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The impact of level of education on age-related deficits in associative memory: Behavioral and neuropsychological perspectives

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ABSTRACT

Older adults have difficulty forming associations and binding distinct item components despite mostly preserved item memory potentially because they rely on more automatic, rather than strategic, processing when attempting to form, store, and retrieve associations from memory. An intriguing possibility is that older adults with greater access to strategic processes (e.g., those with a high level of education) may be less susceptible to age-related associative memory deficits. Two experiments assessed the degree to which a high level of education provides an effective dose of cognitive reserve (CR), potentially preserving associative memory. Standard younger and older adults' item and associative memory performance was compared to older adults who had attained a high level of education (mostly doctoral degrees). In both experiments (Experiment 1: person–action pairs; Experiment 2: unrelated word pairs), consistent evidence was found that older adults, regardless of the level of education, exhibited an age-related associative memory deficit relative to younger adults. Interestingly, neuropsychological assessment of both older adult groups revealed greater frontal lobe, but not enhanced medial temporal lobe, functioning in the highly educated. As such, although the highly educated older adults exhibited greater frontal lobe functioning than the standard older adults, this did not aid in the reduction of the age-related associative memory deficit.

1. Introduction

Aging is accompanied by changes in vital cognitive abilities necessary for activities in everyday life. However, a variety of relevant factors contribute to significant variability in the expression of the degree of decline in certain cognitive processes (e.g., health: Aine, et al., 2011; education: Shimamura, Berry, Mangels, Rustin, & Jurica, 1995; Zahodne et al., 2011; genetic factors: Papenberg, Salami, Persson, Lindenberger, & Bäckman, 2015; neural correlates: MacDonald, Li, &

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Bäckman, 2009). Moreover, aging is associated with brain-related changes such as declines in gray matter volume in cortical and subcortical regions (Sowell, Thompson, & Toga, 2004; Terry, DeTeresa, & Hansen, 1987). However, there is a great deal of variability within older adults with respect to not only which brain regions are impacted but also how quickly these changes occur (Raz, Ghisletta, Rodrigue, Kennedy, & Lindenberger, 2010). These sources of variability within aging populations present a novel challenge for cognitive aging research.

One theoretical perspective attempting to account for variability in cognitive performance within older adults proposes a hypothetical *cognitive reserve* (CR) (Stern, 2002). CR refers to the observation that despite the inevitability of age-related changes within the brain, certain individuals maintain high levels of cognitive performance by accessing intact neurocognitive processes or by recruiting compensatory processes (Barulli & Stern, 2013). *Compensation* involves the recruitment of neural networks that are distinct from the primary network underlying a given cognitive process in service of accomplishing a particular task. Thus, if the neural regions underlying a given cognitive process are not operating effectively, the recruitment of alternative networks may aid in the preservation of cognitive functioning (Barulli & Stern, 2013). Indeed, age-related individual differences in cognitive performance are associated with patterns of neural activation indicative of compensatory processing. For instance, low and high performing older adults exhibit distinct patterns of neural activity during associative memory tasks (e.g., binding unrelated word pairs, Cabeza, Anderson, Locantore, & McIntosh, 2002). Interestingly, while the low performing older adults recruit cortical regions similar to younger adults (e.g., right prefrontal cortex, PFC), they did so ineffectively. High performing older adults, however, recruit PFC regions bilaterally (e.g., left and right PFC), indicating the ability to enlist compensatory mechanisms in service of the memory task (Cabeza et al., 2002).

Moreover, CR models acknowledge that changes in cognitive functioning depend, to some degree, on previous experience across the lifespan. While a number of factors collectively comprise life course experience, one factor that is typically measured in cognitive aging studies is level of education. It is possible that older adults who have completed a greater number of years of formal education during their lifetime may comprise a distinct subgroup of the aging population who exhibit higher or more efficient levels of CR (e.g., Saliasi, Geerligs, Dalenberg, Lorist, & Maurits, 2015). It is possible that a high level of education may help to preserve cognitive function given that diagnoses of common age-related pathologies (e.g., dementia) tend to occur later in life for highly educated older adults compared to those with lower levels of education (Amieva et al., 2014; Bennett et al., 2003; Christensen, Doblhammer, Rau, & Vaupel, 2009; Karlamangla et al., 2009; Yaffe et al., 2009).

Empirically, highly educated older adults surpass those with relatively lower levels of education on certain measures of cognitive functioning. For instance, Shimamura et al. (1995) examined cognitive functioning, using several measures of cognitive performance, in young, middle, and older aged active professors compared to two control groups of standard younger and older adults with similar levels of education. Increased age was generally associated with decreased processing speed, which was most pronounced for standard older adults followed by older professors and then the middle-aged and younger age groups. In comparison to all younger and middle-aged groups, working memory (WM) ability and prose recall, however, were preserved in the older professors relative to the standard older adults (Shimamura et al., 1995). Finally, of primary interest to the current work, level of education, compared to other demographic factors (e.g., race, gender) has been shown to be associated with older adults' performance on measures of episodic memory (e.g., Weschler Memory Scale-Revised Logical Memory), with higher levels of education conceivably providing a proxy-measure of CR (Jefferson et al., 2011).

1.1. Age-related declines in item and associative memory

Importantly, age-related declines in episodic memory are prevalent in the cognitive aging literature (see Craik & Bialystok, 2006; Old & Naveh-Benjamin, 2008a; Zacks, Hasher, & Li, 2000). Viewed within the context of the source monitoring framework (e.g., Johnson, Hashroudi, & Lindsay, 1993; Johnson & Raye, 1981; Mitchell & Johnson, 2009), associative (i.e., binding) processes may be adversely impacted in aging populations. Indeed, older adults have trouble forming associations between components within episodic memory (Chalfonte & Johnson, 1996). Moreover, the associative deficit hypothesis (ADH) suggests that one reason for the age-related declines in episodic memory is that older compared to younger adults have difficulty encoding and retrieving associations between distinct components of an episode while memory for the individual components remains largely intact (Naveh-Benjamin, 2000). In most associative memory task paradigms, stimulus pairs (e.g., face–name pairs, word–word pairs) are originally presented during a study phase and followed, after a delay, by two separate tests. During item tests, participants must indicate whether they have seen an individual component (e.g., a face, a name) during the study phase. In contrast, associative tests involve the presentation of a stimulus pair, which either remains intact (e.g., same face–name pair as shown during the previous study phase) or is recombined between two components that appeared during the study phase but were not originally presented together. Older, relative to younger, adults typically have greater difficulty with the associative memory compared to item memory test events. In support of the ADH, a number of empirical findings from behavioral experiments that have examined older adults with an average level of education have replicated the age-related associative deficit using various types of distinct components (e.g., unrelated word pairs, face–name pairs, face–scene pairs, picture pairs, person–action pairs: Bastin & Van der Linden, 2005; Castel & Craik, 2003; Naveh-Benjamin, Guez, Kilb, & Reedy, 2004; Naveh-Benjamin, Hussain, Guez, & Bar-On, 2003; Old & Naveh-Benjamin, 2008b; for a meta-analytic review see Old & Naveh-Benjamin, 2008a).

Moreover, findings from experiments employing standardized neuropsychological tests indicate dissociable differences in older adults' item and associative memory contingent upon level of frontal lobe and medial temporal lobe