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Protective role of educational level on episodic memory aging: An event-related potential study

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ABSTRACT

The aim of the present experiment was to investigate whether educational level could modulate the effect of aging on episodic memory and on the electrophysiological correlates of retrieval success. Participants were divided into four groups based on age (young vs. older) and educational level (high vs. low), with 14 participants in each group. Event-related potentials (ERP) were recorded while participants performed a word-stem cued-recall task. Age-related memory deficits were greater for the less educated individuals. Age differences in the ERP old/new effects were also modulated by the level of education. This study demonstrated that the effects of age on episodic memory and ERP correlates of retrieval success are smaller in participants with high educational levels than those with lower levels. These findings provide support for the reserve hypothesis and highlight the need to consider individual differences when studying cognitive and cerebral changes in aging.

1. Introduction

Healthy aging is associated with a decline in memory abilities, particularly in the domain of episodic memory (see Balota, Dolan, and Duchek (2000), Craik and Jennings (1992), McDaniel, Einstein, and Jacoby (2008), and Zacks, Hasher, and Li (2000) for reviews). Age-related episodic memory deficits are particularly pronounced in free recall or cued-recall tasks in comparison to recognition tasks (see Craik and Jennings (1992) for a review). However, while some older adults exhibit large cognitive deficits, some with a high level may perform as well as young adults in certain memory tasks (Christensen & Henderson, 1991; Shimamura, Berry, Mangels, & Rusting, 1995).

The concept of cognitive reserve provides an interesting framework for examining this question of inter-individual variability (Christensen, Anstey, Leach, & Mackinnon, 2008; Stern, 2002, 2009). The reserve hypothesis suggests that factors such as innate differences (e.g. childhood intelligence) or life experiences (educational attainment, leisure activities, physical activity, etc.) provide reserve capacity which protects the individual from the negative effects of disease and aging on cognitive and brain functions (Christensen et al., 2008). The cognitive reserve is thus associated with the ability of an individual to cope with the deleterious effects of brain damage, brain degeneration, or age-related changes on cognitive performance. Strong evidence for this reserve hypothesis comes from epidemiological studies showing a link between education and dementia (Dartigues et al., 1991; Launer et al., 1999; Stern, Tang, Denar o, & Mayeux, 1995). The greater reserve of patients with a high educational level would help counteract the effects of neuropathology, thereby delaying the development of clinical symptoms. Among these factors, educational background has been found to be one of the strongest predictors of cognitive decline with age (see Ardila, Ostrosky-Solis, Rosselli, and Gómez (2000) and Anstey and Christensen (2000) for reviews), with cognitive deficits occurring earlier and more extensively in people with a low educational level. From a cognitive perspective, education may help develop a wider repertoire of cognitive strategies and a best use of these strategies to assist performance in cognitive tasks, especially in verbal memory tasks. One challenge is then to identify the brain patterns that may underlie the beneficial impact of greater reserve during aging (see Christensen et al. (2008) for a review). On the one hand, structural models have postulated that a better reserve, thanks to a high level of education for instance, is associated with greater synaptic density and more complex connexions (Kramer, Bherer, Colcombe, Dong, & Greenough, 2004). On the other hand, at a more functional level, the main hypothesis is that elderly adults with a high reserve would compensate for these neurocognitive deficits by recruiting alternative brain networks, which allows them to perform the task adequately (see Dennis and Cabeza (2008) and Park and Reuter-Lorenz (2009) for reviews). In particular, according to the HAROLD (Hemispheric asymmetry reduction in older adults) model, some older adults tend to recruit both hemispheres in cognitive tasks in which young

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adults mostly engage one (Cabeza, 2002). The finding that hemispheric asymmetry is reduced during aging has been observed within the domains of working memory, episodic memory, language and sensory-motor processing (see Dennis and Cabeza (2008) for a recent review). Although this cerebral pattern has been initially described in prefrontal areas, some evidence suggests that it may also be observed on other brain regions such as parietal or temporal areas. A few studies have separated older participants into low vs. high functioning groups according to their performance on neuropsychological tests in order to investigate the functional significance of such observations. They mostly found that low-performing older adults and young adults showed similar patterns of hemispheric asymmetry, whereas high-performing older adults recruited both hemispheres symmetrically (Cabeza, Anderson, Locantore, & McIntosh, 2002; Daselaar, Veltman, Rombouts, Raaijmakers, & Jonker, 2003; Rosen et al., 2002). This finding suggests that the contralateral recruitment may be a compensatory mechanism. Furthermore, the PASA model (for *Posterior Anterior Shift in Aging*; Davis, Dennis, Daselaar, Fleck, & Cabeza, 2007; Dennis & Cabeza, 2008) has proposed that older adults sometimes compensate for deficits of activation in posterior cerebral regions by greater recruitment of anterior areas. One way to interpret these additional recruitments is to consider that they would provide an additional pool of resources in which older adults with a high reserve can draw from, helping them compensate for age-related deficits (Dennis & Cabeza, 2008). However, it is worth noting that the interpretation of additional recruitments is still under debate since they are sometimes associated with greater deficits rather than better performance and might result from older adults' difficulty to recruit specialized neural networks (Buckner & Logan, 2002; Duverne, Habibi, & Rugg, 2008; Persson et al., 2005). Thus, the reserve (education, for example) is likely to be associated with the capacity to activate additional functional neurological areas. It seems also possible that large reserve capacity could be reflected in greater degree of activation in specific cerebral areas in older adults with a high level of reserve than young adults or even in a reduction of brain activation in specific cerebral areas.

Two recent studies have focused on the influence of reserve, indexed by education, on brain activation during an episodic memory task in young and older adults. Using a non-verbal recognition task, a PET study by Scarmeas et al. (2003) revealed that activations in posterior brain regions differed as a function of the index of reserve (based on IQ and education). Young adults with the highest educational level strongly engaged the right inferior temporal and postcentral gyri whereas in the older group, more education was associated with greater activity in the left cuneus. Springer, McIntosh, Winocur, and Grady (2005) examined age-related differences in the relationship between education and fMRI brain activity during an episodic recognition memory task. In young participants, a higher level of education was associated with more activity on medio-temporal than frontal regions, whereas in older adults, memory performance was correlated with activity on frontal areas. This result is consistent with the PASA model since in older adults, high performance (associated with a high educational level) was underlied by greater frontal activity. These two studies suggest that age differences on the pattern of cerebral activation during episodic memory tasks differ as a function of education.

Event-related potentials (ERPs), thanks to their precise temporal resolution, have been used increasingly as a useful source of information in recent studies of memory aging. A consistent finding when recording ERPs during the test phase of a recognition memory task is that ERPs elicited by previously studied and recognized items obtain larger positive amplitude than those elicited by correctly rejected unstudied items (for a review see Friedman & Johnson, 2000). This difference has been labelled the "ERP old/new effect" and is considered as an index of processes that contribute to retrieval success in episodic memory. In ERP studies of recognition processes, three main components have been consistently reported. The early medio-frontal effect (onset around 300–500 ms) would index familiarity processes. Second, a left-parietal effect (onset around 400–600 ms) has been associated to recollection-based processes and would be generated in left medio-temporal or hippocampal regions (Friedman & Johnson, 2000). An additional late frontal effect (onset around 600–1000 ms) has also been observed in some studies, and has been linked to post-retrieval monitoring processes. Old/new effects have also been reported during word-stem cued-recall tasks (Allan, Doyle, & Rugg, 1996; Allan & Rugg, 1997, 1998; Allan, Wolf, Rosenthal, & Rugg, 2001; Angel, Fay, Granjon, Bouazzaoui, & Isingrini, 2009; Fay, Isingrini, Ragot, & Pouthas, 2005). The "ERP cued-recall effect" takes the form of a sustained positive deflection for ERPs from correctly completed and recognized items, in contrast to those from correctly rejected produced items. Studies have consistently found an ERP cued-recall effect from 300 to 400 ms post-stimulus, lasting for 1–1.5 s. It may be dissociated into at least two modulations: an anterior positivity and a left posteriorly distributed effect, which might possibly reflect familiarity and recollection processes respectively (Allan & Rugg, 1998). Several studies have examined the effects of age on the ERP correlates of retrieval success (for reviews, see Friedman, 2000, 2003). The early old/new frontal effect supposed to reflect familiarity processes seems relatively spared in older participants since its amplitude has been found to be age-invariant (Duarte, Ranganath, Trujillo, & Knight, 2006; Morcom & Rugg, 2004; Trott, Friedman, Ritter, Fabiani, & Snodgrass, 1999; Wegesin, Friedman, Varughese, & Stern, 2002), which is in line with intact familiarity processes in aging (Yonelinas, 2002). The amplitude of the parietal effect linked to recollection processes is sometimes reduced in the ERP waveforms of older adults (Fjell, Walhovd, & Reinvang, 2005; Li, Morcom, & Rugg, 2004; Mark & Rugg, 1998; Morcom & Rugg, 2004), especially in paradigms requiring only a simple old/new recognition judgement. Conversely, other studies have reported similar parietal effects in older adults and in young adults, mostly when contextual retrieval is requested or in cued-recall tasks (Angel, Fay, Granjon, Bouazzaoui, & Isingrini, 2009; Duarte et al., 2006; Trott et al., 1999; Wegesin et al., 2002). These findings may suggest that older adults would be able to implement recollection processes as well as young adults, but only when it is explicitly needed by the task. In addition, recent studies have observed that the old/new effect on parietal areas was left-sided in the young group whereas it was symmetrically distributed in the older group, in a cued-recall task (Angel et al., 2009) and in a recognition task (Duverne, Motamedinia, & Rugg, 2009). These topographical differences were related to the HAROLD model and confirmed the reduction of hemispheric asymmetry on parietal areas during aging. Investigations into the effects of age on the late frontal effect associated to post-retrieval processes have also yielded conflicting patterns of results. Some studies using source memory paradigms have observed similar reliable late right prefrontal old/new effects in both age groups (Li et al., 2004; Mark & Rugg, 1998; Morcom & Rugg, 2004), while others have reported late frontal old/new effects in the waveforms of young participants only, or reduced effects for older adults (Trott et al., 1999; Wegesin et al., 2002). In addition, a consistent finding across recall and recognition tasks is that old/new effects are generally delayed in older adults in contrast to young adults (for reviews, see Friedman, 2000, 2003). It suggests that older adults engage later than young adults in a differential processing of old and new items. This delay is in line with the reduction of processing speed during aging (Salthouse, 1996).

Recent studies have highlighted the impact of some individual characteristics such as global cognitive activity, memory