affected by different degrees of cognitive reserve (indexed here by years of education), such that more cognitive reserve would be associated with more pronounced effects. Our predictions were partly confirmed. When we administered an emotional free recall test to 79 cognitively intact, non-demented, adults aged 60-88, we found that level of education moderated the effect of age on recall of positive words – as is visible in the Figure, participants with fewer years of education presented a negative relationship between age and the positivity effect in recall, such that, as age advanced, recall of positive words declined. In contrast, the positive recall performance of participants with more years of education showed a non-significant positive association with age. This finding may be interpreted as the fact that age does not affect the positivity effect in recall when education is high, at least beyond age 60; in alternative, considering the upward slope in Figure 1, it is possible that age may positively affect recall of positive words in participants with more education, although our study was underpowered to show a significant effect. In support of the latter point, if we set years of education to 2 *SDs* above the mean, the simple slope becomes significant [p=.034].

The pattern of our results is tentatively consistent with the notion of an age-related strategic shift towards emotional goals, where, as age advances, emphasis on emotional life goals increases given the corresponding reduction in life expectancy (socioemotional selectivity theory; e.g., Carstensen, 2006) and, thus, positivity effects become more pronounced. This set of strategic adjustments in emotional processing has been argued to depend on the availability of sufficient cognitive resources (cognitive control model; e.g., Mather & Knight, 2005) in order for the age-related positivity effect to show in terms of a difference in cognitive performance (e.g., greater memory for positive over neutral stimuli). By measuring the availability of cognitive resources in terms of cognitive reserve, we provide support to this general idea. An important difference, however, is that Mather and Knight (2005) did not use cognitive reserve as a measure of the availability of cognitive resources, but used performance in executive function tasks. In our study, we adjusted for executive function in our analyses and still observed an age-related effect of cognitive reserve on recall of positive words. Therefore, we can argue that cognitive reserve has an impact on the age-related positivity effect in memory that goes over and above the contribution of executive function.

Although executive function did not appear to have any effect on recall of positive words in our data, it should be noted that the executive function tests employed in our study differed from the tests used in Mather and Knight (Exp. 2; i.e., the executive component of the Attentional Network test, the refresh task, and a modified version of the sentence span task). The tests used by Mather and Knight were specifically selected to obtain measures of self-initiated processing capabilities, whereas our tests were chosen to provide more generic indices of executive function performance. Due to the difference in tests, it is possible that the executive functions we have tapped into with our tests are different from those in Mather and Knight's study and, therefore, it is conceivable that using the same tests as in Mather and Knight's paper, the relative importance of the cognitive reserve and executive function constructs might change. This question will need to be addressed in future studies. Alternatively, at least with respect to the age-related positivity effect in free recall, it is also possible that the impact of cognitive reserve within our data may have exhausted the contribution of executive function measures, thus once again raising the issue of whether the executive control/function and cognitive reserve constructs do genuinely differ.

Another possibility is that the age-related positivity effect we observe with free recall in our study does not depend on deliberate age-related strategic changes, as suggested by socioemotional selectivity theory. Age-related positivity effects may be informed by a bias in the processing of emotional stimuli that emerges as previously unused neural networks are engaged due to age-related changes in functional organization of the brain. For instance, Addis et al. (2010) have shown that, unlike in younger controls, successful encoding of positive information in older adults is accompanied by strong neural activity between typically emotionally-involved areas, such as the ventromedial pre-frontal cortex and the amygdala, and the hippocampus. These results suggest that emotional processing in older adults may be altered as a consequence of organizational changes in brain networks, which may not necessarily depend on, or be reflected by, deliberate and conscious strategic adjustments. In this context, greater cognitive reserve may play an important role especially through its general support of neural compensation. As age advances, episodic memory performance tends to decline, even in the absence of pathology, and these changes have been associated with reduced efficiency of the hippocampus, which plays a critical role in memory consolidation (Wixted, 2004) and the binding of emotional information (Mather, 2007). This decline in general memory and hippocampal function may be, at least in part, moderated by cognitive reserve, which has been shown to associate with greater efficiency of compensatory neural networks (Steffener, Reuben, Rakitin & Stern, 2011) as well as to moderate hippocampal atrophy (Valenzuela, Sachdev, Wen, Chen & Brodaty, 2008). This idea appears to receive support also from the fact that our evidence points more towards a decline in positive word recall when cognitive reserve/education is low, rather than an enhancement in the positive effect when cognitive reserve/education is high. Therefore, cognitive reserve may affect the age-related positivity effect in our data via an implicit and automatic, rather than explicit and effortful, mechanism, which would reduce the importance of executive control. As we did not explicitly enquire with our participants as to their motivations, however, these questions remain largely unanswered in the present study.

A number of limitations in our study should be acknowledged. First, different ways of measuring cognitive reserve should be employed to ensure that our findings are not simply a corollary of more schooling. Although educational attainment has been used extensively as a proxy of cognitive reserve, the employment of a mixture of different proxies is certainly preferable to avoid the inherent confounds that come with education (e.g., it may be representative of other components of cognition in addition to cognitive reserve, it may reflect heavily socio-economic status, etc…), or the use of any other proxy as a single measure of cognitive reserve. Relatedly, the use of years of education also makes it harder to employ younger control groups (e.g., undergraduate students), as younger individuals may still be in the process of completing their education. Finally, another issue is that it is also possible that variables influencing cognitive reserve, such as length of education and IQ, may help individuals to prevent negative events during their life-times, thus reducing negative memories later in life and promoting positivity effects. However, this limitation is moderated by the fact that, if correct, an education-related enhancement of the positivity effect should be observed across all ages and not only within the older subgroup.

An issue that was not directly explored in our study was whether a more pronounced positivity effect may also prelude to a greater capacity for the regulation of emotions and the implementation of affective stability. Isaacowitz and Blanchard-Fields (2012) have recently cautioned against drawing parallels between age-related positivity effects and emotional regulation without specific evidence in support of a connection. Given the importance of this topic, especially in consideration of potential implications for prevention and treatment of affective disorders, further studies are warranted. Koenen et al. (2009; see also Barnett, Salmond, Jones & Sahakian, 2006), for instance, showed an association between lower cognitive reserve, as indexed by lower IQ during childhood, and the emergence of psychiatric disorders in adulthood, including depression, thus indicating that lower cognitive reserve may anticipate greater emotional instability later in life.

In summary, despite some limitations, we believe that we have provided preliminary evidence that cognitive reserve may play a role in accounting for individual differences in the positivity effect in healthy older individuals. As cognitive reserve is thought to reflect more available cognitive resources to withstand the impact of brain insults and pathology, and a higher level of cognitive resilience, then our proposal appears legitimate. In addition, the association between years of education and an age-related positivity effect tentatively suggests that prolonged participation in education may be an effective factor in promoting quality of life in late adulthood.

Word count: 4,313; Tables: 1; Figures: 1

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Table. *Mean (Standard Deviation) scores in the emotional free recall task by Valence.*

Valence	*Mean* (*SD*)
Recall Negative	0.148 (0.126)
Recall Neutral	0.150 (0.126)
Recall Positive	0.213 (0.154)

Figure 1. *Plot of Age (X-axis) by proportion of correctly recalled positively-valenced words (Y-axis; standardized), as moderated by years of education (cognitive reserve).*