Neural recruitment and connectivity during emotional memory retrieval across the adult life span

Jaclyn H. Ford*, John A. Morris, Elizabeth A. Kensinger

Department of Psychology, Boston College, Chestnut Hill, MA, USA

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ABSTRACT

Although research has identified age-related changes in neural recruitment during emotional memory encoding, it is unclear whether these differences extend to retrieval. In this study, participants engaged in a recognition task during a functional magnetic resonance imaging scan. They viewed neutral titles and indicated whether each title had been presented with an image during the study phase. Neural activity and connectivity during retrieval of titles associated with positive and negative images were compared with age (treated as a continuous variable) included as a regressor of interest. Aging was associated with increased prefrontal activation for retrieval of positive and negative memories, but this pattern was more widespread for negative memories. Aging also was associated with greater negative connectivity between a left hippocampal seed region and multiple regions of prefrontal cortex, but this effect of age occurred during negative retrieval only. These findings demonstrate that age-related changes in prefrontal recruitment and connectivity during retrieval depend on memory valence. The use of a life span approach also emphasized both continuities and discontinuities in recruitment and connectivity across the adult life span, highlighting the insights to be gained from using a full life span sample.

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1. Introduction

Healthy aging, even in the absence of dementia, is associated with cognitive declines, including memory retrieval (Salthouse, 2011). However, it has been suggested that memory impairments in older adults can be mitigated by the presence of emotional arousal (Kensinger, 2009b). Critically, some studies have found that older adults’ emotional enhancement is particularly strong when the information is of positive valence (Charles et al., 2003), suggesting that valence, and not only emotional arousal, can influence memory processes in healthy aging. This age-related enhancement of positive information has been of great interest in the cognitive aging literature, as it represents a special circumstance in which age-related cognitive declines may be reduced by specific task-related factors. Further, both young and older adults may process positive and negative information differently, with negative information associated with more visual processing and positive information associated with more conceptual processing (Kensinger, 2009b). As such, age-related changes to positive and negative event retrieval may reflect changes on a number of dimensions relevant to cognitive processing.

One important question that has emerged from the examination of emotional memory in healthy aging is how emotion may alter neural recruitment associated with specific mnemonic processes, and how these influences may differ as a function of age. Identifying the neural correlates of this effect could help researchers understand the underlying cognitive mechanisms contributing to emotional enhancement in older adults. Prior studies have suggested that healthy aging is associated with increased prefrontal cortex (PFC) activity during encoding of emotional relative to neutral information (see St Jacques et al., 2009a for review), and of positive relative to negative information (Leclerc and Kensinger, 2008). In addition to age-related differences in neural recruitment, previous studies have also identified age-related changes in neural connectivity during emotional encoding. Specifically, healthy aging influences connectivity within the medial temporal lobe (MTL) and between the MTL and PFC. Amygdala-hippocampal connections may be weakened in older adults during the encoding of negative information (St. Jacques et al., 2009b), and older adults show stronger connectivity between the hippocampus, amygdala, and mPFC during the encoding of positive information than do young adults (Addis et al., 2010). Age-related changes in neural activity and connectivity during emotional encoding have been
explained as potentially revealing age-related shifts in self-
referential processing, where older adults interpret positive stim-
uli in a more self-relevant way (Kensinger and Leclerc, 2009), as
well as age-related increases in emotional regulation strategies in
healthy older adults (St. Jacques et al., 2009b).

Although most research examining the effects of age on the
neural correlates of emotional memory has focused on encoding
processes, several behavioral studies suggest that healthy aging also
has an effect on processes associated with retrieval. Specifically,
older participants exhibit greater increases in ratings of positive
valence for personal memories (Kennedy et al., 2004), even when
the age of encoding is held constant, and they perceive their recall
of positive events to be more vivid than negative ones (Petrican
et al., 2008). Investigating the effect of emotional valence on the
neural correlates of memory retrieval may elucidate the reasons for
these differences. Previous studies have shown increased activity in
the amygdala (Dolan et al., 2000; Murty et al., 2009; but see, Taylor
et al., 1998) and lateral frontal lobes (Murty et al., 2009) during
retrieval of emotional relative to neutral events, thought to reflect
the retrieval of affective content or the reexperience of an affective
response, and the monitoring and elaboration of the memory,
respectively. However, the effect of valence and healthy aging on
these processes is still unknown. The present study extends prior
work by examining age-related changes in neural recruitment
during retrieval of positive and negative information.

Behavioral studies of memory retrieval reveal linear declines in
performance starting as early as in one’s early 30s (Salthouse, 2011).
Similarly, behavioral studies with continuous age designs suggest
that age-related changes in emotional experience (Pasupathi and
Carstensen, 2003) and emotional memory (Carstensen and Turk-
Charles, 1994) may occur gradually over time. Despite this evi-
dence, previous studies examining the effects of healthy aging on
neural recruitment during memory tasks have often compared
young adults (typically 18–to35-year-old) with older adults (often
aged more than 60-year-old), ignoring individuals between the
ages of 35 and 60 years. Therefore, it currently is unknown whether
the neural changes of middle-aged adults are similar to those of
older adults. In addition, while previous research has shown that
the emotional valence can have opposite effects on neural recruit-
ment in young and older adults (Leclerc and Kensinger, 2008), it is
unknown whether this change is discrete (i.e., valence influences
neural recruitment for young and middle-aged adults in the same
way until a certain age, then this effect is reversed) or gradual (i.e.,
middle-aged adults exhibit a pattern of activity i.e., in-between that
of young and older adults). To answer these questions, the present
study uses a life span assessment to examine the effects of emotion
on the memory network.

One potential difficulty with examining the neural activity
associated with emotional episodic memory retrieval is that re-
presenting participants with studied emotional and neutral stim-
uli could lead to neural differences stemming from the processing
of the retrieval cues, in addition to those related to remembering
the encoding event. A number of recent functional magnetic reso-
nance imaging (fMRI) studies have avoided this potential confound
of on-line emotional processing by having participants encode a
neutral item in a neutral or emotional study context and using the
neutral item as the retrieval cue (Maratos et al., 2001; Sterpenich
et al., 2006). This method helps ensure that valence differences at
retrieval are related to the mnemonic content and not the retrieval
cue. In the present study, we use a paradigm that has been reported
previously (Ford et al., 2014), in which participants encode positive,
negative, and neutral images presented with neutral titles. During a
scanned retrieval session, participants view the neutral titles, to
avoid confounds associated with an emotional retrieval cue, and
retrieve the related emotional or neutral image.

The present study examines age-related changes in neural
recruitment, particularly in prefrontal regions, and in MTL-PFC
connectivity during retrieval of emotional events. Based on prior
evidence that older adults shift to prefrontal rather than sensory
based processing (Davis et al., 2008), we hypothesize that healthy
aging will be associated with increased prefrontal and decreased
posterior activation during successful retrieval. We are particularly
interested in how emotional valence interacts with aging to influ-
ence prefrontal activity and connectivity. During encoding, healthy
older adults recruit prefrontal regions to a greater extent during
positive relative to negative events, whereas young adults exhibit
the reverse activation pattern (i.e., negative > positive; Leclerc and
Kensinger, 2008), and healthy aging is associated with increased
MTL-PFC connectivity during encoding of positive events, but not
negative (Addis et al., 2010). Similar age-related increases in pre-
frontal activity and connectivity during positive event retrieval
would demonstrate that age-related changes in emotional pro-
cessing seen during encoding extend to retrieval. Conversely, age-
related changes in neural activity and connectivity that do not
replicate these patterns would suggest that emotion influences
distinct cognitive processes during encoding and retrieval.

2. Methods

2.1. Participants

Data from 63 healthy adults (mean age = 47.92 years, standard
deviation [SD] = 19.80, ages 19–85 years; mean education = 16.56,
SD = 2.34) are reported. The ratio of males to females was roughly
one-to-one (30 females and 33 males) and was approximately
equivalent within each decade (43%–67% male in each decade),
with no significant difference in this distribution across decades
(x²(6, N = 63) = 0.85, p = 0.99). Twenty-seven of the young adult
subjects from this sample were included in a recent article exam-
ining the interactive effects of emotional valence and memory
phase on neural recruitment (Ford et al., 2014). Gender distribution
was even across the age range and age was not significantly
correlated with education (p = 0.68). Two additional participants
were recruited but not scanned because of contraindications for
fMRI (ages 50 and 75 years; both male). Another 10 participants
were scanned, but were excluded from the current analysis because
of equipment malfunction (n = 1; age = 49 years, education = 16
years, male), an abnormal structural scan (n = 1, age = 49 years,
edu = 17, female), excessive motion (n = 1, age = 56 years, edu = 16,
male), voluntary early termination of the MR session (n = 1, age =
49 years, edu = 14, female), or low behavioral performance (n = 6,
mean age = 55.64, SD = 18.12, ages 30–83 years; mean education
= 16.12, SD = 3.49; 2 female). Participants were right-handed native
English speakers without psychiatric illness or neurologic disorder
and were recruited from the greater Boston area. All participants
were paid for their participation and gave written informed consent
in accordance with the requirements of the Institutional Review
Board at Boston College.

All participants completed the Beck Anxiety Inventory (Beck
et al., 1988) to examine self-reported symptoms of anxiety, as well
as the Beck Depression Inventory (Beck et al., 1961) and the
Geriatric Depression Scale (Sheikh and Yesavage, 1986) to evaluate
symptoms of depression. In addition, participants engaged in a
series of tests intended to examine general cognitive ability, vo-
cabulary, verbal fluency, working memory, and memory (both im-
mediate and delayed). Finally, all participants completed a battery
of cognitive tests implemented in CogState, a computerized neu-
ropsychological test battery that was approximately 30 minutes in
duration. The battery included 6 subtests that examine a range of
cognitive abilities, including: Detection Task (speed of processing),
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