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Unblocking memory through directed forgetting

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The ability to remember an item can be blocked, or negatively primed, by exposure to related items. For example, ALLERGY is less likely to be generated given the word fragment A_L_ _GY if one is first exposed to ANALOGY. We examined whether this memory blocking effect is influenced by list-method directed forgetting. A total of 144 participants learned two lists of items, each consisting of words that were designed to negatively prime performance on a subsequent word fragment completion task. Participants who were told to forget List 1 before learning List 2 suffered significantly less memory blocking owing to the negative primes from List 1 than participants who were told to remember List 1. These results suggest that directed forgetting can modify the memory blocking effect by affecting the accessibility of information in memory.

Keywords: Directed forgetting; Memory blocking; Fixation.

Isaac Newton remarked in reference to his achievements: "If I have seen further, it is by standing on the shoulders of giants." Newton appreciated his predecessors' scientific discoveries and used them as a basis for his own work. In many instances, existing knowledge has the power to facilitate processes such as memory, creative thinking, and problem solving. There are also instances in which existing knowledge can constrain or *fixate* the scope of cognition (for a review of mental fixation, see Smith, 2003). For example, we all experience tip-of-the-tongue states characterised by the frustrating inability to recall a word despite being certain that we know it. Tip-of-the-tongue states are often induced or exacerbated by interference from related words that initially come to mind. Schacter (2001) referred to such words as ugly stepsisters in that they stand in the way of access to the particular word being targeted (i.e., Cinderella).

Memory can be blocked in a number of ways. For example, Smith (1994) asked participants to generate a target word from its definition (e.g., "a mixture of metals, one of quality with a poorer one"). Critically, some definitions were preceded by a word semantically similar to the definition that did not serve as a viable answer ("compound"), thus blocking participants' ability to generate the target word ("alloy"). Similarly, Smith and Tindell (1997) showed that completing a word fragment can be made more difficult by prior exposure to an orthographically similar word. Before attempting to complete a word fragment (e.g., "T_R_ _IN"), participants were either presented the target word ("TERRAIN"), an orthographically similar word ("TURBINE"), or an unrelated word ("UNICORN"). Not surprisingly, exposure to the target word enhanced performance, an effect referred to as *positive priming*. However, exposure to the orthographically similar word impaired performance, an effect referred to as *negative priming*. Stimuli that cause negative priming are generally referred to as negative primes. Interestingly, participants

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can become so fixated by negative primes that they provide them as answers during a fragment completion task despite noting the obvious orthographic mismatch (Landau & Leynes, 2006).

Overcoming or avoiding the memory blocking effect has proven to be particularly difficult in the context of word fragment completion because the fragments themselves can induce the involuntary retrieval of the negative primes. Smith and Tindell (1997) instructed participants to avoid thinking about the negative primes, but the blocking effect remained. They even found that warning participants about specific negative primes immediately prior to the presentation of corresponding fragments failed to reduce the effect (see also Logan & Balota, 2003). Several manipulations, however, have proven successful. Kinoshita and Towgood (2001) found that dividing attention while studying negative primes reduces the memory blocking effect by impairing the encoding of the negative primes and thus making them less likely to be retrieved during fragment completion. Even when negative primes are fully encoded, inserting a long delay between the study of negative primes and word fragment completion can significantly reduce the memory blocking effect (e.g., Leynes, Rass, & Landau, 2008). Presumably, the long delay acts as an incubation period and renders the negative primes less likely to be retrieved.

Manipulations that are able to reduce the memory blocking effect appear to do so by attenuating the accessibility of negative primes at the time of word fragment completion. Another way one might attenuate or alter the accessibility of negative primes is through directed forgetting (Bjork, LaBerge, & LeGrand, 1968; for a review, see MacLeod, 1998). In the list method of directed forgetting, participants learn an initial list of items and are then told to either remember or forget that list prior to learning a second list. The forget instruction can come in a number of forms. In the "oops!" method, participants are told that they were accidentally given the wrong list and that they will now be given the *real* list. In another method, participants are told that the first list was just for practice and that they should forget it before learning the second list. After learning both lists, participants are given a final test in which they are asked to recall items from both lists, regardless of the instruction to remember or forget. Studies examining list-method directed forgetting have shown that instructing participants to forget List 1 prior to learning List 2 causes them to recall fewer items from List 1 (the *costs* of directed forgetting) and more items from List 2 (the *benefits* of directed forgetting).

One popular account of list-method directed forgetting is that of retrieval inhibition (Bjork, 1989). According to this account, when participants are instructed to forget List 1 they initiate an inhibitory process that suppresses, selects against, or sets aside that list in order to facilitate the learning of List 2; participants recall fewer to-be-forgotten items from List 1 as a consequence of this inhibition. The decreased accessibility of List 1 items reduces interference with the learning and recall of to-be-remembered items from List 2, and it is this reduction in interference that presumably leads to the benefits of directed forgetting. It is important to note that List 1 forgetting is believed to reflect a reduction in accessibility or retrieval strength, not a reduction in availability or storage strength. Evidence for this assumption comes from work showing that to-be-forgotten items are not impaired on recognition tests or word-fragment completion tests, and that the effect can be reversed following reexposure to even a subset of the to-be-forgotten items (see, e.g., Bjork & Bjork, 1996).

Another account of list-method directed forgetting suggests that the costs arise due to a shift in context (Sahakyan & Kelley, 2002). Sahakyan and Kelley (2002) found that simply instructing participants to engage in a diversionary thought (e.g., imagine being invisible) prior to List 2 has the same effect as the directed forgetting instruction. It is possible that in attempting to comply with the forget instruction participants engage in some type of diversionary thought to help them stop thinking about List 1, consequently altering the participant's mental context prior to encoding List 2. Thus, when given the final test, a participant's mental context may have changed in such a way that provides fewer contextual cues to aid the recall of List 1. The benefits of directed forgetting could also be related to this shift in context. Specifically, learning List 1 and List 2 in different contexts may help prevent List 1 items from interfering with the recall of List 2 items. Another possibility is that the benefits are caused by a change in encoding strategy. If participants receive a forget cue they may be more likely to adopt a more effective study strategy for List 2 than when given a remember cue (Sahakyan & Delaney, 2005).

Whatever the mechanism, directed forgetting has been shown to alter the accessibility of information in memory. When two sets of items are learned, an instruction to forget renders the first set less accessible and the second set more accessible. In the present research we examined whether this relative change in accessibility can modify the memory blocking effect. As in typical directed forgetting experiments, participants learned two lists of words; half of the participants were instructed to remember List 1 prior to learning List 2 (remember condition) and the other half were instructed to forget List 1 prior to learning List 2 (forget condition). Critically, a subset of the items from each list served as negative primes for a surprise word fragment completion task administered at the end of the experiment. Rather than being interested in the participants' ability to recall List 1 and List 2 items, we were interested in the extent to which those items negatively primed the ability to complete subsequent word fragments. We predicted that owing to the costs and benefits of directed forgetting, participants in the forget condition would suffer relatively less negative priming from List 1 and relatively more negative priming from List 2.

METHOD

Participants

A total of 144 undergraduates from the University of Illinois at Chicago participated for partial credit in an introductory psychology course.

Materials

The stimuli included the 18 triplets shown in the Appendix (each consisting of a target word, a word fragment, and a negative prime). Eleven triplets were taken from Tindell (1994) and the other seven triplets were created using a similar set of criteria. Word fragments were created by removing two or three of the letters from the target words that were not shared with the negative primes (e.g., "T_R_ _ IN" was created for the target word "TERRAIN"). The negative primes were chosen to be orthographically similar to the target words in order to misleadingly appear to complete the associated word fragments (e.g., "TURBINE"). Importantly, none of the word fragments could be solved using the negative primes. Sixteen of the triplets consisted of target words and negative primes that began with the same first letter, shared four or five letters, and were seven letters long. Moreover, the word fragments associated with each of these target words consisted of letters following the same order as the negative primes. Two of the triplets did not adhere to these criteria (and did not produce memory blocking effects), so we removed them prior to analysis ("JANUARY" and "TRILOGY").

For counterbalancing purposes, the triplets were divided into three subsets. One subset consisted of items that would serve as negative primes in List 1, a second subset consisted of items that would serve as negative primes in List 2, and a third subset consisted of baseline items that would not be presented in List 1 or List 2. The particular items serving in each subset were counterbalanced across participants. Lastly, 26 filler items were selected that were six to eight letters in length and orthographically dissimilar to the target words.

Procedure

Participants took part in each of the phases shown in Figure 1: target activation, List 1 and List 2 learning, and word fragment completion.

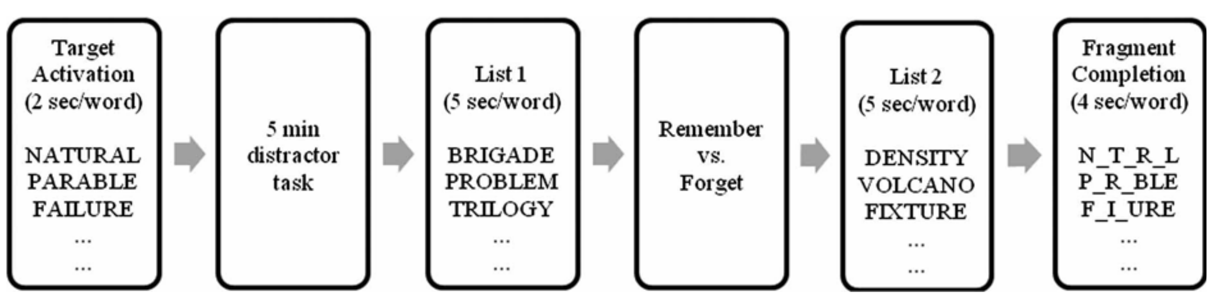

Figure 1. Schematic of the experimental procedure. In this example, P_R_BLE (target: PARABLE) would serve as a fragment negatively primed by List 1 (PROBLEM), F_I_URE (target: FAILURE) would serve as a fragment negatively primed by List 2 (FIXTURE), and N_T_R_L (target: NATURAL) would serve as a fragment in the baseline condition.

Target activation. A target activation phase was included because pilot work showed that exposure to target words before beginning the experiment was necessary to counteract floor effects and to produce a memory blocking effect. All 18 target words and six filler items appeared on the computer screen in a randomised order for 2 s each. Participants were instructed to look at the words and "take them in" but not to study or memorise them. Because we did not want participants to realise the connection between the activation list and the subsequent phases of the experiment, no mention was made of it later in the experiment and participants engaged in a 5-min nonverbal distractor task before learning List 1. Another reason we separated target activation from List 1 learning is because prior research has shown that when participants study three lists, instructions to forget the second list can cause the forgetting of the first list (Sahakyan, 2004). By separating the phases we hoped to minimise the possibility of target items suffering directed forgetting.

List 1 and List 2 learning. Each list consisted of six negative primes and 10 filler items presented in a block-randomised order such that each block of eight items consisted of three negative primes and five filler items randomly intermixed. The particular filler items used in List 1 and List 2 were counterbalanced across participants. List 1 items were presented at a rate of 5 s per word and participants were instructed to remember the words for a subsequent memory test. Following List 1 learning, participants were randomly assigned to one of two directed forgetting conditions (remember vs. forget). Participants in the remember condition were told that they only learned half of the items they needed to remember and that the second half would be presented next. Thus, participants in the remember condition were instructed to remember items from List 1 and List 2. Participants in the forget condition were told that List 1 was only provided as practice and that they did not need to remember the items from that list. Furthermore, participants in the forget condition were told that they would not be tested on List 1 and that they would only be tested on the subsequently presented List 2. List 2 was presented in the same fashion as List 1.

Word fragment completion. The word fragment completion task was administered immediately following List 2 learning. All 18 fragments appeared on the screen for 4 s each in a new randomised order and participants were asked to say out loud a word that completed each fragment for the experimenter to record. Participants were warned that the words presented in the earlier lists may or may not help them complete the word fragments. No mention was made of the target activation list.

RESULTS

The proportion of fragments successfully completed were analysed as a function of when the fragments were negatively primed (List 1 vs. List 2) and directed forgetting condition (remember vs. forget) using a 2×2 mixed design Analysis of Variance (ANOVA). A main effect of list emerged such that participants performed better on fragments negatively primed by List 1 ($M = 0.37$, $SE = 0.02$) than List 2 ($M = 0.29$, $SE = 0.02$), $F(1, 142) = 12.02$, $MSE = 0.04$, $p = .001$. A main effect of directed forgetting condition was not observed, $F(1, 142) = 0.86$, $MSE = 0.06$, $p = .36$. Participants completed approximately the same proportion of fragments in the remember condition ($M = 0.31$, $SE = 0.02$) as they did in the forget condition ($M = 0.34$, $SE = 0.02$). Most importantly, as can be seen in the left portion of Table 1, a significant interaction was observed, $F(1, 142) = 4.67$, $MSE = 0.04$, $p < .05$. For fragments negatively primed by List 1,

TABLE 1
Mean performance on the word fragment completion task (and *SE*s) and memory blocking effects as a function of item type and directed forgetting condition

	Item type			*Memory blocking*	
Directed forgetting	*List 1*	*List 2*	*Baseline*	*List 1*	*List 2*
Remember	0.33 (0.02)	0.30 (0.03)	0.46 (0.03)	13%***	16%***
Forget	0.41 (0.02)	0.28 (0.03)	0.46 (0.03)	5%	18%***

***$p < .001$.

participants in the forget condition performed significantly better than participants in the remember condition, $t(142) = 2.14$, $p < .05$, $d = .36$. For fragments negatively primed by List 2, however, performance in the forget and remember conditions failed to differ significantly, $t(142) = 0.61$, $p = .54$, $d = .10$.

Memory blocking effects were calculated for each experimental condition by taking the proportion of baseline fragments successfully completed by a given participant and subtracting the proportion of negatively primed fragments associated with each list that were successfully completed. As shown in the right portion of Table 1, participants in the remember condition suffered significant memory blocking owing to negative primes from List 1, $t(71) = 3.61$, $p < .001$, $d = .43$, and List 2, $t(71) = 4.32$, $p < .001$, $d = .51$, whereas participants in the forget condition suffered significant memory blocking owing to negative primes from List 2, $t(71) = 5.02$, $p < .001$, $d = .59$, but not List 1, $t(71) = 1.51$, $p = .14$, $d = .18$. A 2×2 ANOVA confirmed that the List $\times$ Directed forgetting condition interaction was statistically significant, $F(1, 142) = 4.67$, $MSE = 0.04$, $p < .05$.

Finally, although we tried to ensure that participants did not think back to the target activation list during word fragment completion, it is possible that some did. To explore this possibility, 105 of the participants were questioned after completing the experiment and 81 reported being completely unaware of the connection between target activation and word fragment completion. We reanalysed the data limiting our sample to these 81 participants (consisting of 44 and 37 participants in the remember and forget conditions, respectively) and found a pattern of results very similar to that which was observed for the entire sample. Specifically, a 2×2 ANOVA revealed a significant effect of list, $F(1, 79) = 19.01$, $MSE = 0.04$, $p < .001$, a nonsignificant effect of directed forgetting condition, $F(1, 79) = 0.10$, $MSE = 0.06$, $p = .75$, and a significant interaction, $F(1, 79) = 6.25$, $MSE = 0.04$, $p = .01$. For fragments negatively primed by List 1, participants in the forget condition ($M = 0.44$, $SE = 0.03$) performed marginally better than participants in the remember condition ($M = 0.35$, $SE = 0.03$), $t(79) = 1.89$, $p = .06$, $d = .42$. For fragments negatively primed by List 2, however, performance in the forget condition ($M = 0.23$, $SE = 0.04$) and remember condition ($M = 0.30$, $SE = 0.04$) did not differ significantly, $t(79) = 1.19$, $p = .24$, $d = .27$. It is interesting to note that the size of each of these effects was larger than that observed for the entire sample, suggesting that our results cannot be explained by participants being aware of the target activation phase during word fragment completion.

DISCUSSION

Exposure to orthographically similar words can impair performance on a word fragment completion task (e.g., Smith & Tindell, 1997). This memory blocking effect is one of many examples in which people are unable to complete some type of cognitive process because inappropriate knowledge or information gets in the way (Smith, 2003). The present research investigated whether directed forgetting can reduce memory blocking by making an initial list of items less accessible. As in typical list-method directed forgetting studies, participants learned two lists of words. Half of the participants were instructed to forget the first list before learning the second list (forget condition) and the other half were instructed to remember both lists (remember condition). Unlike typical directed forgetting studies, we did not measure performance on a final memory task. Rather, participants attempted to complete a series of word fragments in which some of the fragments were negatively primed by words presented in the earlier lists.

A significant interaction was found such that participants in the remember and forget conditions were differentially affected by negative primes in the two lists. As predicted, participants in the forget condition completed significantly more fragments negatively primed by List 1 than participants in the remember condition. In other words, the costs of directed forgetting appeared to facilitate performance on the word fragment completion task. Interestingly, a significant difference was not observed owing to the benefits of directed forgetting. Although in the predicted direction, participants in the forget condition did not complete significantly fewer fragments negatively primed by List 2 than participants in the remember condition. One possibility is that the effect of the directed forgetting manipulation on List 2 accessibility was too small to have a meaningful impact on the word fragment completion task.

It should be noted that Leynes et al. (2008) also investigated whether directed forgetting can influence orthographic memory blocking. Although they failed to find an effect, their outcome may have been due to aspects of their methodology. In studies of list-method directed forgetting, participants are typically told to forget the first list prior to learning the second list, but Leynes et al. instructed participants to forget the first list after learning both lists. This difference is critical because the success of list-method directed forgetting is contingent upon participants learning a second list after receiving the forget instruction (see, e.g., Bjork, 1989; Pastötter & Bäuml, 2007).

Our findings are somewhat surprising given that prior research has suggested that indirect data-driven tasks, such as word fragment completion, are not influenced by list-method directed forgetting. For example, Bjork and Bjork (1996) found that directed forgetting failed to influence the extent to which words from List 1 and List 2 positively primed word fragment completion. That is, exposure to target words in List 1 and List 2 primed performance on the word fragment completion task equally in both conditions. One possible explanation is that participants in our study explicitly attempted to recall List 1 and List 2 items while completing the word fragments. Because Bjork and Bjork utilised positive primes, the word fragments may have been sufficiently powerful to prevent participants from needing to explicitly think back to the lists, allowing them to escape the consequences of directed forgetting. However, the majority of our participants did report thinking back to List 1 and List 2 when attempting to complete the word fragments. Thus, the accessibility of List 1 and List 2 would have been likely to determine the extent to which the negative primes from those lists interfered with fragment completion. This rationale may also explain why participants who were unaware of the connection between target activation and word fragment completion exhibited the same if not larger differences as a consequence of directed forgetting. Participants who did not think back to the initial target activation phase may have been more likely to think back to List 1 and List 2, which would have made their performance on the word fragment completion task even more sensitive to the relative accessibility of the items on those lists.

The current findings are also consistent with a study by Storm, Bjork, and Bjork (2007) examining the protective effects of directed forgetting on retrieval-induced forgetting. Work on retrieval-induced forgetting has shown that attempting to retrieve an item in memory can cause the forgetting of other items in memory (e.g., Anderson, Bjork, & Bjork, 1994). The forgetting is argued to be the consequence of an inhibitory process that acts to overcome interference (Storm & Levy, 2012)—if an item fails to interfere with retrieval then that item should not suffer retrieval-induced forgetting. Storm et al. instructed participants to remember or forget a list of category exemplars before attempting to retrieve other category exemplars from semantic memory. Retrieval-induced forgetting was only observed on lists that participants were told to remember, suggesting that only the to-be-remembered items—and not the to-be-forgotten items—interfered with the semantic generation task.

Finally, it is important to note that the results of the current study are consistent with both the context-change account (Sahakyan & Kelley, 2002) and the inhibition account (Bjork, 1989) of directed forgetting. Both accounts predict that a forget instruction should reduce the accessibility of List 1 items, thus reducing the extent to which those items block performance on the subsequent word fragment completion task. In fact, although the two accounts are often discussed as if they are in competition, some have argued that inhibition and context change may actually be intimately related. Anderson (2005), for example, argued that one of the ways in which participants may implement a mental context change is by inhibiting access to their previous context.

CONCLUDING COMMENT

Bjork (1989, pp. 321–322) argued that forgetting plays an important role in the updating of memory: "When we need to remember our current phone number, the current married name of a female acquaintance, the trump suit on this hand, and where we left the car today, it does not help us to remember our old phone numbers, our friend's maiden name, the trump suit on the last hand, and where we left the car yesterday. That is, we need some means to suppress, set aside, destroy, or discriminate out-of-date information in memory in order to remember current information effectively." Directed forgetting appears to facilitate this type of goal-directed forgetting by making outdated information less accessible. Yet, the current results suggest that these changes in accessibility may also influence one's ability to remember other information by making to-be-forgotten information less likely to interfere. In this way, the consequences of directed forgetting may be farther reaching than generally supposed—intentions to remember and forget may not only determine whether a particular item is recalled, but whether that item interferes with the retrieval or generation of other items in the future.

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APPENDIX

Negative prime	*Target word*	*Word fragment*
BRIGADE	BAGGAGE	B_G_A_E
CLUSTER	COUNTRY	C_U_TR_
DENSITY	DIGNITY	D_ _NITY
FIXTURE	FAILURE	F_I_URE
GATEWAY	GRAVITY	G_A_ _TY
HOLSTER	HISTORY	H_ST_R_
JANUARY	JOURNEY	J_URN_Y
NOSTRIL	NATURAL	N_T_R_L
POVERTY	PARSLEY	P_R_ _EY
PROBLEM	PARABLE	P_R_BLE
RACCOON	REACTOR	R_ AC_ O_
SPARROW	SOPRANO	S_PR_ _O
SEAPORT	SUNSPOT	S_ _ _POT
SYRINGE	SHINGLE	S_ING_E
TURBINE	TERRAIN	T_R_ _IN
TONIGHT	TANGENT	T_NG_ _T
TRILOGY	THEORY	T_ _ORY
VOLCANO	VILLAIN	V_L_A_N