Brain Research 1697 (2018) 83–92

Contents lists available at ScienceDirect

Brain Research

journal homepage: www.elsevier.com/locate/bres

Research report

Age differences in the neural correlates underlying control of emotional memory: An event-related potential study

Sara N. Gallant [a,b,*], Carson Pun [b], Lixia Yang [b]

[a] *Leonard Davis School of Gerontology, University of Southern California, USA*
[b] *Department of Psychology, Ryerson University, USA*

ARTICLE INFO

Article history:
Received 12 March 2018
Received in revised form 7 June 2018
Accepted 15 June 2018
Available online 18 June 2018

Keywords:
Event-related potentials
Aging
Emotion
Memory
Intentional forgetting

ABSTRACT

The ability to selectively remember important information and forget irrelevant details is fundamental to successful memory. Research has shown that both younger and older adults can intentionally remember and forget information varying in emotional valence; however, whether the neural correlates of these processes change with age is unknown. In this event-related potential (ERP) study, we sought to fill this knowledge gap using the item-directed forgetting (DF) task. Younger and older adults encoded positive, negative, or neutral words that were cued as either to-be-remembered (TBR) or to-be-forgotten (TBF), while brain activity was recorded with electroencephalography (EEG). Behaviorally, both age groups showed DF effects, although the magnitude of DF was reduced in older adults. Moreover, DF was not influenced by the emotional valence of words in either age group. In the brain, age differences emerged across both word- and cue-related ERPs. Whereas the late positive potential (LPP) was greater for negative than positive words in younger adults, older adults showed a reduced LPP for negative versus positive items. In response to memory cues, younger adults' ERPs showed enhanced parietal and frontal positivity following TBR and TBF cues, respectively. In contrast, older adults displayed greater frontal activity while encoding TBR items than younger adults but age invariance in parietal ERPs following TBR cues. Together, these findings suggest that both younger and older adults are able to intentionally forget information that varies in emotional valence but that the neural mechanisms underlying these processes may change with age.

1. Introduction

We tend to prioritize understanding how we encode and retrieve meaningful information while undermining the significance of forgetting. When intentional, however, forgetting can facilitate memory by removing irrelevant details and facilitating processing of important material (Bjork, 1970). The literature on intentional forgetting thus provides a basis for understanding how we control the contents of memory and reduce interference in memory from no longer needed information (for a review, see MacLeod, 1998). In the laboratory, the directed forgetting task is typically used to study intentional forgetting, in which participants learn a series of items cued as either to-be-remembered (TBR) or to-be-forgotten (TBF), and later recall all items, regardless of their initial cue. The resulting *directed forgetting effect* is characterized by a memory advantage for TBR relative to TBF items. In this paper, we investigate how intentional forgetting, as indexed by behavior and brain activity during a directed forgetting task, is modulated by age and the emotional valence of information—factors that influence selective control of information in memory (e.g., Titz and Verhaeghen, 2010; Hauswald et al., 2010).

Many studies have shown that various cognitive functions decline as we get older (for a review, see Grady, 2012). When compared to younger adults, older adults are generally slower to process information (Salthouse, 1996), remember fewer items on recall tests (Naveh-Benjamin, 2000), and show a reduced ability to filter out distraction (Hasher and Zacks 1988). Similarly, evidence suggests it becomes difficult to control the contents of memory via intentional forgetting with age (e.g., Andrés et al., 2004; Collette et al., 2009; Gallant and Yang, 2014; Hogge et al., 2008; Sego et al., 2006). Indeed, in a meta-analysis of 24 independent samples from 10 directed forgetting experiments, Titz and Verhaeghen (2010) showed that directed forgetting effects are reliably smaller in older (d = 0.81) relative to younger adults (d = 1.17). These age differences are often attributed to age-related declines in the ability to inhibit TBF items (e.g., Zacks et al., 1996) as well as

* Corresponding author at: Leonard Davis School of Gerontology, 3715 McClintock Avenue, Los Angeles, CA, USA.
E-mail address: sgallant@usc.edu (S.N. Gallant).

https://doi.org/10.1016/j.brainres.2018.06.019
0006-8993/© 2018 Published by Elsevier B.V.

episodic memory processes (e.g., Collette et al., 2014; Gamboz and Russo, 2002).

Although age differences in intentional forgetting have been established, only a handful of studies have examined whether these differences vary according to the type of information entering memory, such as its emotional tone. This is an important question to address, considering that older adults typically perform on par with younger adults when detecting emotionally-relevant stimuli in the environment and exhibit similar emotional enhancement effects in memory (Kensinger et al., 2014; Mather, 2010). Yet, different from younger adults, who tend to show a preference for negative information, older adults often display a bias for positive information and/or avoidance of negative relative to neutral information (i.e., age-related positivity effect; for reviews, see Mather and Carstensen, 2005; Reed and Carstensen, 2012). Such differences typically are observed when participants process emotional information in a strategic or goal-directed manner (Reed et al., 2014), and are thought to result from a greater focus on emotionally meaningful goals in later life (Reed and Carstensen, 2012).

Given older adults' preserved ability to remember emotional information and preference for positive stimuli, we previously sought to determine age differences in how emotional valence may affect intentional forgetting (Gallant and Yang, 2014). Specifically, would it be more difficult for older adults to forget positive relative to negative information? To address this question, we asked younger and older participants to complete an item-directed forgetting task for positive, negative, and neutral words that were cued as either TBR or TBF. Consistent with the literature, we found emotional enhancement in recognition memory across age groups (i.e., emotional > neutral recognition) and an age-related decline in the overall magnitude of directed forgetting. Contrary to our expectations, emotional content did not modulate directed forgetting—both younger and older adults were able to intentionally forget emotional information just as well as neutral information. Despite an age-related decline in overall intentional forgetting, these results suggest that both younger and older adults can maintain control over the encoding of emotional information. Importantly, these findings have been replicated by other labs with young-old and old-old adults (Berger et al., 2016) as well as using other paradigms such as value-directed remembering (Eich and Castel, 2016).

Although both younger and older adults in Gallant and Yang (2014) were able to control memory for TBR and TBF emotional words, it is unknown whether similar patterns of brain activity give rise to these behavioral effects across age groups. Investigating the effects of age on neural activity is important as age differences in task-related brain activity are often observed, even when behavior is equivalent (Grady, 2012). For example, ERP studies have illustrated an age-related anterior shift in the topography of the P300[1] component, which has a parietal scalp distribution in younger adults and is thought to reflect goal-directed attention toward task-relevant stimuli (Friedman, 2003, 2012; Nieuwenhuis et al., 2005). A study using simultaneous ERP/fMRI recordings during an oddball task showed that the anterior shift in older adults' P300 was accompanied by greater engagement of prefrontal and temporal sites and diminished parietal recruitment when compared to younger adults who relied more on posterior regions of the brain (O'Connell et al., 2012). Moreover, this age-related divergence in brain activity occurred despite similar task performance across groups. Compensatory models of aging argue that such age-related shifts in brain activity represent a form of compensation in which additional resources are recruited in older relative to younger brains to offset declines in other regions of the brain. This, in turn, may serve to enable age equivalence in performance (Dennis and Cabeza, 2008; Friedman, 2003; Grady, 2012).

To the best of our knowledge, only one study has examined age differences in the neural correlates of directed forgetting using functional magnetic resonance imaging (fMRI; Rizio and Dennis, 2014). In this study, the authors found patterns of brain activity consistent with models of age-related compensation. Behaviorally, both groups showed directed forgetting effects but different patterns of brain activity emerged in response to these behaviors. When compared to younger adults, older adults exhibited increased parietal and PFC activity during intentional encoding, the latter of which was associated with successful recognition of TBR items. These findings suggest that, while the directed forgetting effect may not differ across groups, the neural processes contributing to the effect do indeed change with age. The results of this study, however, cannot shed light on the time course of age-related effects associated with directed forgetting or how they might be modulated by the emotional tone of information. In the current study, analysis of ERPs allowed us to track younger and older adults' brain responses to emotional and neutral words as well as memory cues as they unfolded over milliseconds.

Studies examining the ERP correlates of directed forgetting in younger adults have found distinct ERP patterns evoked by TBR and TBF cues (e.g., Brandt et al., 2013; Gallant and Dyson, 2016; Hauswald et al., 2010; Paller, 1990; Paz-Caballero and Menor, 1999; Paz-Caballero et al., 2004; van Hooff and Ford, 2011; Yang et al., 2012). Following a TBF cue, enhanced positive potentials emerge over frontal sites in early time windows (100–300 ms) and persist into later epochs (>300 ms; e.g., Brandt et al., 2013; Gallant and Dyson, 2016; Hauswald et al., 2010; Paz-Caballero et al., 2004; van Hooff and Ford, 2011). These frontal ERPs are thought to reflect an active mechanism that may suppress TBF items until the next item is presented. On the other hand, TBR cues evoke parietal positivity around 300–600 ms following cue onset (i.e., the P3b) that is thought to represent top-down allocation of attention toward stimuli (Brandt et al., 2013; Gallant and Dyson, 2016; Hauswald et al., 2010; Paz-Caballero et al., 2004). Together, these distinct ERPs in response to cues lend support to an active account of intentional forgetting in which selective rehearsal mechanisms (parietal positivity) may enhance processing of TBR items and active processes (frontal positivity) may deprioritize or dampen processing of TBF items (Anderson and Hanslmayr, 2014).

The influence of emotional content on cue-related ERP patterns has also been primarily investigated in younger adults (e.g., Bailey and Chapman, 2012; Brandt et al., 2013; Hauswald et al., 2010; Gallant and Dyson, 2016; Yang et al., 2012). In these studies, particular attention is paid to the LPP as increased attention toward emotional stimuli is typically found to enhance this component relative to neutral stimuli (e.g., Brown et al., 2012; Hajcak and Olvet, 2008; Schupp et al., 2000; for a review, see Olofsson et al., 2008). For instance, Brandt and colleagues (2013) found the LPP to be enhanced following emotional relative to neutral words even before presentation of the TBR or TBF cues. This modulatory effect of emotion persisted after the memory cues, with enhanced parietal positivity following negative words cued as TBR. Frontal activity associated with TBF cues, on the other hand, was not influenced by emotion. A later study further supported these findings, showing that negative words at both high and low levels of arousal specifically modulated TBR- but not TBF-related ERP activity in younger adults (Gallant and Dyson, 2016). Together, these results may imply that emotional words have a specific impact on the

[1] The P3 component encompasses two distinct subcomponents, the P3a and P3b. The P3a is typically evoked around 250 ms after stimulus onset over anterior sites and is thought to reflect an orienting response to task-irrelevant stimuli (Friedman, 2012; O'Connell et al., 2012). The P3b has more of a parietal distribution and onsets slightly later than the P3a, around 300–600 ms following stimulus onset. In contrast to the P3a, the P3b is argued to reflect top-down allocation of attention toward task-relevant stimuli.