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Research Report

The functional and structural significance of the frontal shift in the old/new ERP effect

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ABSTRACT

There is a lack of studies mapping electrophysiological event-related potentials (ERPs) to structural neuroanatomical characteristics. The aim of the present study was to integrate electrophysiological memory-related activity with cortical and hippocampal volume, as well as psychometric memory performance, in a life-span sample. More specifically, we wanted to investigate the functional significance of the often-observed frontal shift of ERP amplitude with increasing age and whether neuroanatomical characteristics can explain this shift. Sixty six healthy participants (20–78 years) went through a neuropsychological examination, MRI scans, and a visual recognition ERP task with verbal stimuli. The results showed that ERPs elicited in the recognition memory task (the old/new effect) correlated significantly with cortical volume, but not with hippocampal volume. Large cortex predicted more differentiated ERP activity and not just larger amplitude in general, implying more distinct and efficient retrieval. Furthermore, ERP amplitude, cortical volume, and hippocampal volume all predicted scores on a composite memory scale. All these relationship were dependent upon the common influence of age. Finally, the participants with the most anterior distribution of activity showed the poorest recognition memory performance. Neither cortical nor hippocampal volume were related to this frontal shift. It is concluded that the distribution of activity along the anterior–posterior axis in a memory paradigm may have functional but not neuroanatomical volumetric correlates. The functional correlates need not be restricted to the older age groups.

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1. Introduction

By use of different scanning methods, studies have identified differential patterns of neural activation in older vs. younger adults (Cabeza et al., 2002; Fabiani et al., 1998). A central question regards whether such differences reflect compensatory processing, cognitive inefficiency, or, alternatively, may not be related to cognitive function. In a recent review, Friedman (2003) states that there are too few event-related potential (ERP) age-related investigations focusing on individual differences to determine whether the changes in ERP patterns can be deemed "compensatory" or "inefficient." He recommends that future electrophysiological investigations of cognitive aging include individual difference measures, so that the implication of a given neural pattern in the genesis of a given, age-related behavioral outcome can be determined. The present study is aimed at giving a contribution along these lines. By including both validated and standardized neuropsychological memory tests, as well as measures of gross neuroanatomical brain structures (cortical and hippocampal volume), in a study of the topography of the old/new ERP effect, we hope to shed light on the question of compensation vs. inefficiency in aging.

1.1. *Neuroanatomy of the old/new effect*

A considerable body of literature validates ERP as a powerful tool in memory research (for reviews, see Friedman, 2000; Friedman, 1992; Johnson et al., 1995; Kutas et al., 1988; Rugg, 1994). In a continuous string of stimuli, old recognized items elicit larger amplitude than new items in the 300 to 800 ms interval. What is sometimes referred to as the parietal old/new ERP effect typically manifests itself in this time window and is seen as a large positive deflection, often with a posterior or parietal maximum (e.g., Rugg, 1985, 1987). This effect is the focus of the present study and will be referred to as 'the old/new effect' in this article since the effect arguably does not *need* to have its maximum at parietal scalp areas. Johnson et al. (1995) argue that this old/new effect is a distinct ERP component, related to memory retrieval processes. Some recent research has indicated that the effect specifically reflects recollection rather than familiarity (e.g., Curran et al., 2001; Wilding, 2000; for reviews, see Friedman and Johnson, 2000; Mecklinger, 2000). However, the validity of such claims has been questioned (Yovel and Paller, 2004), but there is general agreement that the old/new effect indexes successful memory retrieval and is unrelated to perceptual priming. Olichney et al. (2000) found a correlation between the old/new effect and memory performance in both controls and amnesic patients and that the correlations were stronger for recall than recognition tests in the controls. While some studies have found an age decrease (Fjell et al., 2005a; Nielsen-Bohlman and Knight, 1995; Rugg et al., 1997; Wegesin et al., 2002), others have not (Friedman et al., 1993; Trott et al., 1997; Trott et al., 1999). In a recent review of ERP investigations of memory in aging, Friedman (2000) concluded that the old/new effect seems relatively spared in older persons.

Patient data (Guillem et al., 1995b; Rugg et al., 1991; Smith and Halgren, 1989) suggest that structures within the medial temporal lobe contribute to the old/new effect, either directly or through their interconnections with other structures. Intracranial recordings in patients suffering from epilepsy have shown old/new effects from the medial temporal lobe and the hippocampus (Smith et al., 1986). In a series of such studies, Guillem et al. (1995a,b, 1996, 1999) have detected the old/new effect in a number of different brain areas: hippocampus, amygdala, anterior temporal cortex, anterior cingulate cortex, lateral frontal cortex, the orbito-frontal region, and parietal cortex. Thus, it is evident that the old/new effect has widespread neural origins, including structures within the medial temporal lobe. However, when registering the old/new effect at the scalp, it is less probable that the activity from structures such as the hippocampus can be directly measured. Rather, we can assume that some of the cortical activity measurable at the scalp is dependent upon processes that originate in the medial temporal lobe.

1.2. *The frontal shift in aging*

In several different ERP paradigms, especially oddball tasks, but also recognition memory paradigms (Swick and Knight, 1997; but see Friedman et al., 1993; Rugg et al., 1997), a more even distribution of activity along the posterior–anterior axis has been found (Anderer et al., 1996; Fjell and Walhovd, 2001, 2003, 2004; Iragui et al., 1993; Pfefferbaum et al., 1984; Vesco et al., 1993; Walhovd and Fjell, 2001). In a previous publication from the present study, with a largely overlapping sample, a frontal shift of the old/new difference amplitude was found, and not only a general amplitude effect (Fjell et al., 2005a). However, it remains an open question what functional correlates this often-observed frontal shift in ERP amplitude may have and whether such a shift is related to the volume of neuroanatomical structures. Traditionally, the frontal shift has been studied in the context of the classical oddball tasks, using the amplitude to non-frequent target stimuli, or the difference between target stimuli and frequent standards. A more even amplitude distribution of ERPs (P3b) along the posterior–anterior axis in aging has previously been found to be related to poorer task performance on parts of the Wisconsin Card Sorting Test (Fabiani et al., 1998). In a PET study of source memory, however, Cabeza et al. (2002) found that low-performing older adults recruited similar right prefrontal cortical regions as young adults, but high-performing older adults engaged these regions bilaterally. Thus, these results suggested that low-performing older adults recruited a similar network as young adults but used it inefficiently, whereas high-performing older adults counteracted age-related neural decline through a plastic reorganization of neurocognitive networks. This shows that age changes in neural activity, at least as measured by PET, may have important functional behavioral correlates. A topic of interest is whether or not the reduced hemispheric lateralization observed in PET studies and its association with maintained behavioral performance could have an ERP analogy in the anterior–posterior shift and associated performance level.

As Friedman (2003) states, more studies comparing the ERP topography to validated criteria variables are needed. By including a 'global' memory score in addition to the recognition memory task used during the ERP recordings, it is possible to test whether the ERP old/new effect has implications for