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A steady state visually evoked potential investigation of memory and ageing

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ABSTRACT

Old age is generally accompanied by a decline in memory performance. Specifically, neuroimaging and electrophysiological studies have revealed that there are age-related changes in the neural correlates of episodic and working memory. This study investigated age-associated changes in the steady state visually evoked potential (SSVEP) amplitude and latency associated with memory performance. Participants were 15 older (59–67 years) and 14 younger (20–30 years) adults who performed an object working memory (OWM) task and a contextual recognition memory (CRM) task, whilst the SSVEP was recorded from 64 electrode sites. Retention of a single object in the low demand OWM task was characterised by smaller frontal SSVEP amplitude and latency differences in older adults than in younger adults, indicative of an age-associated reduction in neural processes. Recognition of visual images in the more difficult CRM task was accompanied by larger, more sustained SSVEP amplitude and latency decreases over temporal parietal regions in older adults. In contrast, the more transient, frontally mediated pattern of activity demonstrated by younger adults suggests that younger and older adults utilize different neural resources to perform recognition judgements. The results provide support for compensatory processes in the aging brain; at lower task demands, older adults demonstrate reduced neural activity, whereas at greater task demands neural activity is increased.

1. Introduction

It has been well documented that old age is accompanied by changes in memory and cognition (e.g. Budson & Price, 2005). Specifically, older adults experience difficulties with episodic memory, defined as the explicit and declarative recollection of previously experienced personal events (Tulving, 1985). Age-associated episodic memory deficits have been demonstrated during the performance of recognition tasks, where older adults tend to exhibit greater difficulties recalling the context of an item than the item itself (Glisky, Rubin, & Davidson, 2001). Old age is also associated with a reduction in the efficiency of working memory processes (Hartley, Speer, Jonides, Reuter-Lorenz, & Smith, 2001). Working memory involves short-term memory combined with the executive processes involved in the temporary storage, maintenance and manipulation of information (Baddeley, 1992). In addition to a reduction in performance, ageing is accompanied by increased response times on memory tasks, thought to be the consequence of elongated processing times in the brain (Christensen, 2001).

Neuroimaging studies utilizing techniques such as positron emission tomography (PET) and functional magnetic resonance imaging (fMRI) have provided evidence that older adults recruit additional resources mediated by the prefrontal cortex (PFC) to encode, store and retrieve information from memory in order to compensate for reduced neural processing efficiency in the brain (Cabeza, Anderson, Locantore, & McIntosh, 2002; Reuter-Lorenz et al., 2001). Specifically, age-associated increases in bilateral activity of the PFC during memory performance are thought to reflect such compensatory processes (Cabeza et al., 2002). With younger adults, spatial working memory has typically been found to be lateralised in the right hemisphere and verbal and object working memory to be lateralised in the left hemisphere (Courtney, Ungerleider, Keil, & Haxby, 1996; Smith et al., 1995). In contrast, older adults have been found to show a reduction in the lateralisation of neural activity during working memory activation (Mattay et al., 2006), regardless of the nature of the processed material (Reuter-Lorenz et al., 2000). Similarly, studies have demonstrated that older adults show a more bilateral pattern of PFC activity during episodic encoding and retrieval than younger adults (Grady, Bernstein, Beig, & Siegenthaler, 2002; Madden et al., 1999; Morcom, Good, Frackowiak, & Rugg, 2003). Collectively, these findings provide evidence that older adults recruit more neural resources in the PFC to perform the same memory processes as younger adults (Cabeza, 2002).

The PFC has been found to play an essential role in executive function (D'Esposito et al., 1998), with the dorsolateral region specifically implicated in the storage and manipulation of the contents of working memory (Smith & Jonides, 1997). Consistent with the

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premise that memory deficits in older adults stem from reductions in frontal lobe function (West, 1996), the findings from neuroimaging studies suggest that decreases in the activity of the right dorsolateral prefrontal cortex (DLPFC) during retrieval contribute to age-associated deficits in the executive processes underlying working memory (Rypma & D'Esposito, 2000, 2001; Rypma, Prabhakaran, Desmond, & Gabrieli, 2001). In line with a compensatory approach to ageing in the brain, increases in bilateral frontal activity have been proposed to compensate for such inefficient PFC processes (Cabeza, 2002; Cabeza et al., 2002). Additionally, several studies have provided evidence that older adults engage additional frontal resources to compensate for less efficient activity in posterior neocortex (Grady et al., 1994; Schiavetto, Kohler, Grady, Winocur, & Moscovitch, 2002). Similarly, the results from electrophysiological research have revealed that both the frontal and posterior regions of the fronto-parietal network involved in spatial working memory are vulnerable to the effects of ageing (McEvoy, Pellouchoud, Smith, & Gevins, 2001; Muller & Knight, 2002).

Electrophysiological studies of the event related potential (ERP) old/new recognition effect have provided insights into the temporal characteristics of episodic retrieval in both young and older adults (Friedman, 2000). In the old/new recognition memory task, participants discriminate between previously studied (old) and unstudied (new) items. Correctly recognised old stimuli elicit larger N400 and P600 components of the ERP waveform than items correctly identified as new (Curran, 1999). Wilding and Rugg (1996) initially identified two distinct old/new effects when participants recognised items and later recalled whether words were presented by a male or female voice. The first effect was maximal in amplitude over the left parietal and temporal scalp and had an onset of around 400–500 ms post stimulus, with a duration of approximately 400 ms. A second effect had a later onset and exhibited a more sustained time course (>1 s), with a maximum amplitude over the right frontal scalp. The ERP parietal effect is thought to represent a simple judgment of prior occurrence (Morcom & Rugg, 2004) and parietal activity observed in neuroimaging studies of recognition has been interpreted in a similar manner (Cansino, Maquet, Dolan, & Rugg, 2002; Iidaka, Matsumoto, Nogawa, Yamamoto, & Sadato, 2006). In contrast, the frontal effect mediated by right prefrontal regions is involved in monitoring the outcome of a retrieval attempt (Morcom & Rugg, 2004), as well as integrating information about an item's previous occurrence with its initial contextual features (Rugg, Fletcher, Chua, & Dolan, 1999).

In older adults, the parietal old/new effect tends to be attenuated and occurs later in time than it does for younger adults, whereas the frontal effect is relatively preserved (Fjell, Walhovd, & Reinvang, 2005; Li, Morcom, & Rugg, 2004; Morcom & Rugg, 2004). On the basis of this finding, it has been suggested that the recruitment of the PFC during successful episodic retrieval is not necessarily compromised by age (Li et al., 2004). This view is at odds with the behavioural findings that during episodic retrieval, older adults tend to exhibit greater difficulty with memory for context than memory for items (Glisky et al., 2001). In contrast, several studies have failed to identify the frontal ERP effect in older adults and this has been attributed to a deficit in source memory mediated by the PFC (Fabiani, Trott, Friedman, Ritter, & Snodgrass, 1999; Wegesin, Friedman, Varughese, & Stern, 2002).

To date, the neural networks underpinning episodic and working memory have been specifically investigated using PET and fMRI neuroimaging techniques, as well as electrophysiological techniques such as ERPs. The steady state visually evoked potential (SSVEP) elicited by a task irrelevant 13 Hz light flicker has also been found to be sensitive to a range of rapidly changing cognitive processes such as attention (Silberstein, Line, Pipingas, Copolov, & Harris, 2000b), working memory (Ellis, Silberstein, & Nathan, 2006; Silberstein, Nunez, Pipingas, Harris, & Danieli, 2001), recognition memory (Pipingas & Silberstein, 1995) and long term memory (Silberstein, Harris, Nield, & Pipingas, 2000a). A 13 Hz visual flicker has been used to target the low frequency resonant system (alpha band) described by Regan (1989). SSVEP (13 Hz) amplitude changes have been described as being akin to changes in the alpha band (8–12 Hz) (Silberstein, 1995). For example, reduced 13 SSVEP amplitude was found during an attentional task (Silberstein et al., 1990) and increased 13 Hz SSVEP amplitude was found during the hold period of a working memory task (Silberstein et al., 2001). These changes are consistent with the many reports of reductions in alpha amplitude during attentional processing (Klimesch, 1999) and increased alpha activity during a rejection task (Ray & Cole, 1985), respectively. A specific advantage of the SSVEP is that it enables the assessment of both sustained task related cognitive processes, such as visual vigilance (Silberstein et al., 1990) and more transient, fast, occurring processes associated with memory (Silberstein, 1995). More recently, the SSVEP has been found to be useful for isolating neural activity associated with "hold" period of a working memory task (Silberstein et al., 2001). PET and fMRI neuroimaging methods are limited in their ability to resolve such brief cognitive activity and ERP activity is generally not maintained for time periods exceeding 1 s following stimulus presentation (Perlstein et al., 2003). SSVEP investigations allow continuous monitoring of cognitive processes over extended periods with the possibility of resolving activity down to 1/13 s.

Silberstein et al. (2001) have proposed a neurophysiological model of SSVEP changes, in which the 13 Hz SSVEP amplitude indexes the resonance properties of thalamo–cortico and cortico–cortico loops. Within this model, increases in the SSVEP amplitude reflect increases in the transmission efficiency of the re-entrant loops. For example several studies have identified a frontal SSVEP amplitude increase associated with the hold period of a working memory task (Ellis et al., 2006; Perlstein et al., 2003; Silberstein et al., 2001). Reduction in the SSVEP latency (i.e. phase advance) has been suggested to index increased neural information processing speed corresponding to either an increase in excitatory processes or decrease in inhibitory processes (Silberstein et al., 2000b). There is also evidence that distinct changes in SSVEP amplitude and latency accompany different levels of cognitive effort. In a graded working memory task, where subjects held either one or two objects in memory, SSVEP amplitude increases identified at occipital and prefrontal sites and latency decreases at left prefrontal and central parietal sites were more prominent during the higher demand than the lower demand task (Silberstein et al., 2001). SSVEP amplitude changes with increasing task difficulty have also been identified in a visual recognition task where greater amplitude and latency attenuation occurred in right occipital and bilateral parietal–temporal regions for recognition of five objects as compared to recognition of a single object (Pipingas & Silberstein, 1995).

As the SSVEP has been shown to be sensitive to memory related processes, it was anticipated that this methodology would be an ideal tool to examine age-associated changes in the neural correlates of memory. Consequently, the present study investigated age-associated changes in the two memory domains which are commonly impaired with age; working memory and episodic memory. Changes in SSVEP amplitude and latency associated with the 3 s delay period of an object working memory (OWM) task was compared to a 3 s fixation period of an object working memory control (OWMC) task. These comparisons were designed to isolate the neural activity associated with the maintenance of a single object in working memory, in a group of younger and older adults. In order to investigate age-associated changes in recognition using a contextual recognition memory (CRM) task, changes in SSVEP amplitude and latency were compared for previously studied visual images and novel visual images.