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Research Report

The effect of age on word-stem cued recall: A behavioral and electrophysiological study

Alexandra Osorio[a,b], *Soledad Ballesteros*[b,*], *Séverine Fay*[c], *Viviane Pouthas*[a]

[a]*CRICM Université P. and M. Curie-CNRS UMR-7225-Hôp. de la Salpètriere, Paris, France*
[b]*Department of Basic Psychology II, UNED, Madrid, Spain*
[c]*UMR-CNRS 6234 CeRCA, Université François Rabelais, Tours, France*

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ABSTRACT

The present study investigated the effects of aging on behavioral cued-recall performance and on the neural correlates of explicit memory using event-related potentials (ERPs) under shallow and deep encoding conditions. At test, participants were required to complete old and new three-letter word stems using the letters as retrieval cues. The main results were as follows: (1) older participants exhibited the same level of explicit memory as young adults with the same high level of education. Moreover older adults benefited as much as young ones from deep processing at encoding; (2) brain activity at frontal sites showed that the shallow old/new effect developed and ended earlier for older than young adults. In contrast, the deep old/new effect started later for older than for young adults and was sustained up to 1000 ms in both age groups. Moreover, the results suggest that the frontal old/new effect was bilateral but greater over the right than the left electrode sites from 600 ms onward; (3) there were no differences at parietal sites between age groups: the old/new effect developed from 400 ms under both encoding conditions and was sustained up to 1000 ms under the deep condition but ended earlier (800 ms) under the shallow condition. These ERP results indicate significant age-related changes in brain activity associated with the voluntary retrieval of previously encoded information, in spite of similar behavioral performance of young and older adults.

1. Introduction

In the present study, we investigated the neural correlates of explicit memory by using a cued-recall word-stem completion task in a group of high-performing older adults (with a high educational level and still professionally active), and we compared their behavioral and electrophysiological data with that of a group of young adults matched for years of education. The word-stem cued-recall task has received much attention during the last two decades and has been widely used to assess explicit memory in behavioral (e.g., Richardson-Klavehn and Gardiner, 1995, 1996) and electrophysiological studies (e.g., Allan et al., 1996, 2000, 2001; Allan and Rugg, 1997, 1998; Angel et al., 2008; Fay et al., 2005). The task involves two phases: study (encoding) and test (retrieval). In the study phase, participants are presented with a series of target words on which they generally have to perform a task which mainly implies either shallow (perceptual or lexical) or deep (semantic) processes. In the levels-of-processing paradigm, participants are oriented to engage in either shallow or deep

* *Corresponding author.* Department of Basic Psychology II, Universidad Nacional de Educación a Distancia, Juan del Rosal, 10, 28040, Madrid, Spain. Fax: +34 91 2987958.
E-mail address: mballesteros@psi.uned.es (S. Ballesteros).

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encoding (Craik and Lockhart, 1972). Incoming words can be processed at different levels of analysis. Shallow encoding (processing words based on their orthographic or phonemic components) leads to a fragile memory trace susceptible to rapid forgetting. In contrast, deep encoding (semantic or meaning based processing) leads to a more durable memory trace. After a brief interval, the test phase starts. In this part of the task, participants are shown a series of three-letter word stems (e.g., SOL___) which they are asked to complete using the previously studied words (e.g., SOLEIL), in other words, they use the word stems as retrieval cues. Some of the word stems come from the previously studied list and some from an unstudied list. In short, participants are required to complete each stem with a studied word or, if this is not possible, with any suitable word that comes to mind.

1.1. *Cognitive neuroscience of aging*

Several recent theoretical approaches consider aging as a complex phenomenon better understood as a dynamic set of "gains" and "losses" (see Baltes et al., 2005). Cognitive research has relied until very recently upon behavioral measures of cognitive performance (mainly accuracy and response time). However, advances in electrophysiology and neuroimaging techniques have made it possible to investigate the relationship between cognitive performance and brain activity. Recent structural neuroimaging research suggests that the age-related decline of gray and white matter is greater in anterior brain regions than in more posterior regions (Raz et al., 2005; Dennis and Cabeza, 2008). These results correlate with behavioral findings showing larger performance declines in tasks mediated by the frontal lobes (see Park et al., 2002; West, 1996). Moreover, according to the HAROLD (hemispheric asymmetry reduction in older adults) model (Cabeza, 2002) functional imaging studies show a reduction in the asymmetry of brain activity in elderly adults. These consistent results suggest that increased activation in the prefrontal cortex and/or hemispheric asymmetry reduction play a compensatory role for age-related deficits in other brain regions, suggesting that older adults use different strategies than young adults when performing difficult tasks (Park and Gutchess, 2005; Park and Reuter-Lorenz, 2009; Reuter-Lorenz, 2002; Reuter-Lorenz and Lustig, 2005).

An extensive literature suggests that aging is accompanied by a decline in episodic memory, i.e., the retrieval of an item accompanied by contextual information about the episode in which this item was encountered (e.g., Spencer and Raz, 1995; Zacks et al., 2000). By contrast, retrieval in semantic memory (knowledge of language, rules and concepts) is generally preserved in older adults (e.g., Balota et al., 2000; Mayr and Kliegl, 2000; Nessler et al., 2006). The term explicit memory refers to the conscious and intentional recollection of facts and episodes (e.g., Cabeza et al., 2005; Fleischman and Gabrieli, 1998; Nilsson, 2003; Park et al., 2002; Park and Gutchess, 2005). However, a large body of research has shown that with strong cues, recollection can be automatic (see, Richardson-Klavehn and Gardiner, 1995). Although there is considerable intersubject variability (Duarte et al., 2006; Guillaume et al., 2009), episodic memory seems more vulnerable to aging than other forms of long-term memory such as implicit memory (e.g., Ballesteros and Reales, 2004; Ballesteros et al., 2007, 2008, 2009; Fleischman and Gabrieli, 1998; La Voie and Light, 1994; Mitchell, 1989; Mitchell and Bruss, 2003; Osorio et al., submitted for publication) or familiarity-based recognition (e.g., Li et al., 2004; Yonelinas, 2001).

1.2. *Age-related changes in ERP components of explicit memory*

Recording the electrical activity at different brain sites using tin electrodes placed on the surface of the scalp is a very useful way to assess neural activity associated with episodic memory retrieval (Fabiani et al., 2000). Studies of young adults have identified ERPs that dissociate explicit retrieval and recognition of recently encountered items from correct production and rejection of new items ("old/new effect"). The ERP old/new effect normally starts at 300 ms post-stimulus and lasts for several hundred ms post-stimulus. ERPs elicited by stems attracting explicit retrieval of studied items are modulated by a sustained positive-going shift compared to those elicited by stems completed with unstudied words (Allan et al., 1996; Trott et al., 1999). Allan and Rugg (1997) interpreted this old/new effect (or cued-recall effect) as a correlate of retrieval success associated with explicit memory. The old/new effect can be separated into three components: (1) An early frontal effect, starting at around 300 ms after stimulus onset, thought to reflect familiarity-based retrieval processes (Morcom and Rugg, 2004; Wegesin et al., 2002; Duarte et al., 2006; Ranganath, 2006). (2) A parietal old/new effect occurring between 300 and 800 ms which is maximal at left parietal sites in recognition tasks but which is not always lateralized in cued-recall tasks (Johnson, 1995; Rugg, 1995, for reviews). The authors linked this (left) parietal effect with retrieval of items and contextual information from memory, operations supported by the medial temporal system. (3) A late frontally distributed old/new effect, focused on right prefrontal sites presumably related to post-retrieval processes. Some age-related findings during the performance of explicit memory tasks suggest that the early frontal old/new effect and the left-sided posterior old/new effect are generally similar in young and older adults. By contrast, the later right-sided prefrontal old/new effect associated with the search and /or retrieval of item-contextual information (i.e., source memory) has been found to be either of the same magnitude in the two age groups (Li et al., 2004; Mark and Rugg, 1998; Morcom and Rugg, 2004), or smaller or even absent in the waveforms of older adults. The spared early frontal old/new effect is consistent with intact familiarity-based memory performance observed in recognition tasks (see Yonelinas, 2001, for a review). The relative preservation of the posterior old/new effect has been interpreted as showing that medial temporal memory functions are not affected by normal aging but that the diminished late frontal old/new effect reflects impaired source memory mechanisms in the elderly (Friedman, 2000; Gutchess et al., 2007).

Moreover, it has been assumed that both behavioral and electrophysiological measures of explicit memory are sensitive to depth-of-processing manipulations at encoding. Allan et al. (1996, 2000) examined event-related potential correlates of word-stem cued recall for items studied under two different encoding conditions: a ''shallow'' task (to judge whether the