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Research Report

Brain activity during source memory retrieval in young, middle-aged and old adults

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ABSTRACT

We investigated neurofunctional changes associated with source memory decline across the adult life span using functional magnetic resonance imaging (fMRI). Young, middle-aged and old adults carried out a natural/artificial judgment of images of common objects that were randomly presented in one of the quadrants of the screen. At retrieval, the images were displayed at the center of the screen and the participants judged whether each image was new or old and, if old, they indicated in which quadrant of the screen the image had originally been presented. Comparing the items associated with correct versus incorrect source judgments revealed that no regions showed greater activity in young adults than in middle-aged adults; however, in young and middle-aged adults the activity in the left hippocampus and left anterior temporal cortex was of greater magnitude than in the older adults. Several regions also exhibited greater activity in young adults than in old adults. These results suggest that in middle age the recollection neural network, assessable by fMRI, is still preserved.

1. Introduction

The ability to retrieve any contextual detail of the circumstances in which our personal experiences took place, such as the moment or place an experience occurred or the sensations or emotional state associated with it, is considered a recollection process. In contrast, the lack of this information at memory recall is considered a familiarity process (Mandler, 1980; Yonelinas, 2002). Whether these processes differ qualitatively (e.g., Brown and Aggleton, 2001) or quantitatively (e.g., Johnson et al., 1993), empirical evidence has consistently demonstrated that recollection is remarkably affected by age,

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whereas familiarity is only slightly affected (Spencer and Raz, 1995). For this reason, examining the effects of age on the neural correlates of recollection is crucial to understanding the decline of this process with advancing age. These effects have been examined by several positron emission tomography (PET) (Bäckman et al., 1997; Cabeza et al., 1997, 2000, 2002) and functional magnetic resonance imaging (fMRI) (Daselaar et al., 2006; Duarte et al., 2008; Dulas and Duarte, 2012; Duverne et al., 2008; Kukolja et al., 2007; McDonough et al., 2013, 2014; Mitchell et al., 2013; Morcom et al., 2007; Rajah et al., 2010; Spaniol and Grady, 2012) studies (for a review see Mitchell and Johnson, 2009).

However, few of these experiments (Duarte et al., 2008; Dulas and Duarte, 2012; Duverne et al., 2008; Kukolja et al., 2007) have evaluated the relevant comparison that allows isolating brain activity related exclusively to recollection, i.e., the contrast between items correctly recognized associated with a correct source retrieval and those associated with a failure to retrieve the source. Instead, some of these studies (Morcom et al., 2007) focused on the analysis of old/new effects, i.e., items recognized with a correct source response compared to correctly identified new items. This type of comparison includes both familiarity and recollection, because both processes may be in play during the correct identification of an old item (Dulas and Duarte, 2012; Duverne et al., 2008). Other studies have employed a remember–know procedure that provides a subjective measure of recollection (Angel et al., 2013; Cabeza et al., 2004) that is not always impaired in old adults (e.g., Duarte et al., 2008; Mark and Rugg, 1998). Still others compared the brain activity associated with correct responses generated by different tasks, for example, cued recall with priming (Bäckman et al., 1997), cued recall versus recognition (Cabeza et al., 1997), cued recall with source memory (Cabeza et al., 2002) or recognition with source memory (Cabeza et al., 2000; Rajah et al., 2010; Spaniol and Grady, 2012).

Recollection has also been assessed using source monitoring (McDonough et al., 2013), cued recollection (McDonough et al., 2014) and source identification (Mitchell et al., 2013) tasks to investigate specific recollection difficulties identified in old adults. McDonough et al. (2013) manipulated retrieval monitoring demands to explore whether prefrontal activity in old adults is related to compensation or dysfunction. Two source tasks, which engaged activity in different brain regions during encoding, were used to test whether old adults activated these same regions at retrieval. A repeated activation pattern was interpreted as evidence of the search for the appropriate features to remember (Mitchell et al., 2013). The neural reactivation of perceptual details during recollection was evaluated by McDonough et al. (2014) to investigate whether old adults, relative to young adults, retrieve less information from memory.

Moreover, previous PET and fMRI studies of the effects of aging on recollection have only examined groups of extreme ages, i.e., young and old adults. Assessing these effects in middle-aged adults will reveal whether brain activity changes related to the recollection deficits of aging start by middle age or late in adulthood. Additionally, if these changes appear between the two extreme age groups, then a gradual alteration of the neural resources responsible for recollection is indicated. This approach is particularly important because the few behavioral studies that have examined source memory decline across the entire adult life span suggest that source memory either declines linearly with advancing age across the adult life span (Cansino et al., 2013) or start by middle age (Erngrund et al., 1996a, 1996b; but see Uttl and Graf, 1993, for a late onset of source memory decline in adulthood).

Only one previous fMRI study (Grady et al., 2006) on episodic memory retrieval has included middle-aged adults. This study employed a recognition task in which familiarity and recollection processes are mixed. Brain activity during encoding and recognition was analyzed together to search for their common correlations with age. The authors of this study observed a linear decrease in brain activity in the dorsolateral prefrontal cortex but also a linear increase in activity in regions not related to the encoding or recognition of episodic memory.

The studies that included only groups of extreme ages to investigate the neural changes associated with recollection, based on the contrast between correct versus incorrect source memory retrieval, identified that old adults exhibit more right (Dulas and Duarte, 2012) or left (Daselaar et al., 2006) activation in the perirhinal regions compared to young adults. In this last study, activity related to recollection was determined though correlations with quasi-exponential functions based on confidence level rates. However, the results observed in the hippocampus formation were less consistent. Some studies detected less activity in the left hippocampus in old adults relative to young adults (Daselaar et al., 2006; Kukolja et al., 2007). Others reported no differences between the age groups (Duarte et al., 2008; Dulas and Duarte, 2012) or even activity in the opposite direction, i.e., greater activations in old adults relative to young adults (Duverne et al., 2008). Activations in the prefrontal cortex also varied. One study (Duarte et al., 2008) identified less right inferior frontal activity in low-performing old adults relative to young adults but greater activity in the right middle and ventromedial frontal regions in high-performing old adults relative to young adults. In contrast, another study (Dulas and Duarte, 2012) found less right inferior orbitofrontal activity in young adults relative to old adults when comparing incorrect source versus correct source retrieval.

The variable patterns of brain activity observed in the aforementioned studies revealed that the effects of age on the neural network responsible for recollection are multiple and still far from being understood. The aim of the current study was to investigate whether brain activity underlying recollection starts to change by middle age or if these changes occur only in late adulthood. To achieve this purpose, a source memory paradigm (Cansino et al., 2002) was used that provides sufficient correct and incorrect source memory responses to perform the crucial comparison that can reliably isolate the brain activity related to recollection. This procedure evaluates source memory for four different spatial locations instead of assessing only two possible sources, for that reason the possibility of providing a correct source response by chance is $P=0.25$ instead of $P=0.50$. In a dichotomous procedure, the number of correct responses needed to exceed this chance level leaves too few incorrect