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Intending to forget is not easy: Behavioral and electrophysiological evidence

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ABSTRACT

Previous researches have shown that recognition accuracy is lower for items cued to-be-forgotten (TBF) than to-be-remembered (TBR). Does directed forgetting help people forget more items than non-directed forgetting? Here, we modified the directed forgetting paradigm by adding a non-cue condition (NC). Consequently, non-directed forgetting would occur in NC. Behavioral results showed higher recognition accuracy for TBF than NC items, indicating that directed forgetting is less effective than non-directed forgetting. Electrophysiological results indicated that: (1) Remembered TBF items evoke an increased late positive component (LPC) than remembered NC items; (2) compared with remembered NC items, remembered TBF items showed a pronounced left-lateralized old/new effect and a reduced right-lateralized reversed old/new effect; (3) a right-lateralized reversed old/new effect was observed for forgotten TBF, but it was absent for forgotten NC items. These results demonstrate that the TBF items have a greater memory trace than the NC items. Forgetting cue has little effect of forgetting item from memory, and it might prompt subject to process or at least focus attention on the TBF items.

1. Introduction

Forgetting is treated as a failure to encode, maintain, or retrieve information; it has been hypothesized to result from various processes including passive decay, interference, interrupted consolidation, and retrieval failure (Benoit and Anderson, 2012; Bentin et al., 1992; Sadeh et al., 2014). In daily life, we are often instructed to forget something, especially unpleasant things. This intentional forgetting differs from the simple attenuation of memory (non-directed forgetting). The directed forgetting (DF) paradigm is often used to study intentional forgetting. During the study phase, different cues are provided to indicate which items are to be remembered (TBR) and which are to be forgotten (TBF). The remember/forget cues can be presented either following a complete set of study items (list-method) or following each study item individually (item-method). Typically, behavioral performance is worse for to-be-forgotten (TBF) than for to-be-remembered (TBR) items (Bastin et al., 2012; Bjork, 1972; Wylie et al., 2008).

Two theoretical hypotheses have been proposed to explain the item-directed forgetting effect. The selective rehearsal hypothesis emphasizes differential encoding and rehearsal for TBR and TBF items, and this view is supported by electrophysiological evidence: remembering cues elicited greater ERP positivity than TBF items during the 200–800 ms time window over parietal scalps (Paller, 1990; Paz-Caballero et al., 2004). However, some studies demonstrated that the differential ERP activity could be attributed to inhibitory processes for TBF items, supporting the attentional inhibition hypothesis, according to which the DF effect occurs because the forgetting cue triggers attentional inhibition of TBF items. Specifically, the forgetting cues evoked more positive ERPs than the remembering cues over frontal scalp (Hauswald et al., 2011; Ludowig et al., 2010; Paz-Caballero et al., 2004; Van Hooff and Ford, 2011; Van Hooff et al., 2009). Two recent DF studies (Patrick et al., 2015; Yang et al., 2012) found that forget cues evoked a more negative N2 component than the remember cues. They also considered the N2 component as an electrophysiological correlate of cue-induced memory inhibition. The inhibition account was also supported by some EEG studies on the list-method directed forgetting. For example, Bäuml et al. (2008) found two effects of the forget cue on oscillatory function: an increase in upper alpha power which reflects a change in encoding strategy for new material (list 2) and a reduction in upper alpha phase coupling which reflects inhibition of out-of-date information (list 1). Similarly, Hanslmayr et al. (2012) found that directed forgetting disrupts long-range alpha/beta neural synchrony. These findings suggest that an active inhibitory process disrupts list 1 context in directed forgetting.

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The evidence for the attentional inhibition hypothesis has also been found in studies on the ERPs evoked by correctly recognized TBR and TBF items (Nowicka et al., 2009; Ullsperger et al., 2000; Van Hooff et al., 2009). Specifically, Ullsperger et al. (2000) found that correctly recognized TBR and TBF words resulted in qualitatively different patterns of the old/new effect, with TBF items showing less early frontal activity and the absence of the old/new effect in the parietal area. This led the authors to suggest that the TBF words had been inhibited. Similarly, other studies (Nowicka et al., 2009; Van Hooff et al., 2009) have found that TBF and successfully forgotten words elicited more negative ERPs than the correctly rejected new words. Nowicka et al. (2009) termed this phenomenon as the reversed old/new effect and they suggested that this effect seems to reflect intentional and effective inhibition for the f-TBF items.

The theoretical accounts about the DF effect remain debated. The main purpose of the present study is not to test the above hypotheses. Instead, we ask whether a DF cue has the effect of enhancing forgetting, that is, can intentional forgetting help us to forget more. Several studies have confirmed the existence of an active process by which people can prevent awareness of TBF items (Bjork, 1972, Basden et al., 1993, Macleod, 1999; Fawcett and Taylor, 2008, 2012), and specified the neural systems that underlie it (Ullsperger et al., 2000; Van Hooff and Ford, 2011; Wylie et al., 2008). However, whether suppression can produce complete and lasting amnesia for an unwanted memory remains unknown. Some studies have suggested that when attentional resources are available, irrelevant information will be processed involuntarily, and merely asking participants to forget is not sufficient to prevent further processing (Lavie, 2005; Lee, 2012). Participants might continue to process TBF items after the forget cues were presented. Although some information could be suppressed, it does not necessarily indicate that they were actually forgotten (Bancroft et al., 2013; Lee et al., 2007; Lee and Lee, 2011). Based on these studies, we tentatively predicted that DF cue might not help us to forget more.

In order to test the above predictions, we modified the typical DF paradigm by adding a control condition in which remember/forgetting cues were not presented (see Fig. 1). Thus, we can investigate the different cognitive mechanism underlying DF (forgetting in TBF trials), and non-directed forgetting (forgetting in control NC trials).

We hypothesized that if DF is less effective than the non-directed forgetting, improved behavioral performance would be evidenced on TBF items. While if the TBF items showed worse memory retention than the NC items, it would supported the view that DF cue might have significant effect on forgetting. It has been previously reported that the successful recognition of old words is positively correlated with the late positive component (LPC, elicited between 500 and 800 ms after item presentation) and evidence has indicated that the parietal old/new effect is associated with conscious recollection (Allan et al., 1998; Düzel et al., 1997; Mecklinger, 2000; Wilding and Rugg, 1996; Paller et al., 1995). Moreover, previous DF studies suggest that the ERP old/new effect might reflect the strength of memory trace and the reversed old/new effect might reflect memory inhibition or response confidence (Nowicka et al., 2009; Ullsperger et al., 2000; Van Hooff et al., 2009). Therefore, the ERPs evoked by TBF items were expected to be different from that of NC items, reflected by differential LPC amplitudes and a differential pattern of the ERP old/new effect. Specifically, if TBF items were better encoded during the study phase, the correctly recognized TBF items might evoke more positive LPC amplitudes than the correctly recognized NC items during the test phase. Accordingly, a pronounced old/new effect would be expected for the correctly recognized TBF relative to recognized NC items. Moreover, a pronounced reversed old/new effect which reflects lower response confidence would be expected for unrecognized TBF relative to unrecognized NC items.

2. Methods

2.1. Participants

Twenty-five undergraduate native Chinese students were recruited for this study. Five participants were excluded from the analysis due to excessive artifacts (more than 50% of their trials were invalid). Therefore, data from 20 participants were included in the analyses (8 male and 12 female, mean age = 21.8 years, $SD = 1.55$). All participants were healthy and right-handed. All participants had normal or corrected-to-normal eyesight, and none were color blind. This study was approved by the Research Ethics Committee of Liaoning Normal University of China and was in accordance with the ethical guidelines of the Declaration of Helsinki. All participants gave informed consent, and were paid on completion of the experiment.

2.2. Design and materials

In the study phase, a remember/forget cue followed each item. We also included a control condition (no cue, NC) in which study items were not followed by any remember/forget cues. Thus, there were 3 conditions: remember (TBR), forget (TBF), and control (NC). These conditions were manipulated within-subjects. The order of experimental trials was pseudo-randomized with the constraint that no more than three consecutive trials could be from the same cue condition.

Stimuli were Chinese single-character nouns selected from the top 8000 words in "The Modern Chinese Frequency Dictionary" with mean frequency of 16.499 per thousand. Words were allocated to six lists of 80. Each list was matched for mean number of strokes and frequency. Half the lists were used as study items, and the remaining lists served as distractors for the test phase, and two additional two buffer words followed by a remember instruction were presented at the beginning and end of the study task, which were excluded from subsequent analyses. Excepting the two buffer words, the study phase consisted of 240 trials (80 trials per condition) and the test phase consisted of 480 trials. The order of presentation for each of the list sets was counterbalanced across subjects.

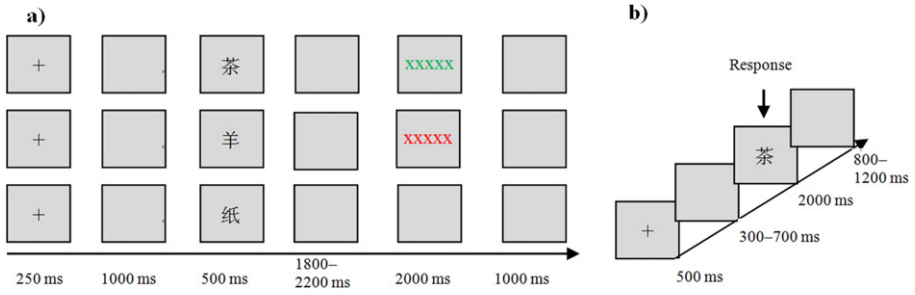

Fig. 1. The experimental design and procedure. a) Sequence of events in the study phase. The green or red "XXXXX" were used as remembering and forgetting cues. In the control condition, there was no explicit cue, and the remembering/forgetting cue was replaced by a blank screen. b) Sequence of events in the test phase. ERPs were time-locked to word onset.