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Ageing affects brain activity in highly educated older adults: An ERP study using a word-stem priming task

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ABSTRACT

In this event-related evoked potentials (ERP) study, the neural correlates of a group of highly educated older adults were compared with those of a group of young adults while performing a word-stem completion priming task under semantic and lexical encoding conditions. The results revealed that both age groups exhibited robust priming. The older participants showed better performance than the young adults. Both groups exhibited ERP repetition effects at posterior sites, but only the older adults showed additional frontal activity. The results suggest that highly performing older adults compensate for their lower level of parieto-occipital functioning, reflected by smaller P300 amplitude at posterior sites, by recruiting frontal sites as a mode of brain adaptation.

1. Introduction

This report presents the results of a behavioural and electrophysiological study that investigated the neural correlates of repetition priming using an incidental word-stem completion task in highly educated older adults and compared their performance with that of a group of young adults matched in years of education. The word-stem completion task is the most widely used repetition priming test and comprises a study (encoding) and test phase. In the study phase, participants are presented with a series of target words. After a brief interval, the test phase starts. In this phase, participants are shown a series of three-letter word stems and instructed to complete these stems with the first word coming to mind. Some of the word stems come from the study list and some from a different list. Repetition priming is shown by the difference between the proportion of stems completed with primed (studied) words and the probability that the stem of a critical word will be completed with that word in the absence of prior study.

Behavioural repetition priming has been assessed using different types of stimuli (e.g., words, pictures, three-dimensional objects) and incidental implicit memory tasks (e.g., word-stem completion, word-fragment completion, picture naming, object naming, picture-fragment completion) and also with stimuli presented to different perceptual modalities

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(vision, audition, touch, smell). Behavioural results suggest that repetition priming is generally stable with age. In this study, we used Electroencephalography (EEG) to investigate whether the topography and temporal course of brain activity of elderly people are the same or different from those of younger adults despite preserved perceptual facilitation.

1.1. *Aged-related behavioural and neural changes*

Ageing is a complex process that profoundly affects the cognitive processing and the brain activity and function of all individuals. Until quite recently, the neural and cognitive mechanisms of age-related changes in cognitive function were studied independently. However, in recent years the cognitive neuroscience of ageing has emerged as a new discipline with studies focusing on the relationships between the effects of ageing on cognitive processes, and on the brain areas involved in these processes (see Cabeza et al., 2005).

Declines in many of the main cognitive functions during the ageing process have been well-documented in the literature (Salthouse, 1996; Baltes and Lindenberger, 1997; Park, et al., 2001; Nilsson, 2003). However, this deterioration differs across cognitive functions producing different patterns of decline, stability or gains across the lifespan (e.g., Mitchell, 1989; Park et al., 2001, 2002; Nilsson, 2003; Hedden and Gabrieli, 2004; for reviews see Hedden and Gabrieli, 2004; Rönnlund and Nilsson, 2006; Park and Reuter-Lorenz, 2009). Ageing is accompanied by substantial deficits in declarative memory related to the conscious and intentional recollection of facts and episodes (see Fleischman and Gabrieli, 1998; Cabeza et al., 2005).

Both cross-sectional (Park et al., 2002; Nilsson, 2003) and longitudinal studies (Schaie, 1996; Rönnlund et al., 2008) have shown different patterns of cognitive ageing that vary from decline to stability, and even to growth across the lifespan. It should be noted that it is not only the type of experimental design that is important when evaluating ageing, but also the specific cognitive domain that is assessed (Ballesteros et al., 2009a). Not all cognitive processes deteriorate with age, for example verbal abilities and world knowledge are spared, or even improve across the lifespan (see Park et al., 2002 for a detailed account). Implicit memory, assessed by repetition priming effects using a wide variety of implicit tests and perceptual modalities, is another cognitive ability that appears stable with age (e.g., Mitchell, 1989; La Voie and Light, 1994; Fleischman and Gabrieli, 1998; Ballesteros and Reales, 2004; Fay et al., 2005a; Ballesteros et al., 2007, 2008, 2009b). Behavioural repetition priming refers to better performance in terms of accuracy and/or response times with previously experienced stimuli compared to new stimuli that do not require conscious or intended retrieval of previously encountered information (Graf and Schacter, 1985). Many within-modal studies (using stimuli presented at study and testing the same modality), mostly cross-sectional (e.g., Mitchell, 1989; La Voie and Light, 1994; Ballesteros and Reales, 2004; Ballesteros et al., 2008), but also one four-year longitudinal study (Fleischman et al., 2004), have shown the stability of behavioural repetition priming with age. Moreover, young (e.g., Reales and Ballesteros, 1999) and older adults (Ballesteros et al., 2009b) showed similar magnitudes of priming, within-modal (vision to vision; touch to touch) and cross-modal (vision to audition, vision to touch, and vice versa), suggesting that not only within-modal but also cross-modal priming is preserved with age. The sparing of this type of non-declarative (non-intentional) memory suggests that the underlying brain structures remain relatively intact in old age (Gabrieli et al., 1994; Daselaar et al., 2005) and even in the first stages of Alzheimer's disease (Ballesteros and Reales, 2004). In contrast, the episodic memory system that relies on the hippocampus and the related medial-temporal lobe system deteriorates (e.g., La Voie and Light, 1994; Park et al., 2002; Nilsson, 2003; Hedden and Gabrieli, 2004; Fay et al., 2005a; for reviews see Park and Reuter-Lorenz, 2009).

At the neural level, recent structural neuroimaging investigations suggest substantial age-related grey and white matter shrinkage with age, with anterior regions showing greater decline than posterior regions. The greatest reduction in brain structures with ageing occurs in the caudate nucleus, the lateral prefrontal cortex, the cerebellum and the hippocampus, with minimal or no reduction in volume in the occipital cortex and the entorhinal cortex (Raz et al., 2005; for a review, see Dennis and Cabeza, 2008; Park and Reuter-Lorenz, 2009). These structural brain changes correlate with behavioural data showing larger performance declines in tasks mediated by the frontal lobes (West, 1996; Park et al., 2002). Moreover, functional imaging studies suggest a posterior–anterior shift in older adults and a reduction in the asymmetry of brain activity with age (Dennis and Cabeza, 2008). These functional imaging findings have been interpreted as suggesting that the increase in activation in the prefrontal cortex plays a compensatory role for age-related deficits occurring in other brain regions. Older adults may use different strategies than young adults (Reuter-Lorenz, 2002; Friedman, 2003; Park and Gutchess, 2005; Park and Reuter-Lorenz, 2009).

1.2. *ERP components of repetition priming*

Recording the electrical activity of the brain using electrodes placed on the surface of the scalp is of considerable interest to determine the relationship between this activity and the psychological processes (Fabiani et al., 2000). Although some studies with young adults have used event-related evoked potential (ERP) methods to investigate the neural correlates of repetition priming and perceptual fluency while participants performed different indirect memory tasks (Paller, 2000; Rugg and Allan, 2000; Curran, 2004; Wolk et al., 2004; Fay et al., 2005c), very little ERP research has been conducted with older adults performing similar tasks to investigate age-related changes. ERP studies of visual word-form priming in young adults have reported a positive-going shift relative to the ERPs elicited by the first presentations. That is, ERPs to repeated items are characterized by greater positive amplitude relative to new (non-repeated) items. This ERP repetition priming effect for words has an onset latency of around 300–500 msec post-stimulus and persists for 400 msec in young adults, with a focal topography centred at posterior scalp locations (e.g., Paller and Gross, 1998; Paller, 2000; Rugg and Allan, 2000; Fay et al., 2005c). ERPs evoked by stems completed with primed words are more positive-going than those evoked by stems