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Age-related changes in neural activity associated with familiarity, recollection and false recognition

Audrey Duarte *, Kim S. Graham [1], Richard N. Henson

Medical Research Council - Cognition and Brain Sciences Unit, 15 Chaucer Road, Cambridge CB27EF, UK

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Abstract

Older adults often exhibit elevated false recognition for events that never occurred, while simultaneously experiencing difficulty in recognizing events that actually occurred. It has been proposed that reduced recollection in conjunction with an over-reliance on familiarity may contribute to this pattern of results. This explanation is somewhat inconsistent, however, with recent evidence suggesting that familiarity and associated neural activity are reduced in healthy aging. Alternatively, given that illusory memory may be based, in part, on veridical memory processes (recollection/familiarity), one might predict that older adults exhibit enhanced false alarm rates because the neural signatures associated with true recognition (hits) and false recognition (false alarms) are less distinguishable in old than in young adults. Here, we used event-related fMRI to measure the effects of aging on neural activity associated with recollection, familiarity and familiarity-based false alarms for objects in young and older adults. Compared to young adults, older adults exhibited elevated false alarm rates and impaired behavioral indices of recollection and familiarity. Imaging data showed that older adults exhibited reduced recollection effects in the left parietoccipital cortex. Furthermore, while similar regions in frontal, parietal, lateral and inferior temporal cortices contributed to familiarity-based true and false recognition, reduced familiarity-related activity in frontal and inferior temporal regions in the older adults resulted in decreased differentiation between true and false recognition effects in this group. Our results suggest that reductions in neural activity associated with both recollection and familiarity for studied items may contribute to elevated false recognition in older adults, via reduced differentiation between the neural activity associated with true and false memory.

Keywords: Aging; False memory; Recollection; Familiarity; fMRI

1. Introduction

It is well known that older adults exhibit difficulty remembering previously encountered events as well as young adults (Light, 1991). It is generally believed that this age-related memory loss is primarily restricted to *recollection* for specific contextual details about previously encountered events while *familiarity*-based recognition, which lacks such details, is relatively preserved (see Spencer and Raz, 1995; Yonelinas, 2002, for reviews). Somewhat paradoxically, older adults are more likely than young adults to falsely recognize events that never occurred, particularly for events that share perceptual and/or conceptual characteristics of events actually experienced (e.g. Balota et al., 1999; Henkel et al., 1998; Norman and Schacter, 1997; Schacter et al., 1997).

Several mechanisms have been proposed to account for the elevated level of false recognition or "false alarms" in older adults. For example, some have suggested that an age-related deficit in recollection for studied events may lead to enhanced false alarms for new events (Balota et al., 1999; Johnson et al., 1993; Norman and Schacter, 1997). Impaired recollection may result in a relatively unopposed sense of familiarity elicited by new items and a subsequently increased level of

* Corresponding author. Present address: School of Psychology, Georgia Institute of Technology, 654 Cherry Street, Atlanta, GA 30332-0170, United States. Tel.: +1 404 894 2349; fax: +1 404 894 8905.
E-mail addresses: audrey.duarte@psych.gatech.edu (A. Duarte), GrahamKS@cardiff.ac.uk (K.S. Graham), rik.henson@mrc-cbu.cam.ac.uk (R.N. Henson).
[1] Present address: Institute of Cognitive Neuroscience and School of Psychology, Cardiff University, Tower Building, Park Place, Cardiff CF10 3AT, UK.

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false recognition. This hypothesis is consistent with the idea that recollection is disproportionately affected by aging, as noted above. Another, somewhat related, proposal is that false alarms in older adults reflect an over-reliance on the semantic relatedness or "gist" shared by studied and unstudied items (Balota et al., 1999; Dennis et al., 2008, 2007). Given that familiarity is more likely than recollection to contribute to gist (Yonelinas, 2002), by this account, one might predict that estimates of familiarity for studied items, in addition to unstudied items, would be elevated in older relative to younger adults, consistent with some previous evidence (Bastin and Van der Linden, 2003; Daselaar et al., 2006a,b; Dennis et al., 2008, 2007; Howard et al., 2006).

Some contradictory evidence suggests that neither of these mechanisms can fully account for the elevated levels of false memory in older adults. For example, some behavioral evidence suggests that false alarms can be based on recollection as well as familiarity. Specifically, studies using the "remember-know" procedure – in which participants are instructed to respond "remember" when they recollect details associated with previous events and "know" when the item seems familiar but no contextual details are recollected (Tulving, 1985) – have shown that false alarms can be associated with remember responses (Gallo and Roediger, 2003; Geraci and McCabe, 2006), and that older adults can exhibit enhanced levels of false remembering relative to the young (Jacoby et al., 2005; Norman and Schacter, 1997). Moreover, both young and old adults may misattribute recollected information (e.g. conceptual features) about experienced events to new events (Henkel et al., 1998; Lyle et al., 2006). Collectively, these studies suggest that false recognition may be supported, in part, by illusory recollection in both young and old adults.

Furthermore, other evidence suggests that familiarity, in addition to recollection, may be impaired in older adults. For example, several previous studies using remember-know (Duarte et al., 2006; Light et al., 2000 for review; Prull et al., 2006), "receiver operating characteristic" (ROC) (Healy et al., 2005; Prull et al., 2006) and "inclusion/exclusion" (Davidson and Glisky, 2002) methods, have shown that familiarity for studied information may be impaired in older adults. Despite these decreases in familiarity, false alarms were elevated in old relative to young adults. If an over-reliance on familiarity contributes to enhanced false recognition in older adults, one would predict that false alarm rates should have decreased, not increased, in these previous studies.

Neuroimaging may be useful in elucidating the factors that contribute to false memory in older adults. For example, numerous event-related potential (ERP) and functional magnetic resonance imaging (fMRI) studies have investigated neural activity associated with recognition judgments for studied and unstudied items in young adults (Cabeza et al., 2001; Curran et al., 2001; Dennis et al., 2008; Fabiani et al., 2000; Kahn et al., 2004; Kim and Cabeza, 2007; Okado and Stark, 2003; Slotnick and Schacter, 2004; Wheeler and Buckner, 2003). Although these studies identified notable differences in both magnitude and location of activity associated with true and false recognition, one consistent finding across these studies was that the patterns of neural activity associated with these effects were highly similar. Specifically, ERPs have been shown to dissociate both hits and false alarms from correctly rejected new items at frontal and parietal electrode locations (Duzel et al., 1997; Nessler and Mecklinger, 2003). Furthermore, some fMRI evidence suggests that lateral frontal, lateral and medial parietal and medial temporal areas distinguish both hits and false alarms from correct rejections (Cabeza et al., 2001; Kim and Cabeza, 2007; Okado and Stark, 2003; Slotnick and Schacter, 2004; Wheeler and Buckner, 2003). This suggests that the same cognitive operations that facilitate successful memory retrieval may also support false recognition of new items. Although these regions have previously been differentially associated with recollection and familiarity processes (e.g. Davachi et al., 2003; Henson et al., 2005; Ranganath et al., 2004; Yonelinas et al., 2005), only one previous study directly investigated recollection-based recognition of both studied and unstudied items, revealing regional overlap (Kahn et al., 2004). Thus, it remains largely unclear whether the neural activity associated with both true recognition of studied items and false recognition of unstudied items is associated with recollection, familiarity or both processes.

These neuroimaging studies suggest that activity associated with false recognition is largely overlapping with activity associated with true recognition and typically observed either in a subset of the regions demonstrating true recognition activity or in the same regions but to a lesser degree (Gonsalves and Paller, 2000; Kahn et al., 2004; Kim and Cabeza, 2007; Wheeler and Buckner, 2003). Thus, although similar cognitive processes may contribute to true and false recognition, young adults' brain activity may nonetheless distinguish between studied and falsely recognized new items in these overlapping regions, at least when false recognition rates are relatively low. One interesting possibility is that older adults exhibit enhanced false alarm rates because the neural signatures associated with true and false recognition are less distinguishable than they are in the young. Consistent with this hypothesis, one recent ERP study found that while young adults' ERPs differentiated between hits and false alarms, older adults' ERPs did not (Gutchess et al., 2007). Such a pattern of decreased distinguishability may occur either by a decrease in activity associated with true recognition and/or an increase in activity associated with false recognition. Two recent fMRI studies suggest that both mechanisms may occur in older adults (Dennis et al., 2008, 2007), although these studies did not directly investigate recollection and familiarity processes.

The current study was designed to address the above issues. We used event-related fMRI to investigate neural activity associated with recollection and familiarity-based recognition of studied and unstudied items in young and older adults. We hypothesized that: