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Decreased inhibitory control of negative information in directed forgetting

Tianliang Yang [a,b], Xu Lei [a,b,c,*], Michael Anderson [c,d]

[a] Key Laboratory of Cognition and Personality (Ministry of Education), Chongqing 400715, China
[b] Sleep and NeuroImaging Center, Faculty of Psychology, Southwest University, Chongqing 400715, China
[c] MRC Cognition and Brain Sciences Unit, University of Cambridge, Cambridge, UK
[d] Behavioural and Clinical Neuroscience Institute, University of Cambridge, Cambridge, UK

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ABSTRACT

A great deal of evidence suggests that emotion enhances memory. Thus, it may be harder to forget emotional information. By means of fMRI, this question was investigated in the item-method directed forgetting paradigm. Behavioral results demonstrated that although all kinds of material could be forgotten, negative words showed reduced directed forgetting effect. At the neural level, the initial viewing of negative words elicited increased activities in inferior frontal gyrus and superior parietal lobule when contrasted with neutral words, which reflected the capture of attention by negative content. Forgetting instructions for negative and neutral words led to enhanced activations in frontal and parietal cortex, consistent with the engagement of an active inhibitory process. Surprisingly, whereas successful directed forgetting of neutral words elicited stronger activations in right middle frontal gyrus compared with incidental forgetting, no such activation was observed for negative words. The lack of activation for negative words may be due to an attentional bias in processing negative words, which may briefly interfere with the deployment of inhibitory control. The present findings are consistent with the engagement of an active forgetting mechanism that contributes to the item-method directed forgetting. However, evidence of impeded inhibitory control suggests that forgetting negative words is harder.

1. Introduction

Former studies have suggested that emotion can enhance memory (Phelps and Sharot, 2008). Importantly, the benefits for emotional information have been documented with plenty of material, including pictures and words (Brandt et al., 2013; Yang et al., 2012). From an evolutionary perspective, this may be beneficial. Enhancement of emotion may increase survival by facilitating rapid and accurate responding to familiar stimuli, which can elicit prominent emotional reactions. However, the persistence of memories for negative experiences or unpleasant events can also wreak havoc on people's lives (Butler and James, 2010). One way in which people cope with unwanted memories is by intentionally forgetting them. Intentional forgetting engages memory mechanisms, which can ensure that current memory process is free from irrelevant information (Anderson and Hanslmayr, 2014; Bjork, 1989). However, if emotion enhances memory (Doerksen and Shimamura, 2001; Fox et al., 2001), emotional information may be harder to forget.

One experimental method used to investigate intentional forgetting is the directed forgetting paradigm. Importantly, the paradigm takes two forms: item-method and list-method (Basden and Basden, 1998; Bjork, 1989; Macleod, 1999). For the item-method, participants view a succession of items, followed by an instruction of to-be-forgotten (TBF) or to-be-remembered (TBR) for each of them. For the list-method, the items include two parts. For the first part, fifty percent of the participants are asked to remember these items, while the remaining fifty percent are required to forget these items. Then, the participants study the second list, which is followed by a surprise final test for the original list. In both paradigms, there will be a prominent directed forgetting effect, if memory performance of TBF items is significantly lower in contrast to TBR items.

The mechanisms underlying the item-method and list-method paradigm are often thought to be different. In the item-method, theoretical accounts have focused on selective rehearsal and attentional inhibition (Basden, 1996; Macleod, 1999; Wylie et al., 2008). According to the selective rehearsal hypothesis, the items are put into working memory before memory instructions appear. TBR instructions are proposed to

* Corresponding author at: Faculty of Psychology, Southwest University, 2nd Tiansheng Road, Beibei District, Chongqing, 400715, China.
E-mail address: xlei@swu.edu.cn (X. Lei).

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make participants elaborately encode the items, whereas TBF instructions lead participants to drop the items from working memory and not to elaborately encode them. In contrast, the attentional inhibition hypothesis emphasizes that TBF instructions elicit inhibitory control processing that interrupts deeper encoding of the items. In the list-method, the retrieval inhibition mechanism is proposed to account for the directed forgetting effect (Bjork, 1989). Because the item in the list-method has been encoded into long-term memory when a cue to forget is received, its existing representation cannot be readily expunged. Instead, the TBF cue causes the representation of that item to be inhibited such that on later retrieval tests, its reactivation is less probable than the reactivation of other items that have not been inhibited (Anderson, 2005; Anderson and Hanslmayr, 2014). Importantly, given that both selective rehearsal and attentional inhibition are thought to play important roles in supporting the item-method directed forgetting, the item-method gives us the chance to investigate not only encoding process but also inhibitory control process. Additionally, there are only some successful TBF and TBR items, so the item-method also enables us to study the intentional forgetting (TBF items have been forgotten successfully) and incidental forgetting (TBR items have been remembered successfully). Considering these advantages of the item-method, the focus of the study is on the item-method paradigm.

The brain correlates of item-method directed forgetting have been explored in a rapidly increasing number of studies. Evidence from event-related potentials (ERPs) shows that TBF cues elicit enhanced prefrontal positivities relative to TBR cues, which is considered to support the attentional inhibition account (Brandt et al., 2013; Paz-Caballero et al., 2004). Additionally, fMRI studies using the item-method show that TBF instructions, contrasted with TBR instructions, elicit activations mainly in lateral prefrontal and parietal cortices, which also is consistent with the possibility of an active inhibitory process acting on TBF items (Rizio and Dennis, 2013; Wylie et al., 2008).

Recently, researchers have started to investigate the emotional information forgetting. Importantly, studies about clinical patients have shown consistent results that forgetting emotional memories is harder (Joormann et al., 2005; Patrick and Christensen, 2013; Tolin et al., 2002). Unfortunately, however, behavioral research in healthy individuals has reported inconsistent findings (Brandt et al., 2013; Hauswald et al., 2011; Yang et al., 2012). Some studies suggest that negative memories show less directed forgetting than do neutral memories, whereas others indicate that negative and neutral memories are comparably forgettable. For example, Hauswald et al. (2011) found that emotional memories were free from forgetting, whereas Yang et al. (2012) showed that, compared with neutral information, emotional information exhibited a normal directed forgetting effect.

Additionally, the potential for the directed forgetting mechanism to disrupt emotional memories has been examined using ERP and fMRI. By means of the item-method procedure, Brandt et al. (2013); Hauswald et al. (2011) and Yang et al. (2012) consistently found that TBF instructions elicited increased frontal positivities relative to TBR instructions, suggesting the engagement of an active forgetting process that may inhibit TBF items. However, inconsistencies exist among these ERP studies. Whereas Brandt et al. (2013) and Hauswald et al. (2011) found that the frontal activities elicited by TBF instructions were not measurably affected by the potentially disruptive effect of emotional valence, Yang et al. (2012) showed that TBF cues following emotional information elicited enhanced frontal positivities compared with those elicited by neutral information, raising the possibility that more cognitive resources were required to block the encoding of negative information.

Till now, however, only one fMRI study has explored the neural basis of emotional information forgetting. For that investigation, Nowicka et al. (2010) demonstrated that the intention to forget (measured by comparing activations in response to the TBF cues compared to the TBR cues) negative information led to widespread activations in prefrontal cortex, parietal cortex and occipital cortex, whereas the intention to forget neutral information only resulted in activations in lingual gyrus. In addition, successful directed forgetting (measured by comparing successful TBF items with unsuccessful TBR items) also was associated with greater activations for negative than for neutral information. These findings suggest that intentionally forgetting emotional information, while possible, may demand more effort than forgetting neutral information, at least for the item-method directed forgetting procedure.

An interesting topic within directed forgetting research concerns the neural circuits supporting intentional and incidental forgetting. Intentional forgetting reflects the outcome of participants' conscious action, and is observed on TBF trials in which the item is successfully forgotten (Nowicka et al., 2010; Rizio and Dennis, 2013; Wylie et al., 2008). In contrast, incidental forgetting is a failure of memory encoding arising passively, and is measured on TBR trials in which the item is not successfully remembered (Nowicka et al., 2010; Rizio and Dennis, 2013; Wylie et al., 2008). Rizio and Dennis (2013) and Wylie et al. (2008) reported evidence indicating that the neural processes of intentional forgetting and incidental forgetting were different for neutral information. Specifically, intentional forgetting, relative to incidental forgetting, elicited significant activations in right prefrontal cortex and right superior parietal lobe, which have been theorized to contribute to inhibitory processing; incidental forgetting, by contrast, was related to the employment of left inferior frontal gyrus involving in encoding. Critically, however, existing studies have not fully differentiated intentional forgetting from incidental forgetting for emotional information. If intentional forgetting of emotional information arises from processes similar to those involved in intentional forgetting of neutral information, intentional forgetting should also be associated with right prefrontal regions thought to be involved in inhibition, whereas incidental forgetting should be associated with the engagement of left inferior frontal regions associated with encoding.

For the present study, the neural substrates underlying directed forgetting of emotionally negative and neutral information were investigated by use of the item-method directed forgetting procedure. At the behavioral level, we speculated that there would be a prominent directed forgetting effect for negative and neutral information. Moreover, if emotional items yielded stronger encoding and better retention than do neutral items, we further predicted that emotionally negative items might prove harder to forget than would neutral items, yielding a significantly smaller directed forgetting effect for negative items. Neurally, we predicted that, like previous studies, the intention to forget would elicit significantly greater activations in right frontal and parietal cortices, consistent with the possibility that inhibitory control is engaged to terminate encoding. If so, TBF cues should elicit greater activations in these regions compared with TBR cues. Moreover, we predicted that intentional forgetting and incidental forgetting would be mediated by distinct neural processes, with intentional forgetting associated with right prefrontal regions supporting inhibition and incidental forgetting associated with left inferior frontal regions supporting encoding.

Critically, if the encoding of emotional information is harder to inhibit than the encoding of neutral information, one of two patterns should emerge. First, if directed forgetting is similarly successful for both negative and neutral items (as measured by the relative size of the directed forgetting effect for each valence), significantly greater engagement of right frontal cortices should be observed for negative, compared with neutral items. The greater engagement would reflect the increased demand for inhibitory control brought about by the need to inhibit memories with negative valence (Nowicka et al., 2010). Alternatively, if participants are less able to forget negative items (i.e., they show a significantly reduced directed forgetting effect), this may reflect the disrupted engagement of inhibitory processing brought about by attention to negatively valenced content (Hauswald et al., 2011). If so, significantly less engagement of right prefrontal cortex should be observed for negative, compared with neutral information.