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Prefrontally-mediated alterations in the retrieval of negative events: Links to memory vividness across the adult lifespan

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ABSTRACT

Prior research has identified age-by-valence interactions in both behavior and neural recruitment; age has been associated with increased retrieval of positive relative to negative information as well as an increased tendency to recruit prefrontal regions during negative event retrieval and for this recruitment to correspond to decreased hippocampal connectivity. To date, the explicit relation between prefrontal recruitment and memory phenomenology has not been examined. The current study examined the link between these two measures by examining age-by-valence interactions in the relation between prefrontal recruitment and subjective ratings of memory vividness. Participants (ages 18–85) encoded visual images paired with verbal titles. During a scanned retrieval session, they were presented with titles and asked whether each had been seen with an image during encoding. Participants provided vividness ratings following retrieval of each image. Age was associated with greater prefrontally-mediated alterations in negative event phenomenology, with age-related *increases* in the relation between ventral prefrontal regions and negative event vividness and age-related *decreases* in the relation between dorsal prefrontal regions and negative event vividness. This analysis confirmed a critical role of PFC regions in age-by-valence interactions, where age reversed the relation between PFC recruitment and the subjective richness of retrieved memory representation. These findings are consistent with studies that reveal age-related enhancements in emotion regulation, and suggest that older adults may be engaging in these processes during retrieval of negative events.

1. Introduction

Healthy older adults are often less able to recall specific episodic details relative to their younger counterparts (Salthouse, 20011). Despite this overall decline, research suggests that pockets of preservation may exist in which aging is *not* associated with such substantial deficits. Specifically, it has been suggested that memory impairments in older adults can be mitigated by the presence of emotional arousal (e.g., Kensinger, 2009), particularly when the information is of positive valence (Reed et al., 2014). This relative enhancement has been of great interest in the cognitive aging literature, because it represents a circumstance in which the ability for older adults to have access to a detailed or vivid recollection is altered by the emotional content of the memory.

In an effort to better understand this interactive influence of age and emotion on memory retrieval, recent research has examined the neural mechanisms related to this shift. These studies have highlighted age-related increases in prefrontal cortex (PFC) activity during the first several seconds of emotional memory retrieval (Murty et al., 2009; Ford et al., 2014a; Ford and Kensinger, 2014) and have further suggested that this PFC enhancement tracks with age in a relatively linear fashion: across the ages of 18–83, the older the individual, the greater the PFC activity during emotional memory retrieval (Ford et al., 2014a). In addition to this linear effect of age, it has also been demonstrated that older adults can rely more heavily on PFC regions during negative relative to positive event retrieval (Ford et al., 2014a; Ford and Kensinger, 2014). This valence difference, however, is significant in only the “oldest-old” participants (i.e., 70 and older), with the “young-old” (i.e., 55–69) indistinguishable from middle-aged adults (Ford and Kensinger, 2014). The emergence of a distinct valence pattern after age 70 suggests a mechanism that is separate from the more continuous effects of age that occur across all emotional memory. The nature of this valence pattern is also broadly consistent with a meta-analysis of behavioral age-by-valence interactions, revealing that such interactions were more likely to occur when the ages being compared differed more dramatically from one another – such as when the “oldest-old” were compared to young adults rather than when the “young-old” were compared to young adults (Reed et al., 2014).

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The research described above implicates a memory retrieval mechanism that is prefrontally-mediated, negative valence-specific, and strongest in the oldest-old; however, the cognitive correlates of this mechanism are still unclear. One possibility – given prior research suggesting enhanced encoding of positive relative to negative information by older adults (reviewed by Kensinger and Leclerc, 2009) – is that older adults may over-recruit PFC regions to enhance vivid retrieval of negative events that were more poorly encoded initially. This possibility would be consistent with the role of the PFC in the control of retrieval and in the enhancement of memory detail (e.g., selection, maintenance, reorganization; see Badre and Wagner, 2007; Simons and Spiers, 2003). By this account, PFC activity should aide in the retrieval of vivid negative memories and thus increased PFC activity during retrieval of a particular item should be associated with increased vividness of the memory for that event. Alternatively, healthy aging has been associated with an increased motivation to regulate emotion to optimize mood during cognitive tasks (Carstensen, 1995). It is possible, then, that the PFC is being preferentially recruited by older adults during negative event retrieval to reduce the vividness of re-experienced negative content (e.g., Phillips et al., 2008; Ochsner and Gross, 2005). By this account, PFC activity should serve to down-regulate the vividness of a memory, such that increased PFC activity during retrieval of a particular event would be associated with decreased vividness for the memory of that event.

There is some support for this latter explanation. One line of support comes from analyses examining age-by-valence changes in functional connectivity between the hippocampus and the PFC during retrieval of positive and negative events (Ford et al., 2014a; Ford and Kensinger, 2014). These analyses reveal negative correlations between the left hippocampus and dorsomedial prefrontal cortex (peak voxel: −8, 30, 44) among older but not younger adults and during negative, but not positive, event retrieval (Ford et al., 2014a). This age-related pattern is consistent with an account whereby older adults' engagement of PFC mechanisms reduces hippocampal processes, and perhaps memory vividness, during retrieval of negative events. An analysis of white matter structural integrity revealed that these changes were particularly prominent in older adults with greater estimates of integrity, suggesting that they may not be driven by age-related impairments but rather by shifts in retrieval strategy (Ford and Kensinger, 2014). In other words, older adults may be engaging PFC processes during negative event retrieval in order to dampen the vividness of those memories. These findings highlight age-related trial-by-trial shifts in neural recruitment that may support greater vividness for positive relative to negative event retrieval. However, a more direct test of this link would be to examine directly how age and valence affect the link between PFC engagement and memory vividness.

The current study examines age-by-valence interactions on the relation between PFC recruitment and ratings of memory vividness provided during retrieval. Based on the prior connectivity findings from this same dataset (Ford et al., 2014a), we hypothesize that older adults will show such an inverse relation during negative event retrieval, further supporting a regulation function of their increased prefrontal recruitment. In particular, the current study focused on the participant's *subjective* experience of how vividly they recall each event rather than objective measurement of a particular event detail. A strong subjective sense of vividness may be supported by retrieval of any additional contextual information, including details about thoughts and feelings that the participant had at the time of encoding (here, called "internal details") *or* details about the event itself (here, called "external details"). There is evidence to suggest that retrieval of these two types of details may be supported by distinct mechanisms. Research has shown that task instructions may be utilized to separately manipulate different types of memory details (e.g., Suengas and Johnson, 1988), and a recent analysis of the dataset utilized in the current study lab revealed a divergence of the neural networks supporting internal and external vividness ratings as early as the first two seconds of neutral memory retrieval (Ford and Kensinger, 2016). Although it is unknown how these networks may differ as a function of age, there is reason to believe that age may interact with vividness-type. Behaviorally, older adults are markedly less impaired when asked to recall internal relative to external details (see Kensinger, 2008), and during encoding they over-recruit regions associated with internal, evaluative processing (Maillet & Rajah, 2014), suggesting that they may depend on distinct cognitive and neural mechanisms.

Successful retrieval of an event includes two distinct phases: an initial *search* phase in which information is accessed and a subsequent *elaboration* phase in which additional event details are retrieved. A recent analysis from our lab (Ford et al., 2014b) revealed significant distinctions in the neural processes supporting the search and elaboration phases, with search being associated with widespread bilateral activations across the entire cortex and elaboration primarily being associated with increased activity in the medial prefrontal cortex. This study also demonstrated a phase-by-valence interaction, with positive emotion playing a larger role during search and negative emotion playing a larger role during elaboration. These results suggest that valence-related effects may also differ across the retrieval trial in the current study. A second analysis has demonstrated unique effects of age on neural recruitment during search and elaboration, with some regions exhibiting a complete reversal in the relation between age and activity during the two phases of successful memory retrieval (Ford and Kensinger, 2017). Therefore, the current analysis takes advantage of the extended retrieval period to compare critical age-by-valence-by-vividness effects in the search and elaboration phases of episodic memory retrieval. That is, we examine whether age-by-valence effects exist across both phases, or exist disproportionately in one phase compared to the other.

2. Methods

2.1. Participants

Data from fifty-nine healthy adults (mean age = 48.17, *sd* = 20.34, ages 19–85; mean education = 16.60, *sd* = 2.41; 27 females) are reported. Other findings from these participants have been reported previously, as reviewed in the introduction (Ford et al., 2014a, 2014b; Ford and Kensinger, 2014, 2016). Age and education did not differ across genders ($p > .2$ for both contrasts) and age was not significantly correlated with education ($p = .64$). Two additional participants were recruited but not scanned due to contraindications for MRI (ages 50 and 75; both male). Another fourteen participants were scanned, but were excluded from the current analysis due to equipment malfunction (n = 1; age = 49, edu = 16, male), an abnormal structural scan (n = 1, age = 49, edu = 17, female), excessive motion in the scanner resulting in termination of MR session (n = 1, age = 56, edu = 16, male), voluntary early termination of the MR session (n = 1, age = 49, edu = 14, female), low behavioral performance (i.e., hit rate below .50 or false alarm rate above .50; n = 6, mean age = 55.64, *sd* = 18.12, ages 30–83; mean education = 16.12, *sd* = 3.49; 2 female), or lack of variability in their vividness ratings (i.e., only providing a single value for all vividness ratings; n = 4, mean age = 44.25, *sd* = 9.00, ages 36–53; mean education = 16.50, *sd* = 1.00; 2 female). Participants were right-handed native English speakers without psychiatric illness or neurological 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, vocabulary, verbal fluency, working