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Research Report

Remember to forget: ERP evidence for inhibition in an item-method directed forgetting paradigm

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ABSTRACT

The present study examined the electrophysiological correlates of intentional forgetting using the item-method directed forgetting paradigm. Participants (N=23) studied a series of words each followed by either a "remember" cue (TBR) or a "forget" cue (TBF) and then undertook an old/new recognition memory test for which they were requested to endorse studied items regardless of original remember/forget status. Event-related potentials time locked to the cues were examined as a function of subsequent recognition-memory accuracy. Results showed that TBR and TBF cues elicited Dm or subsequent memory effects that differed in scalp distribution and polarity, suggesting activation of fundamentally different encoding operations for the respective sets of items. Additionally, analyses that examined the processes underlying successful implementations of intentions to forget (i.e., TBF-miss vs. TBR-miss) and intentions to remember (i.e., TBR-hit vs. TBF-hit) revealed that in case of unwanted information a frontal inhibition mechanism is engaged to stop processes associated with intentional memory formation. These results counter the possibility that directed forgetting reflects only the more elaborate encoding of TBR than TBF words and, instead, implicate the existence of an active inhibitory mechanism directed at TBF words once the forget cue is presented.

1. Introduction

In everyday life it often behoves us to forget information that we have stored in long-term memory, for example, because it is no longer valid (e.g., an old phone number or expired security code), it turns out to be untrue (e.g., a newspaper retracts its previously published claim), or it obstructs ongoing thought processes (e.g., an argument you had with a good friend). How we go about ridding ourselves of unwanted memories is a question that has aroused considerable controversy in the literature. One possibility is that we focus our attention and memorisation efforts solely on useful memories, such that undesired ones fade gradually due to lack of rehearsal. Another possibility is that we strive actively to forget by applying inhibitory processes to unwanted memories that impede their later retrieval. In the present study we sought electrophysiological evidence for a contribution of inhibition to intentional forgetting, specifically, by measuring event-related brain potentials (ERPs) at the time participants received an instruction to forget information that they had studied shortly beforehand.

In the laboratory, the typical approach to investigating intentional forgetting is to use a directed forgetting paradigm for which participants study a series of words accompanied by specific cues to indicate which words are to-be-remembered

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(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). Regardless of which method is used, when participants subsequently undertake an unexpected memory test for *all* studied items, they generally show superior memory for words that were cued to be remembered than for words that were cued to be forgotten, a phenomenon known as the directed forgetting (DF) effect (for review, see MacLeod, 1998). Below we consider competing accounts of the DF effect relevant to item-method intentional forgetting, which was the procedure adopted in the current investigation.

The *selective rehearsal* account of item-method directed forgetting suggests that TBR items are primed for later remembering due to more elaborate processing of these items following the presentation of the remember cue. At the same time, TBF items become relatively less accessible due to passive decay resulting from the lack of further processing (e.g., Basden and Basden, 1996; Basden et al., 1993). In contrast, the *attentional inhibition* account suggests that TBF items are targeted by inhibitory processes when the forget cue appears, so that adequate working memory resources can be released for enhanced rehearsal of TBR items (Zacks & Hasher, 1994; Zacks et al., 1996). Such inhibitory processes may simply terminate rehearsal of TBF items or, additionally, suppress their memory activation to below-baseline levels (i.e., *representational inhibition*; Levy and Anderson, 2002).

Given the difficulty of distinguishing between selective rehearsal and inhibition on a behavioural level, some studies have sought to shed light on the cognitive processes underlying directed forgetting through analysis of event-related potentials (ERPs). The prevailing approach in this regard has been to examine ERPs elicited during memory retrieval. The rationale for this approach is that inhibitory influences acting upon TBF items should result in extra activations to overcome restricted or blocked access, with these extra activations being visible as larger or additional ERP deflections for recognised TBF items relative to recognised TBR items. In line with such reasoning, Paz-Caballero and Menor (1999) observed an early, frontal positivity for recognised TBF items which was lacking for recognised TBR items. They attributed this frontal positivity to impaired semantic access for recognised TBF items, which they presumed to be a consequence of inhibition. Ullsperger et al. (2000) instead reported a more pronounced late right-frontal old/new effect for recognised TBF items, which they construed as evidence of processes dedicated to releasing TBF items from inhibition. More recently, two investigations analysed ERP responses to TBF items that were *not* recognised during the memory test and, thus, were presumably the targets of effective inhibition (Nowicka et al., 2009; Van Hooff et al., 2009). Both studies demonstrated a reversed posterior old/new effect for rejected TBF items that was not apparent for either endorsed TBF items or new items, consistent with the conclusion that the memory records of these items had been actively suppressed to below baseline.

A more direct approach is to capitalise on the potential of ERP methodology for yielding information about cognitive processes elicited during the *study phase* of an intentional forgetting procedure. Outside the DF literature, there has been a long tradition of examining the consequences of variations in episodic memory encoding, for example as a function of age or level of encoding, by comparing study phase ERPs for items that are remembered in a subsequent memory test with those that are not (for reviews see, Paller and Wagner, 2002; Wagner et al., 1999). Differences between ERPs for items that are successfully remembered and those for items that are incorrectly rejected are known as D*m* (Difference in subsequent memory) or *subsequent memory* effects. This ERP difference is believed to reflect the more thorough or more effective processing of some items at study, which is instrumental for their subsequent retrieval (Otten and Rugg, 2001; Wagner et al., 1999). Typically, this difference takes the form of more positive-going ERPs for subsequently remembered items than subsequently forgotten items (e.g., Friedman and Trott, 2000; Sanquist et al., 1980) although the opposite has also been observed (e.g., Mangels et al., 2001; Otten and Rugg, 2001). Otten and Rugg (2001) argued that efficient memory encoding is supported by multiple neural systems and, thus, that D*m* effects might differ *qualitatively* (i.e. in terms of polarity or scalp distribution) when participants engage in different encoding activities. In relation to item-method directed forgetting, it seems reasonable to suppose that if the forget cue activates attentional inhibition then D*m* effects for TBF items should *not* merely be a weaker version of those for TBR items.

This hypothesis was partly supported by Hsieh et al. (2009), who found that for the TBR cues a posterior D*m* effect was present in the 600–900 ms time window which was largely absent for the TBF cues. Given the absence of distinct D*m* effects for TBR versus TBF cues in a preceding time window (200–500 ms), they concluded that similar encoding mechanisms were engaged initially by both types of cues but that subsequently the rehearsal of TBF items was terminated. Moreover, because the TBF cues were found to elicit a positive going effect over the frontal scalp region, independent from subsequent memory, they theorised that inhibitory processes were actively involved in precluding further rehearsal of TBF items. A different approach was taken by Paz-Caballero et al. (2004), who linked ERP responses to the remember/forget cues to individual DF performance scores (i.e., recognition accuracy differences between TBR and TBF items). All participants showed a larger late positive wave (300–600 ms post-stimulus) for remember than forget cues, indicative of the higher target status of the TBR items or the more elaborate encoding of them. In addition, only in participants who were characterised by high levels of directed forgetting, an enlarged early frontal positivity (100–200 ms) was observed. Paz-Caballero et al. (2004) attributed this early frontal effect to a blocking or inhibiting mechanism that was more robust in participants who managed effectively to remember and forget. Hauswald et al. (in press) came to a similar conclusion with regards to an enhanced frontal positivity that was elicited by the forget cues in a later time window (450–660 ms). In accord with the study by Paz-Caballero et al. (2004), the amplitude of this positivity was found to correlate with the magnitude of the behavioural DF effect.

The study items presented in DF paradigms are processed with particular *intentions* in mind (i.e., to remember or to forget) and their D*m* effects are therefore likely to be different from those observed in traditional ERP encoding studies, which typically use *incidental* learning tasks. For example, Munte et al. (1988) found that D*m* effects were smaller, later, and more frontally based in conditions in which participants were explicitly instructed to remember the presented items than