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The Crucial Role of Postcue Encoding in Directed Forgetting and Context-Dependent Forgetting

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People can intentionally forget previously studied material if, after study, a forget cue is provided and new material is learned. It has recently been suggested that such list-method directed forgetting arises because the forget cue induces a change in internal context and causes context-dependent forgetting of the studied material (L. Sahakyan & C. M. Kelley, 2002). The authors compared directed forgetting and context-dependent forgetting by examining whether, like a forget cue, a change in internal context needs subsequent learning of new material to be effective. Participants studied an item list and, after study, received a remember cue or a forget cue or their internal context was changed through an imagination task. In each condition, half the participants learned a second list, and the other half fulfilled an unrelated distractor task. Both the forget cue and the change in internal context induced forgetting of the first list only when learning of the second list was interpolated. These results suggest that postcue encoding of new material is crucial for both directed forgetting and (some forms of) context-dependent forgetting.

Keywords: directed forgetting, context-dependent forgetting, encoding/retrieval mismatch, selective rehearsal, retrieval inhibition

List-method directed forgetting is the demonstration that previously encoded material can be intentionally forgotten, making it less accessible on later recall attempts. In this paradigm, participants study two lists of items and, after the presentation of List 1, receive a cue to either forget or continue remembering this list before studying List 2. After study of List 2, a recall test is conducted in which participants are asked to recall all of the previously presented items, including both to-be-forgotten and to-be-remembered items. Compared with remember-cued participants, forget-cued participants typically show improved recall of List 2 items and impaired recall of List 1 items (for reviews, see Johnson, 1994; MacLeod, 1998).[1]

Two prominent accounts of list-method directed forgetting are selective rehearsal and retrieval inhibition. The *selective rehearsal* explanation is a noninhibitory account that assumes that differential rehearsal of List 1 items after forget-cue presentation accounts for the directed forgetting effect. The proposal is that a forget cue between lists stops rehearsal of List 1 items and causes selective rehearsal of List 2 items, whereas a remember cue between lists causes nonselective rehearsal of both List 1 and List 2 items (Bjork, 1970; Sheard & MacLeod, 2005). In contrast, *retrieval inhibition* assumes that the forget cue causes inhibition of List 1 items. Such inhibition is supposed to make the List 1 items less accessible, thus reducing proactive interference from List 1 and facilitating retrieval of List 2 (Bjork, 1989; Geiselman, Bjork, & Fishman, 1983; see also Bäuml, in press).

A more recent, third account of directed forgetting is the *context change hypothesis* (Sahakyan & Kelley, 2002). This hypothesis claims that directed forgetting is a variant of context-dependent forgetting. It is argued that one strategy that would allow participants to intentionally forget List 1 in directed forgetting would be to deliberately attempt to alter internal context cues, creating a larger than normal change of context between lists. Accordingly, the forget cue should create a second context cue and, regarding List 1, should lead to a mismatch between the context at encoding and the context at retrieval (Mensink & Raaijmakers, 1988; Tulving, 1979, 1983). Consistent with this hypothesis, Sahakyan and colleagues found that a change in internal context can simulate typical directed forgetting data and that not only context-dependent forgetting but also directed forgetting can be reduced if, at test, the original List 1 encoding context is reinstated (Sahakyan & Delaney, 2003; Sahakyan & Kelley, 2002).

In the study of context-dependent forgetting, first-order and second-order paradigms can be contrasted (Bjork & Richardson-Klavehn, 1988). First-order paradigms are those in which a single context at encoding is either matched or mismatched to the context at retrieval. Second-order paradigms are those in which multiple contexts at encoding are used. Using first-order paradigms, various

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[1] In the literature, two different directed forgetting tasks have actually been used: the list-method and the item-method task. In contrast to the list-method task, in the item-method task, participants study a list of items, and the exposure of each item is followed closely by the cue either to remember it or to forget it. On a later memory task, to-be-remembered items are typically better recalled than to-be-forgotten items (for a review, see MacLeod, 1998).

studies have shown that changes of both physical environment (e.g., Godden & Baddeley, 1975; Smith, Glenberg, & Bjork, 1978; for a review, see Smith & Vela, 2001) and internal state or mood between study and test (e.g., J. E. Eich, 1980; Macht, Spear, & Levis, 1977; for a review, see E. Eich, 1989) can reduce recall of previously learned material when the contextual mismatch between study and test is enhanced. Using second-order paradigms and manipulating the number of physical or internal contexts at encoding, the learning of lists of items in different contexts has been found to reduce interference between lists (Dallett & Wilcox, 1968; Greenspoon & Ranyard, 1957), thus providing evidence that unique context information can improve later recall of single sets of items.

Sahakyan and Kelley (2002) reported context-dependent forgetting when people's internal context was changed through simple imagination tasks. Participants studied two lists of items and, after the presentation of List 1, were asked to mentally walk through their parents' home or to imagine what they would do if they were invisible. After study of List 2, a recall test was conducted in which participants were asked to recall all of the previously presented items. The imagination task improved recall of List 2 and, in particular, impaired recall of List 1. The List 2 improvement was explained through reduction of List 1 interference caused by the introduction of the new contextual cue (second-order effect), whereas List 1 forgetting was explained by the contextual encoding/retrieval mismatch for this list (first-order effect).

The question arises of whether List 2 encoding is necessary to induce List 1 forgetting in Sahakyan and Kelley's (2002) imagination task or whether the forgetting would have also arisen when no learning of new items had taken place after the internal context change. This point is important because there is evidence that directed forgetting depends on the learning of new material after presentation of the forget cue. Corresponding evidence comes from an experiment by Gelfand and Bjork (1985; described in Bjork, 1989), in which participants learned a list of 10 nouns (List 1) and then received a cue to either forget or continue remembering this list. Immediately after cuing, one group of participants learned a second list of 10 nouns (List 2), another group rated a list of 10 adjectives, and a third group of participants did nothing while "the experimenter fumbled around killing time" (p. 320). After this interpolated activity, a recall test was conducted in which participants were asked to recall the List 1 items, regardless of initial cuing. Forgetting of List 1 was observed only when the learning of List 2 was interpolated, suggesting that the learning of new material is necessary to create the forgetting effect.

Thus, if directed forgetting was mediated by a change in internal context (Sahakyan & Kelley, 2002), then the crucial role of List 2 encoding for List 1 forgetting should not be restricted to the directed forgetting paradigm. Rather, List 2 encoding should also be necessary to cause List 1 forgetting in the context-change paradigm, at least if the context changes were mental in nature and realized through imagination tasks. The goal of the present study, therefore, was to examine whether, like a forget cue, a change in internal context needs subsequent learning of new material to induce forgetting of List 1 items. Another goal of the study was to reexamine the previously reported crucial role of List 2 encoding for successful directed forgetting. This finding is important for directed forgetting theory but, to date, has only been reported as part of a conference paper.

An experiment is reported in which participants studied a list of items (List 1). After study, a remember cue or a forget cue was provided or a change in the participants' internal context was induced by means of an imagination task. Then a second list of items (List 2) was to be learned or an unrelated distractor task was carried out. At test, List 1 items were to be recalled, followed by List 2 recall when a second list of items had been learned. On the basis of the Gelfand and Bjork (1985) finding, we expected that directed forgetting of List 1 items was present only when List 2 learning was interpolated. The main issue of interest was whether the same would hold for the context-change condition. If List 2 encoding was necessary for successful directed forgetting but not for successful context-dependent forgetting, then the context-change hypothesis of directed forgetting would be challenged. If List 2 encoding turned out to be necessary for both successful directed forgetting and successful context-dependent forgetting, then an interesting parallel between the two forms of forgetting would emerge.

Method

Participants

Three hundred twenty-four students (133 men and 191 women) at Regensburg University, Regensburg, Germany, participated in the experiment. They were tested individually, with 54 participants in each of the six experimental conditions.

Material

Thirty unrelated German nouns of medium frequency were drawn from the CELEX database using the Wordgen Version 1.0 software toolbox (Duyck, Desmet, Verbeke, & Brysbaert, 2004). Two lists of 15 words each were prepared (see the Appendix). Across lists, words were matched on frequency and word length. The assignment of items to lists was constant for all participants. Item order within lists was random for each participant. Each list was equally often used in the remember condition, the forget condition, and the context-change condition. In the conditions in which participants had to learn both lists, the two lists served equally often as the first and second presented list.

Design

The experiment had a 3 × 2 design, with the between-participants factor of CUE (remember, forget, context change) and the between-participants factor of ENCODING (List 2 encoding, no List 2 encoding). First, conditions differed in which cue was provided after List 1 encoding. In the remember condition, List 1 was followed by a cue to remember the items; in the forget condition, List 1 was followed by a cue to forget the items; in the context-change condition, List 1 should be remembered and was followed by a mental context change. Second, conditions differed also in whether, after cuing, a second list was to be learned or not. In the List-2-encoding condition, an additional second list was to be learned; in the no-List-2-encoding condition, no additional learning took place, and an unrelated distractor task was carried out. Mean recall frequency was used as a dependent variable. Items were counted as correctly recalled if they were recalled with the correct list. Each participant took part in one combination of the three CUE and the two ENCODING conditions.

Procedure

In accordance with the multiple cue version of directed forgetting (MacLeod, 1999; see also Conway & Fthenaki, 2003; Zellner & Bäuml, 2006), participants were told from the outset that they would be presented with lists of words to learn but that following each list, they would be given a cue to remember or to forget the previous list.

The experiment consisted of four main phases: an encoding phase, an intermediate phase, an encoding/distractor phase, and a test phase. In the initial encoding phase, in all conditions the List 1 items were read out individually by the experimenter at a rate of 2 s per word. Conditions differed in what happened in the subsequent intermediate phase. In the context-change condition, participants were instructed to remember the List 1 items and then were subject to an internal context change. They were asked to imagine their parents' house, to mentally walk through it, and to tell aloud their imaginations to the experimenter. They were told to use the next 30 s for this task. The purpose of the task was to shift participants' mental context from studying words in an experiment to something quite different (Sahakyan & Delaney, 2003; Sahakyan & Kelley, 2002). In the remember and the forget condition, List 1 was followed by the cue to remember List 1 or by the cue to forget List 1. The forget cue specified that there was no need to remember List 1 items. Following the remember and forget cues, participants had to count backward from a three-digit number in steps of ones for 30 s to match duration with the imagination task in the context-change condition.

After initial encoding and the intermediate phase, a third phase followed in which half the participants in each of the three CUE conditions studied List 2, and the other half counted backward as a distractor task of the same duration. In the List-2-encoding condition, the items of List 2 were read out individually by the experimenter at a rate of 2 s per word, and participants were instructed to remember these items; in the no-List-2-encoding condition, participants continued their backward counting from the intermediate phase for another 30 s or, in the context-change condition, started backward counting for an equivalent amount of time. Finally, all participants took part in another 30-s backward counting as a recency control. In the fourth phase of the experiment, a free recall test was carried out in which all participants in all conditions were asked to recall as many of the List 1 items as possible. In the List-2-encoding condition, after List 1 recall, participants were additionally asked to recall as many of the List 2 items as possible. The recall time for each list was 1 min. If a participant had indicated that he or she would need additional time to recall a list's items, then the recall period was prolonged.

Results

List 2 Recall

In the List-2-encoding condition, in which participants learned both List 1 and List 2, 23.1% of the List 2 items were recalled in the remember condition, 30.0% in the forget condition, and 31.4% in the context-change condition (see Figure 1, left panel). A one-way analysis of variance (ANOVA) on proportion of correct List 2 recall revealed a reliable effect of the factor CUE, $F(2, 159) = 4.0$, $MSE = .027$, $p < .025$, partial $\eta^2 = .05$. List 2 recall was lower in the remember condition compared with both the forget condition, $t(106) = 2.4$, $p < .025$, $d = 0.45$, and the context-change condition, $t(106) = 2.7$, $p < .01$, $d = 0.52$. No difference was found between the forget condition and the context-change condition, $t(106) < 1$.

List 1 Recall

In the List-2-encoding condition, 34.6% of the List 1 items were recalled in the remember condition, 24.3% in the forget condition, and 25.5% in the context-change condition (see Figure 1, middle panel). A one-way ANOVA on proportion of correct List 1 recall showed a significant effect of CUE, $F(2, 159) = 8.6$, $MSE = .020$, $p < .001$, partial $\eta^2 = .10$. List 1 recall was higher in the remember condition compared with both the forget condition, $t(106) = 3.9$, $p < .001$, $d = 0.76$, and the context-change condition, $t(106) = 3.2$, $p < .01$, $d = 0.61$. No difference was found between the forget condition and the context-change condition, $t(106) < 1$.

In the no-List-2-encoding condition, in which participants learned List 1 but not List 2, 42.3% of the List 1 items were recalled in the remember condition, 41.7% in the forget condition, and 40.6% in the context-change condition (see Figure 1, right panel). A one-way ANOVA on proportion of correct List 1 recall showed no reliable effect of CUE, $F(2, 159) < 1$.

A comparison of results between the List 2 encoding and the no-List-2-encoding condition suggests that the effect of CUE on List 1 recall depended on whether List 2 items were to be encoded or not. Consistently, a 3 × 2 ANOVA on proportion of List 1 recall, with the factors of CUE (remember, forget, context change) and ENCODING (List 2 encoding, no List 2 encoding), showed a main effect of CUE, $F(2, 318) = 4.8$, $MSE = .022$, $p < .01$, partial $\eta^2 = .03$; a main effect of ENCODING, $F(1, 318) = 67.2$, $MSE = .022$, $p < .001$, partial $\eta^2 = .17$; and an interaction between the two factors, $F(2, 318) = 3.1$, $MSE = .022$, $p < .05$, partial $\eta^2 = .02$.

Intrusion Errors

In the List-2-encoding condition, we also analyzed intrusion errors from the wrong list. The mean proportion of List 2 intrusions during List 1 recall was 2.6% in the remember condition, 3.7% in the forget condition, and 2.6% in the context-change condition. A one-way ANOVA on proportion of intrusions of List 2 items during List 1 recall showed no effect of the factor CUE, $F(2, 159) < 1$. The mean proportion of List 1 intrusions during List 2 recall was 2.0% in the remember condition, 2.8% in the forget condition, and 2.7% in the context-change condition. A one-way ANOVA on proportion of intrusions of List 1 items during List 2 recall showed no effect of the factor CUE, $F(2, 159) < 1$.

Discussion

To the best of our knowledge, this study is the first one to replicate Gelfand and Bjork's (1985) observation that the presence

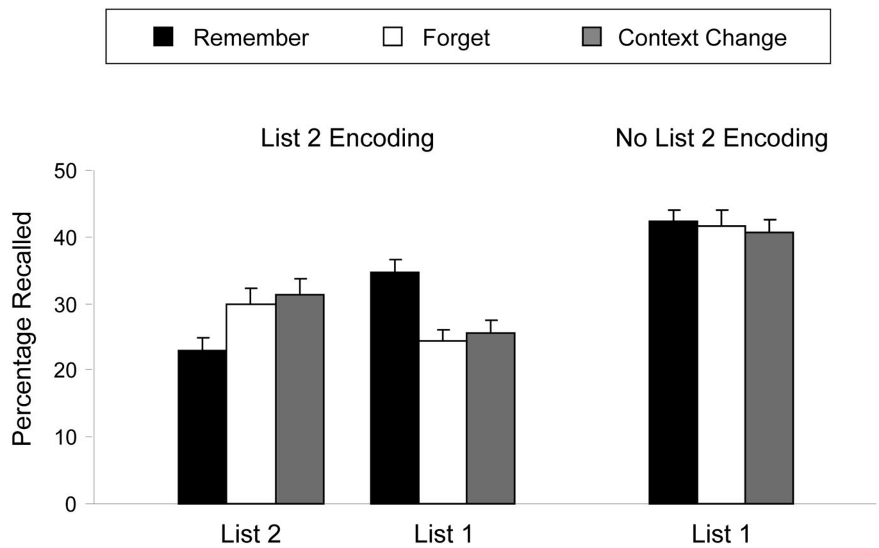

Figure 1. Mean recall frequency as a function of LIST (List 1, List 2), CUE (remember, forget, context change), and ENCODING (List 2 encoding, no List 2 encoding). Error bars represent standard errors.

of the forget cue in list-method directed forgetting is not sufficient to induce List 1 forgetting. Rather, the subsequent learning of further items is necessary to induce successful directed forgetting. Going beyond this prior work, the present results show that a change in internal context, as realized through an imagination task, is also not sufficient to induce List 1 forgetting. Rather, the context change induces forgetting only when there is subsequent learning of further material in the new internal context. As holds for directed forgetting, postcue encoding of new material seems to be necessary for successful context-dependent forgetting.

The present result that context-dependent forgetting needs postcue learning of new material seems to disagree with other results in the literature. In their classical study, Godden and Baddeley (1975), for instance, found reliable context-dependent forgetting when letting divers learn and recall word lists on land or underwater. However, when weaker environmental manipulations were used, like simple room changes or manipulations of internal states such as mood induction, context changes sometimes failed to generate a context effect, which led to concerns about its reliability (e.g., E. Eich, 1985; Fernandez & Glenberg, 1985). The present results provide another demonstration that changes in internal context may not be sufficient to induce context-dependent forgetting. In addition, however, the results suggest that changes in internal context can become effective when followed by subsequent learning of further material. This suggestion is in line with research showing that mood induction differentiates context only when participants learn two or more word lists in different moods (Bower, Monteiro, & Gilligan, 1978; Schare, Lisman, & Spear, 1984). It also indicates that weak context changes can induce forgetting, though apparently only when encoding of further material follows the context change.

From a theoretical point of view, one could argue that context changes should lead to forgetting of List 1 items regardless of whether List 2 learning is present or absent. Indeed, if the nonoverlap between the retrieval context and the encoding context is what underlies the decrease in recall of List 1 items (e.g., Mensink & Raaijmakers, 1988), then forgetting of List 1 should arise irrespective of whether List 2 items were encoded. However, there are at least two possible reasons why a context change in the absence of List 2 encoding may not produce forgetting of List 1 items. The first reason is that in the presence of List 2 learning, the retrieval cues at test have to differentiate between precue and postcue information. In the absence of List 2 learning, no such differentiation is needed, which may lead to better List 1 recall in the absence of than in the presence of List 2 learning. The second reason is that the encoding of List 2 items may have provided an opportunity to strengthen the representation of the new context, which may have made it hard for the participants to mentally reinstate the List 1 context at test. In contrast, in the absence of List 2 learning, no such strengthening of the context representation may have taken place, and the List 1 context may have been fairly easy to reinstate at test. Indeed, context effects have generally been found to be rather small in first-order paradigms, in which context differentiation appears needless and reinstatement of the original context may be easy (e.g., E. Eich, 1985; Fernandez & Glenberg, 1985).

The present results reveal a parallel between directed forgetting and context-dependent forgetting by identifying a common necessary condition for successful forgetting. Previous studies identified further parallels. One such parallel is the demonstration that both directed forgetting and context-dependent forgetting are present in recall but not in recognition (Basden, Basden, & Gargano, 1993; Godden & Baddeley, 1980; MacLeod, 1999; for exceptions, see Benjamin, 2006, and Sahakyan & Delaney, 2005, who show List 2 improvement in recognition). A second parallel is that both forms of forgetting are present in explicit but not in implicit memory tests (Basden et al., 1993; Parker, Gellatly, & Waterman, 1999). A third parallel is that both directed forgetting and context-dependent forgetting can be reduced if the original List 1 context is reinstated at test (Godden & Baddeley, 1980; Sahakyan & Kelley, 2002).

The present results thus are consistent with the hypothesis that context-dependent forgetting and directed forgetting are mediated by the same mechanisms (Sahakyan & Kelley, 2002). However, the results do not reject the claim that different mechanisms mediate the two forms of forgetting. For instance, although context-dependent forgetting may reflect an encoding/retrieval mismatch, directed forgetting may well be mediated by retrieval inhibition. In fact, it has repeatedly been argued that inhibition should be initiated only if there is postcue encoding of competing material, triggering inhibitory processes on the to-be-forgotten List 1 items (Barnier et al., in press; Conway, Harries, Noyes, Racsmany, & Frankish, 2000). The data are also consistent with the view that context-dependent forgetting reflects an encoding/retrieval mismatch, whereas directed forgetting is mediated by selective rehearsal (Sheard & MacLeod, 2005). This view holds, although in the present experiment, rehearsal of List 1 items in the remember condition may be expected to take place not only in the presence of List 2 learning but also during the interpolated distractor task.

In the present study, we asked participants to recall List 1 items before List 2 items, thus following prior work in which directed forgetting and context-dependent forgetting were compared directly (Sahakyan & Delaney, 2003; Sahakyan & Kelley, 2002). Three previous studies addressed the issue of whether recall order affects directed forgetting, thus examining a possible role of retrieval strategies or output interference in this type of forgetting. In each of these studies, experiments were conducted in which half the participants recalled List 1 before List 2, and the other half recalled List 2 before List 1. Consistent across the single studies, recall order did not affect the results, neither List 1 forgetting nor List 2 improvement (Barnier et al., in press; Geiselman et al., 1983; Zellner & Bäuml, 2006), which suggests that retrieval strategies and output interference are not a major factor in this type of forgetting (but see Golding & Gottlob, 2005, for an output order effect when using a within-subjects-directed forgetting design, in which there is a forget condition but no remember condition). It, therefore, appears likely that the present pattern of results would not have changed if recall order of the two lists (in the List-2-encoding condition) had been reversed.

Although the present results do not answer the question of whether context-dependent forgetting and directed forgetting are mediated by the same mechanism(s) or by different mechanisms, they suggest an important parallel between the two forms of forgetting. This parallel may be of some use for future work that investigates the neural correlates of context-dependent forgetting and directed forgetting. Because the mechanisms that underlie the two forms of forgetting should be active during List 2 encoding, they should be observable in imaging or electrophysiological studies when comparing neural activities during List 2 encoding after a forget cue and after a context change. Such neural measurements together with further behavioral experiments should help discover exactly what processes mediate directed forgetting and context-dependent forgetting, to what extent they are functionally and neurally equivalent, and whether they are inhibitory or noninhibitory in nature.

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Appendix

Translated Material of the Original German Words

List A: chain, elbow, customer, waste, box, cross, hammer, heater, wool, local, sleep, closet, start, bag, retiree

List B: edge, jewel, hunger, elephant, star, chest, balcony, cure, mare, flight, shoe, radio, knife, grade, letter

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