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The impact of focused attention on subsequent emotional recollection: A functional MRI investigation

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ABSTRACT

In his seminal works, Endel Tulving argued that functionally distinct memory systems give rise to subjective experiences of *remembering* and *knowing* (i.e., recollection- vs. familiarity-based memory, respectively). Evidence shows that emotion specifically enhances recollection, and this effect is subserved by a synergistic mechanism involving the amygdala (AMY) and hippocampus (HC). In extreme circumstances, however, uncontrolled recollection of highly distressing memories may lead to symptoms of affective disorders. Therefore, it is important to understand the factors that can diminish such detrimental effects. Here, we investigated the effects of *Focused Attention (FA)* on emotional recollection. FA is an emotion regulation strategy that has been proven quite effective in reducing the impact of emotional responses associated with the recollection of distressing autobiographical memories, but its impact during emotional memory encoding is not known. Functional MRI and eye-tracking data were recorded while participants viewed a series of composite negative and neutral images with distinguishable foreground (FG) and background (BG) areas. Participants were instructed to focus either on the FG or BG content of the images and to rate their emotional responses. About 4 days later, participants' memory was assessed using the R/K procedure, to indicate whether they *R*ecollected specific contextual details about the encoded images or the images were just familiar to them – i.e., participants only *K*new that they saw the pictures without being able to remember specific contextual details. First, results revealed that FA was successful in decreasing memory for emotional pictures viewed in BG Focus condition, and this effect was driven by recollection-based retrieval. Second, the BG Focus condition was associated with decreased activity in the AMY, HC, and anterior parahippocampal gyrus for subsequently recollected emotional items. Moreover, correlation analyses also showed that reduced activity in these regions predicted greater reduction in emotional recollection following FA. These results demonstrate the effectiveness of FA in mitigating emotional experiences and emotional recollection associated with unpleasant emotional events.

1. Introduction

Understanding the differences between recollection- and familiarity-based retrieval and the factors that influence them has been a fundamental goal of memory research for a long time (Tulving, 1982, 1985). Emotion is a critical factor, and there is evidence that memory for emotional events tends to be accompanied by an enhanced sense of recollection (Dolcos et al., 2005; Ochsner, 2000; Sharot et al., 2007; Talarico et al., 2004). Linked to this behavioral effect, brain imaging evidence points to a role of the amygdala (AMY) and hippocampus (HC)

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as part of a synergistic mechanism in which emotion enhances recollection and vice versa. In extreme circumstances, however, uncontrolled recollection of memories for highly distressing events and rumination on such memories may lead to the development of clinical conditions such as post-traumatic stress disorder and depression. Therefore, it is important to identify factors that can diminish such detrimental effects, based on identifying task manipulations that can reduce the experienced emotion during encoding and its subsequent impact on memory recollection. *Focused Attention* (FA) is an emotion regulation strategy that has been proven effective in reducing the impact of emotional responses associated with the recollection of distressing autobiographical memories (Denkova et al., 2015; Iordan et al., 2019). However, it remains unclear whether its engagement during encoding can influence the subsequent memory for emotional events. Here, we investigated the neural mechanisms associated with the impact of FA on emotional recollection, using functional magnetic resonance imaging (fMRI) in a sample of healthy adults.

1.1. Neural mechanisms of emotional memory

There is abundant evidence suggesting that emotional events are better and more vividly remembered than non-emotional, neutral ones (Christianson, 1992; Phelps, 2004). Previous research has investigated the impact of emotion on episodic memory at various stages, from the initial encoding and early consolidation to subsequent retrieval of memory representations (reviewed in Dolcos et al., 2012; Dolcos et al., 2017; LaBar and Cabeza, 2006; Dolcos et al., 2019). In general, available evidence points to the existence of multiple neural routes involved in the impact of emotion on episodic memory. Structures of the medial temporal lobe (MTL), such as the AMY and HC, enhance emotional memory through direct/bottom-up neurohormonal interactions during successful emotional encoding (e.g., Dolcos, LaBar and Cabeza, 2004b; Kensinger and Corkin, 2004; Kensinger and Schacter, 2006), consolidation (e.g., McGaugh, 2004; Ritchey et al., 2008), and retrieval (Dolcos et al., 2005; Kensinger and Schacter, 2005). Non-MTL structures, such as the prefrontal cortex (PFC) and parietal cortex, also contribute to emotional memory processes by top-down modulation of MTL activity through semantic elaboration, executive control, and attention (Dolcos, LaBar and Cabeza, 2004a; Kaneda et al., 2017; Ritchey et al., 2011). The focus here is on MTL mechanisms.

1.2. Mechanisms of recollection-vs. familiarity-based memory

In addition to dissociating the neural correlates of subsequent remembering vs. forgetting at the basic level (Kim, 2011; Murty et al., 2011; Paller and Wagner, 2002), previous studies have also identified a finer distinction between different types of subjective experiences associated with successful memory retrieval. In their seminal works, Tulving and colleagues proposed that there are multiple functionally distinct memory systems (Tulving, 1982, 1985; Tulving and Markowitsch, 1998; Tulving and Schacter, 1990). Specifically, the authors argued that episodic and semantic memory give rise to two different kinds of consciousness – autonoetic and noetic, respectively – that, in turn, are expressed in subjective experiences of *remembering* and *knowing*. Tulving's (1985) so-called *R*emember/*K*now paradigm distinguishes recognition memory performance by asking participants whether they can recall specific details about the experience associated with the studied item (e.g., time, location, sensory details) (*recollection*-based response) or just the feeling of familiarity with the studied item without remembering such details (*familiarity*-based response). This "dual-process" framework of recognition memory has since gained considerable attention in cognitive psychology and neuroscience research (reviewed in Aggleton and Brown, 2006; Diana et al., 2007; Mandler, 2008; Mayes et al., 2007; Ranganath and Ritchey, 2012; Yonelinas, 2002; Yonelinas et al., 2010). Brain imaging studies using the Remember/Know paradigm have demonstrated evidence for partially dissociable mechanisms between recollection and familiarity (Ranganath and Ritchey, 2012; Slotnick, 2013).

Regarding the effect of emotion, previous studies have shown that the memory-enhancing effect of emotion specifically modulates recollection rather than familiarity (Dolcos et al., 2005; Ochsner, 2000; Sharot et al., 2007; Talarico et al., 2004). At the neural level, successful retrieval of emotional items based on recollection was associated with greater activity in the AMY and HC compared to familiarity-based retrieval (Dolcos et al., 2005). This suggests that, in addition to emotional encoding (e.g., Dolcos et al., 2004b; Kensinger and Corkin, 2004) and consolidation (Ritchey et al., 2008), AMY-HC interactions play a critical role in emotional retrieval through a synergistic mechanism in which emotion and recollection enhance each other (Dolcos et al., 2005). However, it is not clear how these mechanisms are affected by emotion regulation engaged during encoding.

1.3. The impact of emotion regulation on memory

Research on emotion regulation (ER) – i.e., the processes influencing which, when, and how emotions are experienced and expressed – has established that the ability to cope adaptively with emotionally challenging situations is vital for both physical and mental health (Gross, 2008, 2015). While significant progress has been made in elucidating the neural mechanisms associated with the effects of engaging specific ER strategies on *immediate* emotional experiences (e.g., Buhle et al., 2014; Dorfel et al., 2014; Ochsner et al., 2012), relatively less is known about the neural correlates of the *long-term* impact of ER on emotional memory. Clarifying the mnemonic consequences of ER is important for understanding both healthy functioning and alterations associated with affective disorders in which an excessive focus and rumination on negative memories and emotion dysregulation are often among the core debilitating features (Dalgleish and Werner-Seidler, 2014; Dolcos, 2013). Forgetting or diminishing the impact of unwanted negative memories, therefore, may serve an adaptive function, given an appropriate context (Dunn et al., 2009; Nørby, 2015).

Although current neuroimaging evidence regarding the impact of ER on emotional memory is still scarce, a few studies have demonstrated that engaging ER strategies can either enhance or inhibit the impact of emotion on memory through modulation of the bottom-up MTL-based mechanisms and/or top-down PFC-based mechanisms (Binder et al., 2012; Hayes et al., 2010; Kaneda et al., 2017; Katsumi and Dolcos, 2018). For instance, studies examining the effect of emotional suppression (i.e. attempts to inhibit the external expression and/or internal experience of emotion; Dunn et al., 2009; Gross, 2008) revealed that engaging this ER strategy during encoding of negative material led to reduced subsequent memory for the suppressed stimuli, and this effect was paralleled by decreased activity and/or functional connectivity in the AMY, HC, and lateral PFC linked to successful encoding (Binder et al., 2012; Hayes et al., 2010; Katsumi and Dolcos, 2018). It remains unclear, however, whether similar mechanisms would be observed with respect to the impact of other ER strategies on emotional encoding, and how this affects recollection-vs. familiarity-related emotional memory.

Focused attention (FA) is part of the so-called attentional deployment family of ER strategies, which typically involve shifts in attention away from emotional aspects of the stimulus, or away from the stimulus altogether, in order to alter emotional responses (Gross, 2008; Sheppes et al., 2014). A meta-analysis of behavioral studies has demonstrated the effectiveness of attentional deployment in regulating emotions (Webb et al., 2012). Notably, attentional deployment strategies such as FA are considered more efficient than other strategies (e.g., cognitive reappraisal) in controlling emotional responses, as their fast deployment enables intervention in the earlier stages of the emotion-generative sequence (Paul et al., 2013; Thiruchselvam et al., 2011). In fact, attentional deployment was found to be effective in modulating emotional responses even when it was engaged after a substantial delay, following the onset of emotion-eliciting stimuli (Sheppes and Meiran, 2007).

Moreover, attentional deployment strategies are generally preferred to reappraisal in high negative intensity situations, due to their ability to block emotional information from being processed (Sheppes and Levin, 2013). This makes FA particularly useful in real-life situations in which individuals may unexpectedly encounter highly negative stimuli and might not have enough time to successfully deal with the stress created by such emotions.

Several empirical studies have begun to reveal the neural mechanisms associated with the immediate impact of engaging such strategies (Dorfel et al., 2014; Ferri et al., 2013; Kanske et al., 2011; McRae et al., 2010), and a recent meta-analysis identified differential brain responses for attention-focused and response-focused emotion regulation strategies, within regions of the broader ER network (Morawetz et al., 2017). However, to our knowledge, no published study has investigated the effect of FA on the neural mechanisms associated with emotional memory encoding, or their link to subsequent emotional recollection. Recent studies from our group point to the role of FA as an effective attentional deployment ER strategy during the retrieval of emotional autobiographical memories (Denkova, Dolcos, & Dolcos, 2013a, 2013b; Denkova et al., 2015; Iordan et al., 2019). Specifically, we showed that instructing subjects to focus away from emotional aspects and onto other non-emotional contextual aspects (e.g., when/where the event happened, who else was involved) during autobiographical memory recollection was linked to reduced subjective emotional experience associated with the recollected memories (Denkova et al., 2015). At the neural level, this behavioral effect was accompanied by decreased activity in the AMY coupled with increased response in brain regions typically associated with ER (PFC) and brain regions involved in processing contextual details (parahippocampal place area, PPA).

1.4. The present study

Despite the potential advantages of FA over other ER strategies, it remains unclear how its engagement during encoding can influence the subsequent memory for emotional events. Given available evidence highlighting the efficacy of FA in mitigating the impact of negative autobiographical memory recollection, it is likely that engaging FA would also affect subsequent remembrance of negative episodes. However, no published study to date has examined the issue or the effect of ER on recollection- vs. familiarity-based recognition memory. Clarification of this issue is important in further understanding the mnemonic consequences of ER and the associated neural mechanisms with increased specificity.

To fill this important gap in the literature, the present study investigated whether the recollection-driven enhancing effect of emotion on memory for pictures is diminished by engaging FA. The associated neural mechanisms, with a focus on MTL regions, were investigated by recording fMRI data during encoding. Participants were shown composite negative and neutral images with distinguishable foreground (FG) and background (BG) areas and were instructed to focus either on the FG or BG content of the pictures. During the retrieval session, about 4 days later, participants' memory was assessed using the Remember/Know procedure (Dolcos et al., 2005; Tulving, 1985), to indicate whether they recollected specific contextual details about the occurrence of pictures during the encoding session, or they only knew that they saw the pictures during encoding but without remembering specific contextual details.

Based on the available evidence, we formulated the following predictions regarding the impact of FA on emotional recollection and the associated MTL mechanisms. First, we expected that focusing on the contextual aspects of negative emotional images would reduce subsequent memory for these stimuli, and this memory-reducing effect of FA would be specifically linked to recollection-based memory. Second, at the neural level, we expected that this memory-reducing effect of focusing away from emotional aspects would be linked to reduced activity in MTL regions typically involved in recollection-based memory enhancements by emotion, including the AMY and HC. Third, we also explored the possibility that activity in these regions would be correlated with memory performance, such that reduced responses in these regions while focusing on non-emotional contextual details of emotional stimuli would be associated with reduced emotional recollection.

2. Methods

2.1. Participants

A total of 24 females participated in this study ($M_{age} = 34.0$, $SD_{age} = 4.76$). All participants were healthy, right-handed, native English speakers, with no recent history of psychiatric or neurological conditions. Only female participants were recruited because they were part of a larger study investigating mother-child dyads during early child development. Data from four participants were excluded from the behavioral analysis testing the effect of FA manipulation on the subjective emotional experience, due to typical reasons contributing to data attrition (e.g., ratings data not being recorded, outlier responses), resulting in a behavioral sample of 20 participants ($M_{age} = 33.85$, $SD_{age} = 4.82$). The eye-tracking data in three of these four participants were also excluded, resulting in 21 participants ($M_{age} = 34.24$, $SD_{age} = 4.90$) whose data sets contributed to the manipulation check analyses involving eye-tracking and fMRI analyses. Finally, data from two additional subjects were unusable for analyses of memory-related fMRI data, because they never responded with "Remember" in the retrieval task across any condition. These resulted in data from 19 participants ($M_{age} = 33.84$, $SD_{age} = 4.92$) being used in the analyses investigating our hypotheses regarding the impact of FA on encoding activity associated with reduced subsequent recollection of emotional images. All participants provided written informed consent under a protocol approved by the Institutional Review Board and received payment for their participation.

2.2. Experimental procedures

Participants completed two tasks: an incidental encoding task, consisting of an emotional rating task, completed in the MRI scanner, while eye-movements were also recorded, and a recognition memory task, completed outside the MRI scanner about 4 days later (range: 3–5 days) (see task diagram illustrated in Fig. 1).

2.2.1. Incidental memory encoding: emotional rating task

Functional MRI and eye-movement data were recorded while participants viewed and rated a total of 90 composite images (60 negative and 30 neutral). Each composite image was created by overlaying a negative or neutral FG component upon a visually complex BG component. The FG components were extracted from images part of the International Affective Picture System (IAPS; Lang et al., 2008), the Geneva Affective Picture Database (GAPED; Dan-Glauser and Scherer, 2011), the Military Affective Picture System (MAPS; Goodman et al., 2016), the Nencki Affective Picture System (NAPS; Marchewka et al., 2014), and the Emotional Picture Set (EmoPicS; Wessa et al., 2010). Images from these sources along with domain-free online image databases were used as BG components. Negative and neutral composite images were matched for human presence, animacy, FG location (i.e., top, bottom, left, right), complexity, brightness and contrast ($ps > .05$). Emotional images were reliably more negatively valenced ($M_{Valence} = 2.62$, $SD_{Valence} = 0.83$) and more arousing ($M_{Arousal} = 4.94$, $SD_{Arousal} = 1.00$) than the neutral images ($M_{Valence} = 5.42$, $SD_{Valence} = 0.52$; $M_{Arousal} = 2.32$, $SD_{Arousal} = 0.45$) ($ps < .001$). Unequal numbers of emotional and neutral images have been commonly employed in studies of emotion control, particularly in those manipulating ER only within the negative condition (e.g., Eippert et al., 2007; van Reekum et al., 2007; Wager et al., 2008). The main goal of this study was to elucidate the neural mechanisms associated with the impact of FA as an ER strategy. As such,

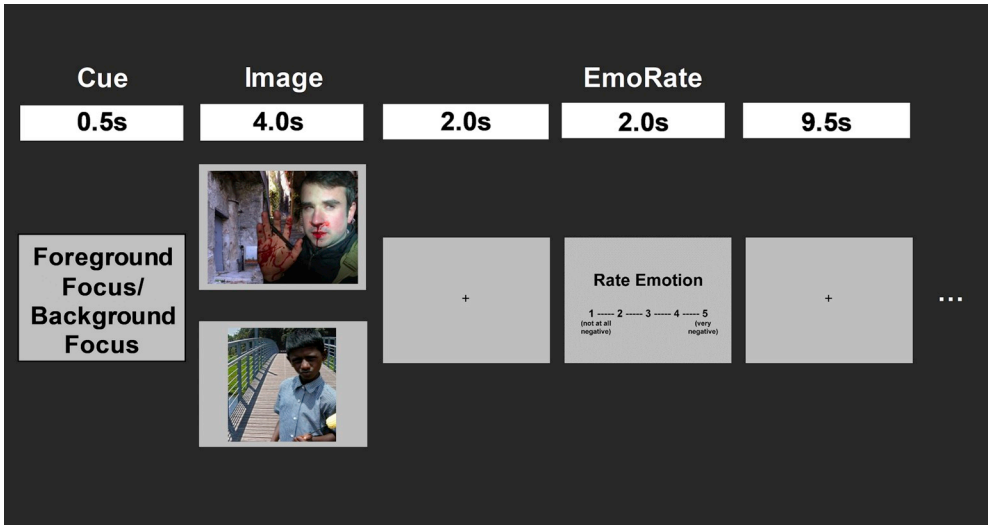

Fig. 1. Diagram of an incidental memory encoding task. Functional MRI data were recorded while subjects rated their emotional responses to negative or neutral images. Preceding image presentation, an attentional cue prompted subjects to focus either on the FG or BG areas of the images. Image presentation was followed by a rating screen where participants reported their emotional response triggered by the images, using a 5-point scale (1 = Not Negative at all; 5 = Very Negative).

we included equal numbers of negative images viewed under FG Focus vs. BG Focus conditions (see below), to maximize the number of negative images for the main targeted contrast. However, the inclusion of neutral images in the design was necessary to avoid prolonged negative mood induction and to have them as a basic control condition. Hence, we sought to have equal numbers of trials for the main three categories of images involved (EmoFG, EmoBG, and Neu), which was also justified by pilot data showing no significant differences in the emotional ratings between the FG and BG foci for neutral images. The pool of 90 images was divided into sets of images that were randomly assigned to five study runs, counterbalanced across image type and attentional cue categories. The run orders were randomly assigned to the participants. To avoid negative mood induction, the order of trials was counterbalanced within each run such that no more than three images of the same emotional category or cue type were presented consecutively. Each image was presented for 4 s and then was removed to minimize the confounding effects of eye movements associated with prolonged scanning of images (Fig. 1).

Participants were asked to view each image under different attentional manipulation conditions, cued by the preceding instruction screen. The cues, presented for 0.5 s, directed them to focus either on the image foreground (FG Focus), which was emotional or neutral, or on the image background (BG Focus), which was always neutral. Following the cue, each negative and neutral image was presented for 4 s. Half of the negative images and half of the neutral images were preceded by each focus cue, and the cue type preceding each image was counterbalanced across participants. Following image presentation, participants were asked to rate their subjective emotional experience triggered by the images on a 5-point scale (1 = *Not Negative at all*, 5 = *Very Negative*). All responses were made on a response pad attached to the participant's right hand. The trial ended with an inter-trial interval of 9.5 s, allowing the hemodynamic response to return to baseline.

2.2.2. Recognition memory task

About 4 days later (range: 3–5 days), participants completed a surprise memory task outside of the MRI scanner. They were shown only the FG components from a total of 135 images consisting of the 90 image FGs from the encoding task intermixed with 45 additional foil FGs (30 negative and 15 neutral), which had similar basic perceptual and emotional properties with those of the images used during encoding, and the two sets of images (*Old* and *New*) did not significantly differ across any of the measured properties (all $p_s > .05$). Each FG was displayed for 4 s. Participants were instructed to make Remember/Know/New responses while the FG was on the screen: *Remember* for seeing the image and remembering the contextual details; *Know* for knowing that they have seen the image, but without being able to recall specific contextual details; and *New* for not seeing the image (Tulving, 1985). Prior to the retrieval task, participants were given ample time to go over these instructions with the experimenter and perform a practice task until they understood the R/K/N procedure. Following the memory decision, participants rated the level of confidence associated with their response on a 3-point scale (1 = *Low*, 2 = *Medium*, 3 = *High confidence*) during the presentation of a prompt displayed for 2 s.

2.3. Eye tracking data acquisition

To assess participants' gaze patterns during the emotional rating task, eye positions and movements were recorded from each participant's right eye using a MR-compatible model (with a long-range mount) of the Eyelink1000 system (SR Research, ON, Canada), at a sampling rate of 1000 Hz.

2.4. fMRI data acquisition

Scanning was conducted on a 3 T Siemens MAGNETOM scanner with a 64-channel head coil, at the Beckman Institute's Biomedical Imaging Center. After the sagittal localizer and the 3D MPRAGE anatomical images (TR = 2000 ms; TE = 2.25 ms; flip angle = 8°; FOV = 230 × 230 mm^2, matrix size = 256 × 256 mm^2; slice thickness = 1 mm; volume size = 172 slices; voxel size = 1 × 1 × 1 mm^3), 5 blocks of full-brain EPI functional images were acquired axially with a simultaneous multi-slice (SMS) sequence (TR = 1500 ms, TE = 30 ms; flip angle = 40°; FOV = 230 × 230 mm^2; matrix size = 144 × 144 mm^2; slice thickness = 1.6 mm; volume size = 76 slices; multi-band acceleration factor = 4, voxel size = 1.6 × 1.6 × 1.6 mm^3; phase encoding direction from anterior to posterior).

2.5. Data analyses

2.5.1. The impact of FA on emotional memory: behavioral analyses

The impact of FA on memory was assessed using corrected recognition scores [% Hits – % False Alarms (FA)], which consider responses to both *Old* and *New* items and correct for the accuracy of self-reported recollection- and familiarity-based responses regarding memory performance. For the present analyses, confidence ratings acquired during the recognition task were collapsed to increase statistical power. Paired

t-tests and repeated-measures ANOVAs were performed to compare memory performance under different encoding conditions. To assess the role of the Remember/Know response in memory, we similarly calculated corrected memory scores for Remember and Know responses, by subtracting the proportion of FAs from that of Hits associated with each response type separately. Differences in memory scores among the conditions were similarly assessed via repeated-measures ANOVAs and post-hoc paired t-tests. All behavioral data were analyzed using the SPSS software (IBM Corp. 2017. Version 25.0).

2.5.2. fMRI data analyses

Preprocessing of fMRI data was performed using SPM12 (Wellcome Department of Cognitive Neurology, London, UK). Functional images were first corrected for acquisition order and realigned to correct for motion artifacts. Next, the high-resolution anatomical image was co-registered to the first functional image for each participant, and functional images were spatially normalized (resampled to 2 mm isotropic voxels) to the Montreal Neurological Institute (MNI) template. Lastly, the functional images were spatially smoothed using a 6-mm Gaussian kernel, full-width-at-half-maximum (FWHM), to increase the signal-to-noise ratio. For data analysis focusing on MTL regions, we used procedures similar to those previously involved when MTL activity was specifically targeted (Dolcos et al., 2004b, 2005). Specifically, voxel-vise analyses were limited to the following anatomically-defined MTL regions of interest (ROIs), identified based on published guidelines (Moore et al., 2014): Amygdala, Hippocampus, and Parahippocampal Gyrus (further separated into anterior and posterior regions) (Dolcos et al., 2004b, 2005; Shafer and Dolcos, 2012). We compared the arithmetic mean of activity within these ROIs associated with the conditions of interest, following our previous investigations using similar analytical techniques (Denkova et al., 2010; Dolcos et al., 2008; Dolcos et al., 2013; Dolcos et al., 2004b, 2005; Dolcos and McCarthy, 2006; Iordan and Dolcos, 2017; Iordan et al., 2019; Morey et al., 2009).

Analyses of fMRI data were conducted using in-house custom MATLAB scripts, which were developed at Duke University's Brain Imaging and Analysis Center and are publicly available online (https://wiki.biac.duke.edu/biac:tools). The fMRI signal was selectively averaged in each participant's data as a function of trial type (e.g., Emotional/Neutral, FG Focus/BG Focus, R/K responses) and TR/time point. Selective averaging across trial types was performed after trial-level baselines (i.e., one TR immediately prior to stimulus onset) were subtracted, hence correcting for potential temporal autocorrelation and low frequency drifts. The impact of in-scanner motion was further mitigated by removing trials exhibiting large global signal intensity deviations ($SD > 3$). No assumptions about the shape of the hemodynamic response function (HRF) were made, because this allows finer comparisons of the MR signal on a TR-by-TR basis (Denkova et al., 2010; Dolcos et al., 2004b, 2008, 2013, 2005; Dolcos and McCarthy, 2006; Iordan and Dolcos, 2017; Iordan et al., 2019; Morey et al., 2009). This is particularly important for investigating brain responses linked to emotion processing and ER, as they can affect the duration of the BOLD response, hence limiting the effectiveness of HRF modeling (Lindquist and Wager, 2007; Waugh et al., 2010; Waugh et al., 2014; Waugh et al., 2016). This procedure generated voxel-based activation t-maps for each condition, contrast of interest, and TR/time point, and the outputs of subject-level analyses were used as inputs for second-level random--effects group-level analyses.

To identify the MTL areas sensitive to the comparisons of interest, functional ROIs were identified within the anatomically-defined MTL ROIs, as follows. First, voxels associated with recollection were identified by a conjunction of the following two contrasts: All Remember (R) > All Miss and All Remember > All Know (K). Then, the signal extracted from functionally identified ROIs identified within the borders of anatomically-defined MTL ROIs was used for further analyses (t-tests, ANOVAs, correlations) to perform additional comparisons of interest (Emo FG-R > Emo BG-R) and to investigate brain-behavior correlations. Moreover, to better interpret the findings from this main analysis, additional analyses were performed by (1) examining the corresponding neutral contrasts (i.e., Neu FG-R > Neu BG-R) within these functionally-defined ROIs, to assess specificity of the observed effects by emotion, and by (2) performing similar analyses on signals extracted from anatomically-defined ROIs based on published guidelines for manual segmentation of the MTL structures (Moore et al., 2014). The latter allowed us to ensure that the main analysis focusing on recollection-based responses was not biased by functional contrasts (memory-related) contributing to the ROI creation. Finally, aside from the functional ROIs defined based on the conjunction of contrasts mentioned above, sensitivity of recollection-based responses to the FA manipulation for emotional images (EmoFG-R > EmoBG-R) was also investigated in ROIs defined based on R vs. K responses for the neutral images, which specifically targeted recollection-sensitive brain regions (e.g., HC). The focus of analyses was on TRs corresponding to the time when the fMRI signal typically peaks in similar studies, which is consistent with those expected in studies of memory encoding (Eldridge et al., 2005; Reber et al., 2002). Repeated-measures ANOVAs involved the following three factors: Emotion (Negative vs. Neutral), Attention manipulation (FG Focus vs. BG Focus), and Memory (Remember vs. Know). Finally, to identify brain regions whose response was related to individual variation in memory performance across conditions, brain-behavior correlation analyses were performed between the fMRI signal and memory performance. For these analyses, the average BOLD signal for conditions of interest was extracted from functional and anatomical ROIs and correlations were calculated offline. A threshold of $p < .05$ was used for these analyses, and a Bonferroni correction for the number of MTL regions explored was also applied.

Similar to the whole-brain manipulation check analyses described below, an intensity threshold of $p < .005$ (uncorrected for multiple comparisons) was used for the contrasts involving the most dissimilar memory conditions (e.g., All R > All Miss) and a more lenient threshold ($p < .05$) was used for more subtle comparisons (e.g., All R > All K). Monte Carlo simulations performed using a MATLAB script developed by Dr. Scott Slotnick (https://www2.bc.edu/sd-slotnick/scripts.htm) estimated a cluster extent of 20 contiguous voxels (corrected for multiple comparisons at $p < .05$). This was based on a cluster-forming uncorrected intensity threshold of $p < .005$ with 1000 iterations, restricted to *a priori* targeted MTL regions, which were identified using a MTL mask that was manually traced based on published guidelines (Moore et al., 2014).

2.5.3. Manipulation check: Eye-tracking, behavioral, and fMRI data analyses

To assess the effect of FA on participants' gaze patterns, we calculated the proportion of time spent on fixations within vs. outside the FG for each trial using the EyeLink Data Viewer. These data were submitted to paired t-tests and repeated-measures ANOVAs. Detailed analyses of the behavioral impact of the FA manipulation on the subjective experience of emotion and the neural effects associated with the experience of FA are the focus of aseparate report. The analyses reported here only serve as a manipulation check and focus on the general effect of the FA manipulation on the subjective emotional ratings for the negative and neutral images. Similarly, at the neural level, the effects of the attentional manipulation on the response to negative stimuli was assessed by comparing brain activity for Emo FG Focus and Emo BG Focus conditions. The Emo FG vs. Emo BG contrast images generated for each participant were analyzed by random-effects group-level t-tests, which allowed identification of brain regions showing differential activation across the attentional manipulation conditions. An intensity threshold of $p < .005$ (uncorrected for multiple comparisons) with a cluster extent of 46 contiguous voxels was used, which corresponds to $p < .05$ corrected for multiple comparisons (based on a Monte Carlo Simulation with 1000 iterations) (Slotnick, 2017; Slotnick et al., 2003).

Table 1
Eye-tracking and behavioral results from the encoding task. Values indicate means (standard deviations). AI, area-of-interest; FG, foreground; BG, background.

	FG Focus		BG Focus	
	Negative	Neutral	Negative	Neutral
FG AI (%)	.71 (.15)	.71 (.11)	.34 (.13)	.31 (.12)
BG AI (%)	.21 (.09)	.22 (.07)	.56 (.13)	.60 (.13)
Emotional Ratings	3.97 (.50)	1.32 (.28)	1.72 (.46)	1.32 (.33)

3. Results

3.1. Manipulation check: Eye-tracking, behavioral, and fMRI data

First, supporting successful engagement of FA, eye-tracking data showed that participants directed their gaze toward the target components of both emotional and neutral images (Table 1). Specifically, they spent more time gazing within the FG areas (t (20) = 12.14, $p < .001$), when instructed to look at the images' FG, and spent more time gazing within the BG areas (t (20) = 4.90, $p < .001$), when instructed to look at the images' BG. Second, there was also an overall reduction in the emotional ratings for the BG Focus (t (19) = 16.40, $p < .001$), which was driven by a reduction in ratings for the negative images (t (19) = 17.32, $p < .001$; Table 1), as no significant differences by attentional focus were identified in the ratings for the neutral images (t (19) = −0.04, $p = .97$).

Third, complementing the behavioral and eye-tracking data, focusing away from the emotional content and on the contextual aspects of negative images (BG Focus) was associated with decreased activity in brain regions typically associated with emotion processing, such as the AMY (MNI coordinates: $x = -16$, $y = 2$, $z = -14$) and the ventrolateral PFC (vlPFC: $x = -44$, $y = 30$, $z = 16$), as well as in regions sensitive to emotional content (e.g., fusiform gyrus: $x = 48$, $y = -44$, $z = -16$). These reductions were accompanied by increased activity in top-down executive control regions, such as the dorsolateral prefrontal cortex (dlPFC; $x = 32$, $y = 32$, $z = 34$) and lateral parietal cortex (LPC: $x = -24$, $y = -56$, $z = 54$), which are typically implicated in attentional control, as well as in the parahippocampal place area (PPA; $x = -28$, $y = -40$, $z = -14$), associated with processing of contextual information.

3.2. The impact of FA on emotional memory

3.2.1. Behavioral results: FA reduces recollection-based effects of emotion on memory

Confirming our prediction, there was reduced memory for images encoded in the BG compared to FG Focus condition, and this effect was driven by recollection-based responses (Table 2 and Fig. 2). These findings were confirmed by a three-way repeated-measures ANOVA examining the effect of Emotion (Negative vs. Neutral), Attention (FG vs. BG Focus), and Memory (R vs. K responses) on corrected memory performance that revealed significant main effects of Attention [F (1, 18) = 63.77, $p < .001$, $\eta_p^2 = .78$] and Memory [F (1, 18) = 12.15, $p = .003$, $\eta_p^2 = .40$]. There was also a significant main effect of Emotion [F (1, 18) = 13.05, $p = .002$, $\eta_p^2 = .42$] and significant two-way Emotion × Memory [F (1, 18) = 5.33, $p = .033$, $\eta_p^2 = .23$] and Attention × Memory [F (1, 18) = 10.47, $p = .005$, $\eta_p^2 = .37$] interactions, as well as a non-significant Emotion × Attention interaction [F (1, 18) = .002, $p = .97$, $\eta_p^2 < .001$]. Interestingly, the three-way Emotion × Attention × Memory interaction was also marginally significant [F (1, 18) = 4.38, $p = .051$, $\eta_p^2 = .20$]. To further qualify this interaction and explore possibly greater effect of FA on memory for emotional vs. neutral stimuli, two-way (Attention × Memory) ANOVAs were conducted separately for negative and neutral images. These analyses revealed a significant Attention × Memory interaction in the negative [F (1, 18) = 18.29, $p < .001$, $\eta_p^2 = .50$], but not in the neutral condition [F (1, 18) = 1.37, $p = .26$, $\eta_p^2 = .07$]. Finally, consistent with our expectation, post-hoc analyses showed that FA affected recollection-based (t (18) = 5.69, $p < .001$) but not familiarity-based responses (t (18) = −0.03, $p = .97$) in emotional memory, and consistent with the idea that the impact of FA was slightly stronger on the recollection-based responses for the negative images, a two-way ANOVA on the recollection trials only (EmoFG-R, EmoBG-R, NeuFG-R, and NeuBG-R) yielded a marginally significant Emotion × Attention interaction (F (1, 18) = 4.38, $p = .051$, $\eta_p^2 = .20$). Overall, these findings show that the recollection-based memory-enhancing effect of emotion is also impacted by engaging FA as an ER strategy.

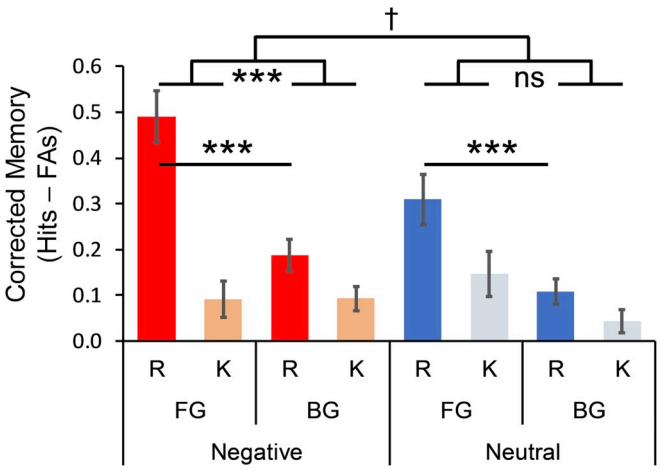

Fig. 2. Reduced Emotional Memory by FA driven by Recollection-based Retrieval. Corrected recognition scores (Hits-FAs) for emotional and neutral pictures linked to FA manipulation (FG vs. BG Focus) and Memory responses (R vs. K) are presented. Error bars indicate the standard error of the mean for each condition. FA, Focused Attention manipulation; FG, Foreground Focus; BG, Background Focus; R, Recollection-based Retrieval; K, Familiarity-based Retrieval. ***$p < .001$, †$p = .051$.

3.2.2. fMRI results: reduced emotional recollection-related activity in MTL following FA

Paralleling the behavioral results and confirming our hypothesis, there was a reduction in the recollection-related encoding activity for emotional images following the engagement of FA in the AMY, HC, and anterior PHG (Fig. 3). Specifically, there was a significant reduction of activation for emotional recollection[1] when focusing away from the

Table 2
Behavioral results from the retrieval task. Corrected memory scores (Hits - FAs) are displayed for Remember/Know responses, along with confidence ratings associated with each response type. Values indicate means (standard deviations).

	FG Focus		BG Focus	
	Negative	Neutral	Negative	Neutral
Memory Scores:				
Remember (R)	.49 (.25)	.31 (.24)	.19 (.16)	.11 (.12)
Know (K)	.09 (.18)	.15 (.21)	.09 (.11)	.04 (.11)
Confidence Ratings:				
Remember (R)	2.73 (.18)	2.38 (.53)	2.51 (.36)	2.38 (.64)
Know (K)	1.94 (.36)	1.92 (.40)	1.84 (.27)	1.76 (.48)

[1] fMRI analyses testing our hypotheses regarding the impact of FA on encoding activity associated with subsequently reduced recollection of emotional images were performed on data from 19 participants (see Methods), except for the signal from left anterior PHG, where one subject was identified as an outlier (based on a z-standardization criterion of >3.0) and thus excluded from analyses for this region. Analyses performed to test for the specificity of the effects for negative images were performed on a smaller sample, due to relatively low number of trials specifically affecting the neutral condition in some participants.

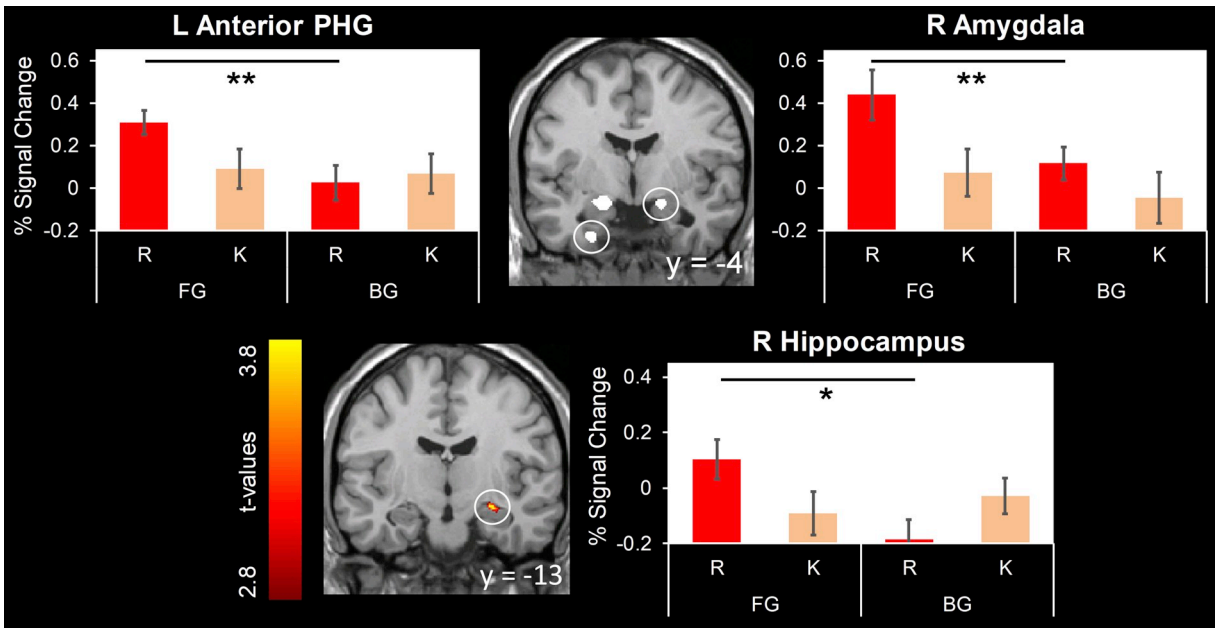

Fig. 3. Reduced Recollection-related Activity in AMY, HC, and Anterior PHG, Associated with Reduced Remembering of Emotional Pictures. The top brain image shows a representative slice of MTL subregions identified by random-effects group analyses targeting overall sensitivity to recollection-related encoding activity (AllR > AllMisses and AllR > AllK) (see Table 3). From the four identified areas, only the left anterior PHG and the right AMY (but not the left AMY or the left HC) showed significant EmoFG-R > EmoBG-R effects. The bottom brain image shows a representative slice of the right HC showing a significant EmoFG-R > EmoBG-R effect, which was part of a larger HC area identified based on a contrast specifically targeting recollection-related encoding activity for the neutral pictures (Neu-R > Neu-K; MNI coordinates: $x = 26$, $y = -12$, $z = -12$). The identified voxels are displayed on high-resolution anatomical images normalized to the Montreal Neurological Institute (MNI) template. The numbers at the right bottom side of each brain slice represent the *y* coordinates in MNI space. The bar graphs display the fMRI signals associated with the encoding of negative images, extracted from the areas highlighted by the white circles, at the peak time points. L, Left Hemisphere; R, Right Hemisphere; FG, Foreground Focus; BG, Background Focus; MTL, Medial Temporal Lobe; AMY, Amygdala; HC, Hippocampus; PHG, Parahippocampal Gyrus; R, Recollection-based responses; K, Familiarity-based responses. *$p < .05$, **$p < .01$.

emotional aspects of negative images (i.e., EmoFG-R > EmoBG-R). Notably, the right AMY and left anterior PHG areas showing sensitivity to the FA manipulation in the recollection-related encoding activity to emotional pictures were identified from among four MTL regions showing overall recollection-related sensitivity (AllR > AllMisses and AllR > AllK), as follows: bilateral AMY, left HC, and the left anterior PHG (Table 3).

Interestingly, in the right AMY, similar effects of FA were found for both emotional (t (18) = 2.97, $p = .008$) and neutral pictures (t (13) = 2.22, $p = .045$), and this similarity was also present when analyses were performed on the signal extracted from the whole anatomical ROI of the right AMY. This suggests that the right AMY has similar contribution to the modulation of recollection-related activity by FA for emotional and neutral stimuli, which was confirmed by a three-way ANOVA that yielded a non-significant three-way Emotion × Attention × Memory interaction. However, consistent with the behavioral data and unlike the right AMY, the three-way ANOVA conducted on the signal from the left anterior PHG yielded a significant three-way interaction (F (1, 12) = 4.77, $p = .050$, $\eta_p^2 = .28$). Post-hoc analyses confirmed that this region showed a significant reduction of recollection-related encoding activation when focusing on the contextual details only for the negative (EmoFG-R > EmoBG-R: t (17) = 3.58, $p = .002$), but not for the neutral images (NeuFG-R > NeuBG-R: t (12) = −1.34, $p = .21$), which was further confirmed by a two-way ANOVA on the recollection trials only (EmoFG-R, EmoBG-R, NeuFG-R, and NeuBG-R) that yielded a significant Emotion × Attention interaction (F (1, 12) = 8.43, p = .013, $\eta_p^2 = .41$).

Neither the left AMY nor the left HC areas identified among the MTL regions showing overall recollection-related sensitivity (AllR > AllMisses and AllR > AllK) showed significant EmoFG-R > EmoBG-R effects. However, similar effects to those identified in the left anterior PHG were also identified in a right HC area, which was identified based on a contrast specifically targeting recollection-related encoding activity for the neutral pictures (Neu-R > Neu-K). Specifically, this area showed a significant reduction in the recollection-related encoding activation when focusing on the contextual details only for the negative (t (18) = 2.59, $p = .02$), but not for the neutral images (t (13) = 0.12, $p = .91$). Although the three-way ANOVA did not yield a significant three-way interaction, the two-way ANOVA on the recollection trials only (EmoFG-R, EmoBG-R, NeuFG-R, and NeuBG-R) yielded a marginally significant Emotion × Attention interaction (F (1, 13) = 3.98, $p = .067$, $\eta_p^2 = .23$). These results show that brain regions associated with recollection-based enhanced memory for emotional stimuli are also sensitive to a manipulation of ER that reduces recollection of memories for negative pictures.

Table 3
MTL regions showing recollection-related sensitivity during encoding. Data are based on signal extracted from clusters of voxels from MTL regions showing overall recollection-related sensitivity (AllR > AllMisses and AllR > AllK; see also Methods). R, Recollection-based responses; K, Familiarity-based responses; PHG, parahippocampal gyrus. *$p < .05$, **$p < .005$, ***$p < .001$.

Brain Regions	Peak MNI Coordinates			R > Miss (T values)	R > K (T values)
	x	y	z		
L Amygdala	−20	−8	−14	5.16***	3.97***
R Amygdala	18	−4	−14	6.46***	3.93***
L Anterior PHG	−26	−4	−34	4.57***	2.34*
L Hippocampus	−36	−30	−6	4.52***	3.51**

3.2.3. *Individual differences in MTL activity linked to reduced emotional recollection*

Brain-behavior correlation analyses within the MTL ROIs identified links between the impact of FA on recollection-related encoding activity and behavioral indices of emotional recollection linked to the FA

manipulation (Fig. 4 and Table 4). For instance, those participants showing lower activity in the left AMY while focusing away from the emotional content (Emo BG-R) also showed greater reduction in subsequent memory (Emo FG-R – Emo BG-R) by the engagement of FA ($r = -.66$, $p = .002$; Fig. 4, left panel). Notably, the correlation performed on difference scores for both the fMRI signal and the memory performance was also significant ($r = .47$, $p = .042$; Fig. 4, right panel). Moreover, similar correlations were also identified in the other MTL regions, including the left anterior PHG, the left HC, and the right AMY. Notably, these results were overall identified for both functional and anatomical ROIs, and, in all cases, correlations performed for the neutral images were not significant (all $ps > .05$) (Table 4).

4. Discussion

The present report targeted the impact of FA on emotional memory and the role of emotion and memory-related MTL regions in this effect. There were three main novel findings: 1. FA reduced recollection-based effects of emotion on memory, which were associated with 2. Reduced emotional recollection-related activity in the AMY, HC, and PHG, and 3. Participants showing reduced recollection-related responses in these regions also showed larger reductions in emotional recollection. To our knowledge, this is the first empirical study investigating the effect of FA on the encoding of emotional stimuli, and the associated neural correlates. The main findings are discussed below.

First, replicating available evidence regarding the effect of FA (Ferri et al., 2013; Sheppes and Meiran, 2007), our results identified decreased self-reported emotion in the BG compared to the FG Focus condition for the negative (but not neutral) images. The current results on the effect of FA on negative emotion processing based on pictorial stimuli complement evidence identified in recent investigations (Denkova et al., 2015; Iordan et al., 2019) showing the effectiveness of this ER strategy in reducing negative emotional experiences associated with the recollection of autobiographical memories. Importantly, our findings show that episodic memory performance was significantly reduced for stimuli encoded in the BG focus condition compared to those encoded in the FG Focus condition, and this effect was driven by recollection- rather than familiarity-based responses. This effect is consistent with previous evidence showing that emotion specifically enhances recollection (Dolcos et al., 2005, 2012, 2017; LaBar and Cabeza, 2006; Ochsner, 2000; Sharot et al., 2007; Talarico et al., 2004; Ventura-Bort et al., 2017).

The effectiveness of FA in reducing subsequent memory is also consistent with evidence identifying a memory-reducing effect of engaging certain ER strategies, such as emotional suppression, linked to the level of processing involved (Binder et al., 2012; Dillon et al., 2007; Dunn et al., 2009; Hayes et al., 2010; Katsumi and Dolcos, 2018; Richards and Gross, 1999, 2000). Attention plays a critical role during encoding (Binder et al., 2012; Chun and Turk-Browne, 2007), and the depth of processing during encoding influences subsequent memory performance (Craik and Lockhart, 1972). In the current study, the increased ability to recall specific details about the images encoded in the FG compared to BG Focus condition confirms enhanced/deeper processing of the emotional images encoded in the FG condition, and diminished/shallower processing of the emotional images encoded in the BG Focus condition.

Paralleling the behavioral results, there was a reduction in the recollection-related activity following the engagement of FA, in the right AMY, left anterior PHG, and right HC. These findings are overall consistent with previous evidence observing the involvement of these regions in memory encoding in general (Dolcos et al., 2012, 2017; LaBar and Cabeza, 2006; Murty et al., 2011), and in the recollection-driven memory, in particular (Ranganath and Ritchey, 2012; Slotnick, 2013). Emotion exerts a memory-enhancing effect through concurrent activation of the AMY, HC, and PHG during successful encoding of emotional information (Dolcos et al., 2004b; Murty et al., 2011). Consistent with the expectation that memory-reducing effects by emotion control would involve similar mechanisms, in the present study, the engagement of FA was associated with a concurrent reduction in the recollection-related activity in these regions. These results are consistent with findings of attenuated AMY activity linked to reduced memory for emotional events during emotional suppression (Hayes et al., 2010). Similarly, other studies have also linked memory-reducing effects of engaging suppression to hippocampal disengagement (Binder et al., 2012), and attributed this effect to a decrease in the availability of cognitive resources for successful memory encoding due to increased self-regulatory demands associated with emotional suppression. Focusing away from the emotional aspects of negative images may also require resources to inhibit the automatic capturing effect of attention by these emotional stimuli, which might have led to overall decreased availability of resources for memory encoding (Binder et al., 2012; Dolcos et al., 2004b; Murty et al., 2011). Our results extend current evidence regarding the impact of emotion control on memory for emotional stimuli, by showing that the memory-reducing effect of FA for emotional stimuli is produced by its interference with activity in brain regions critical for memory encoding that lead to subsequent emotional recollection.

In addition to the AMY and HC, the current results also identified the left anterior PHG showing sensitivity to the engagement of FA during successful encoding of subsequently-recollected emotional pictures. This is consistent with available evidence regarding the role of this region in successful emotional encoding (Dolcos et al., 2004b; Hamann et al., 1999; Ritchey et al., 2008). In particular, functional connectivity between the AMY and anterior PHG was greater for successful encoding of emotional but not neutral items remembered after a longer (one week) vs. shorter (20 min) delay, and this effect was associated with the persistence of emotional recollection as measured behaviorally (Ritchey et al., 2008). Overall, the present results support the idea that, in

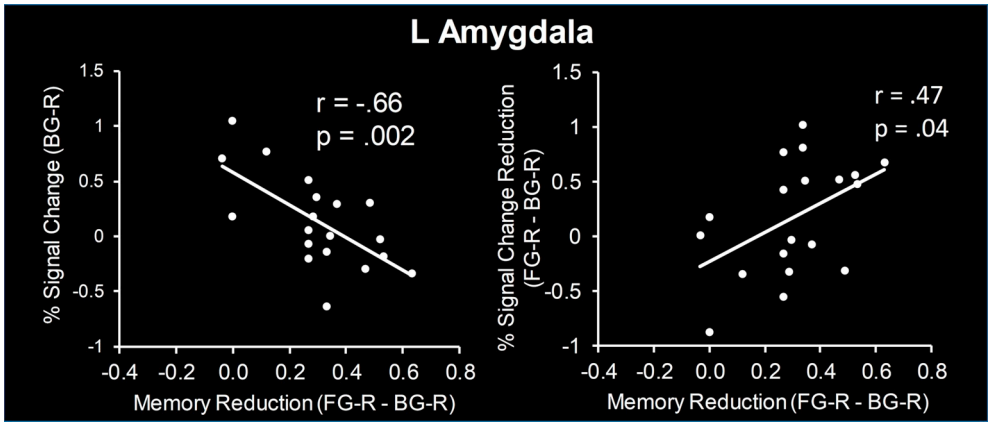

Fig. 4. Individual Differences in the AMY Linked to Reduced Emotional Recollection following FA. Correlations are based on fMRI signal extracted from the functional ROIs identified as being sensitive to recollection-related responses (AllR > AllMisses and AllR > AllK; see Fig. 3 and Table 3). Participants showing lower activity when focusing away from the emotional content (Emo BG-R) also showed greater reduction in subsequent memory (Emo FG-R – Emo BG-R) (left panel). The correlation performed on difference scores for both the fMRI signal and the memory performance was also significant (right panel).

Table 4
MTL regions showing correlations with retrieval performance. Data are based on correlations between fMRI signal extracted from functional (see Fig. 3 and Table 3) or anatomical MTL ROIs and memory scores. Emo Difference, Emo FG-R – Emo BG-R; Neu Difference, Neu FG-R – Neu BG-R; Neu R > Neu K Functional ROI, ROI created using the Neutral Remember > Neutral Know (at $p < .005$) contrast; $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$. $^{\$}$indicates correlations that also survive Bonferroni correction (see Methods).

Brain Regions	Emo BG-R (fMRI) Emo Difference (Memory)	Emo Difference (fMRI) Emo Difference (Memory)	Neu BG-R (fMRI) Neu Difference (Memory)	Neu Difference (fMRI) Neu Difference (Memory)
Functional ROIs				
L Amygdala	-.659**$	.470*	-.269	.097
R Amygdala	-.255	-.122	.119	.057
L Anterior PHG	-.575*	.706***$	-.248	-.193
L Hippocampus	-.406	.150	.100	-.073
Neu R > Neu K				
R Hippocampus	.038	-.250	.264	-.062
Anatomical ROIs				
L Amygdala	-.677**$	.419	-.328	.362
R Amygdala	-.505*	.165	.316	-.145
L Anterior PHG	-.592**$	.850***$	.187	.062
R Anterior PHG	-.162	.288	.204	-.403
L Hippocampus	-.540*	.495*	-.018	.233
R Hippocampus	.024	-.152	.146	.026
L posterior PHG	-.461*	.370	.234	-.270
R posterior PHG	-.513*	.323	-.182	.124

addition to the AMY and HC, focusing away from the emotional aspects of negative images reduces subsequent recollection by modulating the associated activity in the anterior PHG, suggesting the FA's broad impact on the MTL mechanisms subserving emotional memory.

Interestingly, our results also showed that the right AMY had similar contribution to the modulation of recollection-related activity by FA for both emotional and neutral stimuli. In addition to its sensitivity to emotions, prior studies of perception and memory have shown that the AMY is also sensitive to emotionally-neutral stimuli, including faces and pictures (Holt et al., 2006; Kleinhans et al., 2007; Schwartz et al., 2003; Taylor et al., 2000; Todorov and Engell, 2008; Wright and Liu, 2006; Young et al., 2017). In the present study, the FG component of each image oftentimes depicted human faces. Therefore, it is not surprising that focusing away from the FG components had a significant impact on recollection-related activity in this region regardless of their emotional content. It is interesting to note, however, that the right AMY showed unique sensitivity to the effect of FA on memory for emotional pictures as reflected by its correlation with memory performance. Similar specificity for emotional images in brain-behavior correlations was also identified in the left AMY, despite the absence of a reduction in its encoding activity associated with subsequent recollection of emotional images, following the engagement of FA. Although there is no single model that accounts for the pattern of findings concerning the lateralization of amygdalar functions (Cahill et al., 2004; Zald, 2003), the present findings point to possible dissociations linked to the engagement of the AMY in various aspects of processing (basic emotion processing, modulation by ER, subsequent memory, and their links to individual differences). More research is needed to clarify the effect of FA manipulations on AMY activity and the extent to which its lateralization manifests in different task contexts and participant groups.

Interestingly, individual differences were identified linking the difference in neural activity in the MTL while focusing away from vs. onto the emotional content of negative pictures (BG Focus - FG Focus) to the behavioral impact of FA on emotional recollection. Specifically, those participants who showed reduced activity in the AMY and regions of the MTL memory system (including HC and the associated parahippocampal cortices), while focusing on the contextual details of emotional pictures (vs. the emotional aspects of these pictures), also showed greater reduction in the emotional recollection scores. This finding points to the role of individual differences in the ability to engage FA, suggesting that it may be possible to enhance FA skills through training. More research is needed to further clarify the mechanisms of FA, particularly related to its ability to reduce emotional experience and memory following long-term FA training.

Caveats. The following limitations of the present study should be acknowledged. Although justified by our *a priori* hypotheses, some results, particularly regarding the fMRI data, were based on fewer trials and a smaller sample for the neutral images. Hence, although consistent with available evidence and expected findings, it is important for future work to replicate the present findings by maximizing the number of trials in all conditions and confirm all differences in the impact of FA on emotional and neutral images as significant interaction effects. Given these, we cannot totally rule out the possibility that the present findings are, at least partially, driven by participants' attention or time spent viewing particular aspects of the stimuli. By increasing statistical power, future work will allow for a more comprehensive approach in clarifying similarities and differences between emotional and neutral stimuli, in the impact of FA on memory and associated neural correlates.

5. Conclusion

The present study identified novel effects of FA, shedding light on how simply focusing away from the emotional details of pictorial stimuli toward non-emotional contextual details modulates memory, both at the level of behavioral and neural responses. At the behavioral level, FA reduced the subjective ratings of negative images and the subsequent memory for these images, and this memory-reducing effect of FA was driven by recollection-related responses. Paralleling these behavioral findings, the fMRI results showed that reduced memory recollection for images encoded under the BG Focus was associated with decreased activity in the AMY, HC, and anterior PHG, and these effects were also influenced by individual differences in the ability to engage FA. Taken together, these findings advance our understanding of the effects of FA as an emotion control strategy and provide insights into possible ways of modulating the immediate and long-term impact of distressing emotional stimuli. Clarifying the mnemonic consequences of FA is important for understanding both healthy functioning and alterations in affective disorders in which excessive attention to negative aspects during encoding and focus and rumination on negative memories are often among the core debilitating features.

Disclosure of interest

The authors report no conflicts of interest.

Ethical approval

All procedures performed in studies involving human participants

were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent

Informed consent was obtained from all individual participants included in the study.

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References

Aggleton, J.P., Brown, M.W., 2006. Interleaving brain systems for episodic and recognition memory. Trends Cogn. Sci. 10 (10), 455–463. https://doi.org/10.1016/j.tics.2006.08.003.

Binder, J., de Quervain, D.J., Friese, M., Luechinger, R., Boesiger, P., Rasch, B., 2012. Emotion suppression reduces hippocampal activity during successful memory encoding. Neuroimage 63 (1), 525–532. https://doi.org/10.1016/j.neuroimage.2012.07.007.

Buhle, J.T., Silvers, J.A., Wager, T.D., Lopez, R., Onyemekwu, C., Kober, H., et al., 2014. Cognitive reappraisal of emotion: a meta-analysis of human neuroimaging studies. Cerebr. Cortex 24 (11), 2981–2990. https://doi.org/10.1093/cercor/bht154.

Cahill, L., Uncapher, M., Kilpatrick, L., Alkire, M.T., Turner, J., 2004. Sex-related hemispheric lateralization of amygdala function in emotionally influenced memory: an FMRI investigation. Learn. Mem. 11 (3), 261–266.

Christianson, S., 1992. The Handbook of Emotion and Memory: Research and Theory. Lawrence Erlbaum Associates, Inc, Hillsdale, NJ, US.

Chun, M.M., Turk-Browne, N.B., 2007. Interactions between attention and memory. Curr. Opin. Neurobiol. 17 (2), 177–184. https://doi.org/10.1016/j.conb.2007.03.005.

Craik, F.I.M., Lockhart, R.S., 1972. Levels of processing - framework for memory research. J. Verb. Learn. Verb. Behav. 11 (6), 671–684. https://doi.org/10.1016/S0022-5371(72)80001-X.

Dalgleish, T., Werner-Seidler, A., 2014. Disruptions in autobiographical memory processing in depression and the emergence of memory therapeutics. Trends Cogn. Sci. 18 (11), 596–604. https://doi.org/10.1016/j.tics.2014.06.010.

Dan-Glauser, E.S., Scherer, K.R., 2011. The Geneva affective picture database (GAPED): a new 730-picture database focusing on valence and normative significance. Behav. Res. Methods 43 (2), 468–477. https://doi.org/10.3758/s13428-011-0064-1.

Denkova, E., Dolcos, S., Dolcos, F., 2013a. The effect of retrieval focus and emotional valence on the inferior frontal cortex activity during autobiographical recollection. Front. Behav. Neurosci. 7, 192. https://doi.org/10.3389/fnbeh.2013.00192.

Denkova, E., Dolcos, S., Dolcos, F., 2013b. The effect of retrieval focus and emotional valence on the medial temporal lobe activity during autobiographical recollection. Front. Behav. Neurosci. 7 (109) https://doi.org/10.3389/fnbeh.2013.00109.

Denkova, E., Dolcos, S., Dolcos, F., 2015. Neural correlates of 'distracting' from emotion during autobiographical recollection. Soc. Cogn. Affect. Neurosci. 10 (2), 219–230. https://doi.org/10.1093/scan/nsu039.

Denkova, E., Wong, G., Dolcos, S., Sung, K., Wang, L., Coupland, N., Dolcos, F., 2010. The impact of anxiety-inducing distraction on cognitive performance: a combined brain imaging and personality investigation. PLoS One 5 (11), e14150. https://doi.org/10.1371/journal.pone.0014150.

Diana, R.A., Yonelinas, A.P., Ranganath, C., 2007. Imaging recollection and familiarity in the medial temporal lobe: a three-component model. Trends Cogn. Sci. 11 (9), 379–386. https://doi.org/10.1016/j.tics.2007.08.001.

Dillon, D.G., Ritchey, M., Johnson, B.D., LaBar, K.S., 2007. Dissociable effects of conscious emotion regulation strategies on explicit and implicit memory. Emotion 7 (2), 354–365. https://doi.org/10.1037/1528-3542.7.2.354.

Dolcos, F., 2013. Linking enhancing and impairing effects of emotion – the case of PTSD. Front. Integr. Neurosci. 7 https://doi.org/10.3389/fnint.2013.00026.

Dolcos, F., Denkova, E., Dolcos, S., 2012. Neural correlates of emotional memories: a review of evidence from brain imaging studies. Psychologia 55 (2), 80–111.

Dolcos, F., Diaz-Granados, P., Wang, L., McCarthy, G., 2008. Opposing influences of emotional and non-emotional distracters upon sustained prefrontal cortex activity during a delayed-response working memory task. Neuropsychologia 46 (1), 326–335. https://doi.org/10.1016/j.neuropsychologia.2007.07.010.

Dolcos, F., Iordan, A.D., Kragel, J., Stokes, J., Campbell, R., McCarthy, G., Cabeza, R., 2013. Neural correlates of opposing effects of emotional distraction on working memory and episodic memory: an event-related FMRI investigation. Front. Psychol. 4, 293. https://doi.org/10.3389/fpsyg.2013.00293.

Dolcos, F., Katsumi, Y., Weymar, M., Moore, M., Tsukiura, T., Dolcos, S., 2017. Emerging directions in emotional episodic memory. Front. Psychol. 8, 1867. https://doi.org/10.3389/fpsyg.2017.01867.

Dolcos, F., LaBar, K.S., Cabeza, R., 2004a. Dissociable effects of arousal and valence on prefrontal activity indexing emotional evaluation and subsequent memory: an event-related fMRI study. Neuroimage 23 (1), 64–74. https://doi.org/10.1016/j.neuroimage.2004.05.015.

Dolcos, F., LaBar, K.S., Cabeza, R., 2004b. Interaction between the amygdala and the medial temporal lobe memory system predicts better memory for emotional events. Neuron 42 (5), 855–863.

Dolcos, F., LaBar, K.S., Cabeza, R., 2005. Remembering one year later: role of the amygdala and the medial temporal lobe memory system in retrieving emotional memories. Proc. Natl. Acad. Sci. U.S.A. 102 (7), 2626–2631.

Dolcos, F., McCarthy, G., 2006. Brain systems mediating cognitive interference by emotional distraction. J. Neurosci. 26 (7), 2072–2079. https://doi.org/10.1523/JNEUROSCI.5042-05.2006.

Dolcos, F., Katsumi, Y., Moore, M., Berggren, N., de Gelder, B., Derakshan, N., Hamm, A. O., Koster, E.H.W., Ladouceur, C.D., Okon-Singer, H., Pegna, A.J., Richter, T., Schweizer, S., Van den Stock, J., Ventura-Bort, C., Weymar, M., Dolcos, S., 2019. Neural correlates of emotion-attention interactions: from perception, learning, and memory to social cognition, individual differences, and training interventions, 2019 Aug 22. pii: S0149-7634(18). Neurosci. Biobehav. Rev. 31000–31005. https://doi.org/10.1016/j.neubiorev.2019.08.017 ([Epub ahead of print]).

Dorfel, D., Lamke, J.P., Hummel, F., Wagner, U., Erk, S., Walter, H., 2014. Common and differential neural networks of emotion regulation by Detachment, Reinterpretation, Distraction, and Expressive Suppression: a comparative fMRI investigation. Neuroimage 101, 298–309. https://doi.org/10.1016/j.neuroimage.2014.06.051.

Dunn, B.D., Billotti, D., Murphy, V., Dalgleish, T., 2009. The consequences of effortful emotion regulation when processing distressing material: a comparison of suppression and acceptance. Behav. Res. Ther. 47 (9), 761–773. https://doi.org/10.1016/j.brat.2009.05.007.

Eippert, F., Veit, R., Weiskopf, N., Erb, M., Birbaumer, N., Anders, S., 2007. Regulation of emotional responses elicited by threat-related stimuli. Hum. Brain Mapp. 28 (5), 409–423. https://doi.org/10.1002/hbm.20291.

Eldridge, L.L., Engel, S.A., Zeineh, M.M., Bookheimer, S.Y., Knowlton, B.J., 2005. A dissociation of encoding and retrieval processes in the human hippocampus. J. Neurosci. 25 (13), 3280–3286. https://doi.org/10.1523/JNEUROSCI.3420-04.2005.

Ferri, J., Schmidt, J., Hajcak, G., Canli, T., 2013. Neural correlates of attentional deployment within unpleasant pictures. Neuroimage 70, 268–277. https://doi.org/10.1016/j.neuroimage.2012.12.030.

Goodman, A.M., Katz, J.S., Dretsch, M.N., 2016. Military Affective Picture System (MAPS): a new emotion-based stimuli set for assessing emotional processing in military populations. J. Behav. Ther. Exp. Psychiatry 50, 152–161. https://doi.org/10.1016/j.jbtep.2015.07.006.

Gross, J.J., 2008. Emotion regulation. In: Lewis, M., Haviland-Jones, J.M., Barrett, L.F. (Eds.), Handbook of Emotions, pp. 497–512 (New York: Guilford).

Gross, J.J., 2015. Emotion regulation: current status and future prospects. Psychol. Inq. 26 (1), 1–26. https://doi.org/10.1080/1047840x.2014.940781.

Hamann, S.B., Ely, T.D., Grafton, S.T., Kilts, C.D., 1999. Amygdala activity related to enhanced memory for pleasant and aversive stimuli. Nat. Neurosci. 2 (3), 289–293. https://doi.org/10.1038/6404.

Hayes, J.P., Morey, R.A., Petty, C.M., Seth, S., Smoski, M.J., McCarthy, G., Labar, K.S., 2010. Staying cool when things get hot: emotion regulation modulates neural mechanisms of memory encoding. Front. Hum. Neurosci. 4, 230. https://doi.org/10.3389/fnhum.2010.00230.

Holt, D.J., Kunkel, L., Weiss, A.P., Goff, D.C., Wright, C.I., Shin, L.M., Heckers, S., 2006. Increased medial temporal lobe activation during the passive viewing of emotional and neutral facial expressions in schizophrenia. Schizophr. Res. 82 (2–3), 153–162. https://doi.org/10.1016/j.schres.2005.09.021.

Iordan, A.D., Dolcos, F., 2017. Brain activity and network interactions linked to valence-related differences in the impact of emotional distraction. Cerebr. Cortex 27 (1), 731–749. https://doi.org/10.1093/cercor/bhv242.

Iordan, A.D., Dolcos, S., Dolcos, F., 2019. Brain activity and network interactions in the impact of internal emotional distraction. Cerebr. Cortex 29 (6), 2607–2623. https://doi.org/10.1093/cercor/bhy129.

Kaneda, T., Shigemune, Y., Tsukiura, T., 2017. Lateral and medial prefrontal contributions to emotion generation by semantic elaboration during episodic encoding. Cognit. Affect Behav. Neurosci. 17 (1), 143–157. https://doi.org/10.3758/s13415-016-0468-6.

Kanske, P., Heissler, J., Schonfelder, S., Bongers, A., Wessa, M., 2011. How to regulate emotion? Neural networks for reappraisal and distraction. Cerebr. Cortex 21 (6), 1379–1388. https://doi.org/10.1093/cercor/bhq216.

Katsumi, Y., Dolcos, S., 2018. Suppress to feel and remember less: neural correlates of explicit and implicit emotional suppression on perception and memory. Neuropsychologia. https://doi.org/10.1016/j.neuropsychologia.2018.02.010.
Kensinger, E.A., Corkin, S., 2004. Two routes to emotional memory: distinct neural processes for valence and arousal. Proc. Natl. Acad. Sci. U.S.A. 101 (9), 3310–3315. https://doi.org/10.1073/pnas.0306408101.
Kensinger, E.A., Schacter, D.L., 2005. Retrieving accurate and distorted memories: neuroimaging evidence for effects of emotion. Neuroimage 27 (1), 167–177. https://doi.org/10.1016/j.neuroimage.2005.03.038.
Kensinger, E.A., Schacter, D.L., 2006. Amygdala activity is associated with the successful encoding of item, but not source, information for positive and negative stimuli. J. Neurosci. 26 (9), 2564–2570. https://doi.org/10.1523/jneurosci.5241-05.2006.
Kim, H., 2011. Neural activity that predicts subsequent memory and forgetting: a meta-analysis of 74 fMRI studies. Neuroimage 54 (3), 2446–2461. S1053-8119(10)01226-7 [pii] 10.1016/j.neuroimage.2010.09.045.
Kleinhans, N.M., Johnson, L.C., Mahurin, R., Richards, T., Stegbauer, K.C., Greenson, J., et al., 2007. Increased amygdala activation to neutral faces is associated with better face memory performance. Neuroreport 18 (10), 987–991. https://doi.org/10.1097/WNR.0b013e328165d189.
LaBar, K.S., Cabeza, R., 2006. Cognitive neuroscience of emotional memory. Nat. Rev. Neurosci. 7 (1), 54–64.
Lang, P.J., Bradley, M.M., Cuthbert, B.N., 2008. International Affective Picture System (IAPS): Affective Ratings of Pictures and Instruction Manual. Retrieved from. http://csea.phhp.ufl.edu/Media.html.
Lindquist, M.A., Wager, T.D., 2007. Validity and power in hemodynamic response modeling: a comparison study and a new approach. Hum. Brain Mapp. 28 (8), 764–784. https://doi.org/10.1002/hbm.20310.
Mandler, G., 2008. Familiarity breeds attempts: a critical review of dual-process theories of recognition. Perspect. Psychol. Sci. 3 (5), 390–399. https://doi.org/10.1111/j.1745-6924.2008.00087.x.
Marchewka, A., Zurawski, L., Jednorog, K., Grabowska, A., 2014. The Nencki Affective Picture System (NAPS): introduction to a novel, standardized, wide-range, high-quality, realistic picture database. Behav. Res. Methods 46 (2), 596–610. https://doi.org/10.3758/s13428-013-0379-1.
Mayes, A., Montaldi, D., Migo, E., 2007. Associative memory and the medial temporal lobes. Trends Cogn. Sci. 11 (3), 126–135. https://doi.org/10.1016/j.tics.2006.12.003.
McGaugh, J.L., 2004. The amygdala modulates the consolidation of memories of emotionally arousing experiences. Annu. Rev. Neurosci. 27, 1–28. https://doi.org/10.1146/annurev.neuro.27.070203.144157.
McRae, K., Hughes, B., Chopra, S., Gabrieli, J.D., Gross, J.J., Ochsner, K.N., 2010. The neural bases of distraction and reappraisal. J. Cogn. Neurosci. 22 (2), 248–262. https://doi.org/10.1162/jocn.2009.21243.
Moore, M., Hu, Y., Woo, S., O'Hearn, D., Iordan, A.D., Dolcos, S., Dolcos, F., 2014. A comprehensive protocol for manual segmentation of the medial temporal lobe structures. J. Vis. Exp. 89 https://doi.org/10.3791/50991.
Morawetz, C., Bode, S., Derntl, B., Heekeren, H.R., 2017. The effect of strategies, goals and stimulus material on the neural mechanisms of emotion regulation: a meta-analysis of fMRI studies. Neurosci. Biobehav. Rev. 72, 111–128. https://doi.org/10.1016/j.neubiorev.2016.11.014.
Morey, R.A., Dolcos, F., Petty, C.M., Cooper, D.A., Hayes, J.P., LaBar, K.S., McCarthy, G., 2009. The role of trauma-related distractors on neural systems for working memory and emotion processing in posttraumatic stress disorder. J. Psychiatr. Res. 43 (8), 809–817. https://doi.org/10.1016/j.jpsychires.2008.10.014.
Murty, V.P., Ritchey, M., Adcock, R.A., LaBar, K.S., 2011. Reprint of: fMRI studies of successful emotional memory encoding: a quantitative meta-analysis. Neuropsychologia 49 (4), 695–705.
Nørby, S., 2015. Why forget? On the adaptive value of memory loss. Perspect. Psychol. Sci. 10 (5), 551–578. https://doi.org/10.1177/1745691615596787.
Ochsner, K.N., 2000. Are affective events richly recollected or simply familiar? The experience and process of recognizing feelings past. J. Exp. Psychol. Gen. 129 (2), 242–261.
Ochsner, K.N., Silvers, J.A., Buhle, J.T., 2012. Functional imaging studies of emotion regulation: a synthetic review and evolving model of the cognitive control of emotion. Ann. N. Y. Acad. Sci. 1251, E1–E24. https://doi.org/10.1111/j.1749-6632.2012.06751.x.
Paller, K.A., Wagner, A.D., 2002. Observing the transformation of experience into memory. Trends Cogn. Sci. 6 (2), 93–102. https://doi.org/10.1016/S1364-6613(00)01845-3.
Paul, S., Simon, D., Kniesche, R., Kathmann, N., Endrass, T., 2013. Timing effects of antecedent- and response-focused emotion regulation strategies. Biol. Psychol. 94 (1), 136–142. https://doi.org/10.1016/j.biopsycho.2013.05.019.
Phelps, E.A., 2004. Human emotion and memory: interactions of the amygdala and hippocampal complex. Curr. Opin. Neurobiol. 14 (2), 198–202. https://doi.org/10.1016/j.conb.2004.03.015.
Ranganath, C., Ritchey, M., 2012. Two cortical systems for memory-guided behaviour. Nat. Rev. Neurosci. 13 (10), 713–726. https://doi.org/10.1038/nrn3338.
Reber, P.J., Siwiec, R.M., Gitelman, D.R., Parrish, T.B., Mesulam, M.M., Paller, K.A., 2002. Neural correlates of successful encoding identified using functional magnetic resonance imaging. J. Neurosci. 22 (21), 9541–9548.
Richards, J.M., Gross, J.J., 1999. Composure at any cost? The cognitive consequences of emotion suppression. Personal. Soc. Psychol. Bull. 25 (8), 1033–1044. https://doi.org/10.1177/01461672992511010.
Richards, J.M., Gross, J.J., 2000. Emotion regulation and memory: the cognitive costs of keeping one's cool. J. Personal. Soc. Psychol. 79 (3), 410–424.
Ritchey, M., Dolcos, F., Cabeza, R., 2008. Role of amygdala connectivity in the persistence of emotional memories over time: an event-related FMRI investigation. Cerebr. Cortex 18 (11), 2494–2504. https://doi.org/10.1093/cercor/bhm262.
Ritchey, M., LaBar, K.S., Cabeza, R., 2011. Level of processing modulates the neural correlates of emotional memory formation. J. Cogn. Neurosci. 23 (4), 757–771. https://doi.org/10.1162/jocn.2010.21487.
Schwartz, C.E., Wright, C.I., Shin, L.M., Kagan, J., Whalen, P.J., McMullin, K.G., Rauch, S.L., 2003. Differential amygdalar response to novel versus newly familiar neutral faces: a functional MRI probe developed for studying inhibited temperament. Biol. Psychiatry 53 (10), 854–862. https://doi.org/10.1016/S0006-3223(02)01906-6.
Shafer, A.T., Dolcos, F., 2012. Neural correlates of opposing effects of emotional distraction on perception and episodic memory: an event-related FMRI investigation. Front. Integr. Neurosci. 6, 70. https://doi.org/10.3389/fnint.2012.00070.
Sharot, T., Verfaellie, M., Yonelinas, A.P., 2007. How emotion strengthens the recollective experience: a time-dependent hippocampal process. PLoS One 2 (10), e1068. https://doi.org/10.1371/journal.pone.0001068.
Sheppes, G., Levin, Z., 2013. Emotion regulation choice: selecting between cognitive regulation strategies to control emotion. Front. Hum. Neurosci. 7 https://doi.org/10.3389/fnhum.2013.00179, 179-179.
Sheppes, G., Meiran, N., 2007. Better late than never? On the dynamics of online regulation of sadness using distraction and cognitive reappraisal. Personal. Soc. Psychol. Bull. 33 (11), 1518–1532. https://doi.org/10.1177/0146167207305537.
Sheppes, G., Scheibe, S., Suri, G., Radu, P., Blechert, J., Gross, J.J., 2014. Emotion regulation choice: a conceptual framework and supporting evidence. J. Exp. Psychol. Gen. 143 (1), 163–181. https://doi.org/10.1037/a0030831.
Slotnick, S.D., 2013. The nature of recollection in behavior and the brain. Neuroreport 24 (12), 663–670. https://doi.org/10.1097/WNR.0b013e328362e47e.
Slotnick, S.D., 2017. Resting-state fMRI data reflects default network activity rather than null data: a defense of commonly employed methods to correct for multiple comparisons. Cogn. Neurosci. 8 (3), 141–143. https://doi.org/10.1080/17588928.2016.1273892.
Slotnick, S.D., Moo, L.R., Segal, J.B., Hart, J., 2003. Distinct prefrontal cortex activity associated with item memory and source memory for visual shapes. Cogn. Brain Res. 17 (1), 75–82. https://doi.org/10.1016/S0926-6410(03)00082-X.
Talarico, J.M., LaBar, K.S., Rubin, D.C., 2004. Emotional intensity predicts autobiographical memory experience. Mem. Cogn. 32 (7), 1118–1132. https://doi.org/10.3758/BF03196886.
Taylor, S.F., Liberzon, I., Koeppe, R.A., 2000. The effect of graded aversive stimuli on limbic and visual activation. Neuropsychologia 38 (10), 1415–1425. https://doi.org/10.1016/S0028-3932(00)00032-4.
Thiruchselvam, R., Blechert, J., Sheppes, G., Rydstrom, A., Gross, J.J., 2011. The temporal dynamics of emotion regulation: an EEG study of distraction and reappraisal. Biol. Psychol. 87 (1), 84–92. https://doi.org/10.1016/j.biopsycho.2011.02.009.
Todorov, A., Engell, A.D., 2008. The role of the amygdala in implicit evaluation of emotionally neutral faces. Soc. Cogn. Affect. Neurosci. 3 (4), 303–312. https://doi.org/10.1093/scan/nsn033.
Tulving, E., 1982. Synergistic ecphory in recall and recognition. Canadian Journal of Psychology/Revue canadienne de psychologie 36 (2), 130–147. https://doi.org/10.1037/h0080641.
Tulving, E., 1985. Memory and consciousness. Canadian Psychology-Psychologie Canadienne 26 (1), 1–12. https://doi.org/10.1037/h0080017.
Tulving, E., Markowitsch, H.J., 1998. Episodic and declarative memory: role of the hippocampus. Hippocampus 8 (3), 198–204. https://doi.org/10.1002/(SICI)1098-1063(1998)8:3<198::AID-HIPO2>3.0.CO;2-G.
Tulving, E., Schacter, D.L., 1990. Priming and human memory systems. Science 247 (4940), 301–306. https://doi.org/10.1126/science.2296719.
van Reekum, C.M., Johnstone, T., Urry, H.L., Thurow, M.E., Schaefer, H.S., Alexander, A.L., Davidson, R.J., 2007. Gaze fixations predict brain activation during the voluntary regulation of picture-induced negative affect. Neuroimage 36 (3), 1041–1055. https://doi.org/10.1016/j.neuroimage.2007.03.052.
Ventura-Bort, C., Dolcos, F., Wendt, J., Wirkner, J., Hamm, A.O., Weymar, M., 2017. Item and source memory for emotional associates is mediated by different retrieval processes: an ERP study. Neuropsychologia. https://doi.org/10.1016/j.neuropsychologia.2017.12.015 (Epub ahead of print).
Wager, T.D., Davidson, M.L., Hughes, B.L., Lindquist, M.A., Ochsner, K.N., 2008. Prefrontal-subcortical pathways mediating successful emotion regulation. Neuron 59 (6), 1037–1050. https://doi.org/10.1016/j.neuron.2008.09.006.
Waugh, C.E., Hamilton, J.P., Gotlib, I.H., 2010. The neural temporal dynamics of the intensity of emotional experience. Neuroimage 49 (2), 1699–1707. https://doi.org/10.1016/j.neuroimage.2009.10.006.
Waugh, C.E., Lemus, M.G., Gotlib, I.H., 2014. The role of the medial frontal cortex in the maintenance of emotional states. Soc. Cogn. Affect. Neurosci. 9 (12), 2001–2009. https://doi.org/10.1093/scan/nsu011.
Waugh, C.E., Zarolia, P., Mauss, I.B., Lumian, D.S., Ford, B.Q., Davis, T.S., et al., 2016. Emotion regulation changes the duration of the BOLD response to emotional stimuli. Soc. Cogn. Affect. Neurosci. 11 (10), 1550–1559. https://doi.org/10.1093/scan/nsw067.
Webb, T.L., Miles, E., Sheeran, P., 2012. Dealing with feeling: a meta-analysis of the effectiveness of strategies derived from the process model of emotion regulation. Psychol. Bull. 138 (4), 775–808. https://doi.org/10.1037/a0027600.
Wessa, M., Kanske, P., Neumeister, P., Bode, K., Heissler, J., Schönfelder, S., 2010. EmoPicS: subjective and psychophysiological evaluation of new imagery for clinical biopsychological research. Z. Klin. Psychol. Psychother. Suppl (1), 11–77.

Wright, P., Liu, Y., 2006. Neutral faces activate the amygdala during identity matching. Neuroimage 29 (2), 628–636. https://doi.org/10.1016/j.neuroimage.2005.07.047.
Yonelinas, A.P., 2002. The nature of recollection and familiarity: a review of 30 Years of research. J. Mem. Lang. 46 (3), 441–517. https://doi.org/10.1006/jmla.2002.2864.
Yonelinas, A.P., Aly, M., Wang, W.-C., Koen, J.D., 2010. Recollection and familiarity: examining controversial assumptions and new directions. Hippocampus 20 (11), 1178–1194. https://doi.org/10.1002/hipo.20864.
Young, L.R., Yu, W., Holloway, M., Rodgers, B.N., Chapman, S.B., Krawczyk, D.C., 2017. Amygdala activation as a marker for selective attention toward neutral faces in a chronic traumatic brain injury population. Neuropsychologia 104, 214–222. https://doi.org/10.1016/j.neuropsychologia.2017.08.026.
Zald, D.H., 2003. The human amygdala and the emotional evaluation of sensory stimuli. Brain Res Brain Res Rev 41 (1), 88–123. https://doi.org/10.1016/s0165-0173(02)00248-5.