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The Influence of Directional Associations on Directed Forgetting and Interference

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Two experiments examined how cross-list directional associations influenced list-method directed forgetting and the degree of interference observed on each list. Each List 1 item had a (a) bidirectionally related item on List 2 (*chip* ⟷ *potato*), (b) forward association with an item on List 2 (*chip* → *wood*), (c) backward association from an item on List 2 (*chip* ← *chisel*), or (d) no relationship with List 2 items. The results revealed that associative relationships that eliminated retroactive interference in the baseline condition also eliminated the directed forgetting costs. In contrast, associative relationships did not affect List 2 recall in the forget group, which remained unchanged across experimental conditions. However, certain conditions reduced proactive interference in the remember group, thereby eliminating the benefits of directed forgetting. The directed forgetting costs and benefits were observed independently of each other. The authors propose that these effects emerged from a combination of item and context strengthening induced by different associative directions.

Keywords: directed forgetting, interference, directional associations, context, similarity

A central feature of the human memory system is its ability to selectively retrieve appropriate memories and exclude inappropriate ones. Many times when we wish to avoid remembering something and attempt to forget it, we may encounter related information that nonetheless reminds us of the very thing we are trying not to think of. We may come across ideas or events that are inherently related to the things we are trying not to think about, and these pre-existing relationships may work against motivated forgetting. At the same time, reminders may serve a protective function for events we deliberately maintain in memory, insulating them against interference. In this study, we examined how item relatedness impacted forgetting caused by directed forgetting instructions, retroactive interference (RI), and proactive interference (PI).

To study these issues, we chose the list-method directed forgetting paradigm invented by R. A. Bjork, LaBerge, and LeGrand (1968). In a typical list-method design, participants study two lists of items for a later test. After the first list, participants are interrupted and told either to forget that list (“because it was only for practice”; the forget group) or to keep remembering it (“that was only the first half of the items”; the remember group). Then both groups proceed to study the second list, which is followed by a memory test for both lists. Typically, the forget group demonstrates poorer recall of the first list compared with the remember group, a finding known as the *costs* of directed forgetting. The forget group also shows better recall of the second list compared with the remember group, a finding known as the *benefits* of directed forgetting. Thus, the forget instruction has a dual effect on memory: It impairs memory for the information that precedes the instruction, and it also enhances memory for subsequent information (for reviews, see E. L. Bjork, Bjork, and Anderson, 1998; MacLeod, 1998).

It is known that learning one set of materials influences the learning of the second set and that the second set in turn affects the memory of the original information. Thus, the two-list design of the directed forgetting paradigm is conducive for exploring not only the directed forgetting effect but also the magnitude of PI and RI in the remember condition, in which the participants are trying to maintain both lists in memory.

One account of the directed forgetting findings involves retrieval inhibition (e.g., R. A. Bjork, 1989). According to this view, an inhibitory mechanism is invoked at the time of retrieval that reduces access to unwanted memories, leading to lower recall of List 1 items (producing the costs of directed forgetting). Because List 1 items are less accessible, they are also less likely to interfere with List 2 items (producing the benefits of directed forgetting). The recall level of List 2 in the forget group is often comparable to the level of recall of a group that studied only one list, suggesting that directed forgetting can reduce interference (E. L. Bjork & Bjork, 1996; R. A. Bjork & Woodward, 1973).

Retrieval inhibition is a single-process account because it invokes the same mechanism to explain both the costs and the benefits of directed forgetting. More recently, dual-process accounts have emerged that attribute the costs and benefits of directed forgetting to different mechanisms (Sahakyan & Delaney, 2005). The costs are explained by invoking a context change mechanism (Sahakyan & Kelley, 2002), whereas the benefits are explained by invoking a strategy change explanation (Sahakyan & Delaney, 2003). According to this dual-process account, the costs

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emerge because participants in the forget group attempt to establish a new mental context to comply with the instruction. The testing context better matches List 2 than List 1 in the forget group, leading to forgetting. The benefits of directed forgetting are attributed to better encoding of the second list because forget group participants often adopt better encoding strategies on the second list.[1]

Conditions Limiting Directed Forgetting

Certain conditions are known to prevent directed forgetting. For example, the observation of directed forgetting costs is dependent on new learning following it (Gelfand & Bjork, 1985; Pastötter & Bäuml, in press). Without second-list learning, instructions to forget do not produce forgetting. Also, when the quality of List 2 learning is impoverished by performing a divided attention task while encoding the second list, the costs of directed forgetting are eliminated (Conway, Harries, Noyes, Racsmány, & Frankish, 2000). Finally, when List 1 and List 2 items are related to each other, the costs of directed forgetting are not observed, although the benefits remain significant (Conway et al., 2000). For example, Conway et al. (2000) intermixed unrelated items with primary associates, which are words that most frequently produce each other in free association (e.g., salt–pepper, mother–father). Thus, half of the items on each study list were primary associates of the items on the next list, whereas the remaining half consisted of unrelated items. Conway et al. did not observe directed forgetting costs for related or unrelated items, and they attributed the results to integration of "to-be-forgotten" items with "to-be-remembered" items. They proposed that integration weakened competition between the two lists, reducing the need to invoke an inhibitory process.

Taken together, these findings imply that certain amounts of RI are necessary for observing directed forgetting costs. Traditionally, directed forgetting research has acknowledged the relationship between interference and directed forgetting by focusing more on PI. This was largely motivated by the retrieval inhibition account, according to which directed forgetting reduces PI on List 2 by inhibiting List 1 items, thereby serving an adaptive function for memory updating (e.g., E. L. Bjork & Bjork, 1996; R. A. Bjork, 1989; R. A. Bjork & Woodward, 1973). Therefore, the effectiveness of directed forgetting instruction was in part evaluated by whether or not it reduced PI on List 2.

In this article, we propose to examine the relationship between RI and directed forgetting costs because all the conditions that prevent or eliminate directed forgetting costs imply that RI may be a necessary condition for observing the costs. For example, in the absence of RI (i.e., no List 2 learning) or reduced RI (i.e., reducing the quality of List 2 learning by dividing attention), there are no directed forgetting costs. Likewise, when List 2 items are related to List 1 items, the costs of directed forgetting are eliminated (Conway et al., 2000). Numerous studies from the paired-associate era support the role of item relatedness in reducing interference. For example, when the response terms are related to each other, as in the A–B, A–B′ design, interference is significantly reduced, compared with unrelated response terms, as in the A–B, A–D design (for reviews, see Anderson & Neely, 1996; Crowder, 1976; Postman, 1971; Postman & Underwood, 1973). In some of these studies, similarity of response terms was manipulated by varying judgments of synonymity (Kanungo, 1967; Osgood, 1946; Runquist & Marshall, 1963; Underwood, 1951; Young, 1955). For example, when B and B′ were synonyms or antonyms, interference was reduced (compared with unrelated control items) with synonyms but not with antonyms (Gladis & Braun, 1958; Young, 1955). Other studies manipulated the associative similarity of response terms as indexed by free association norms (Bastian, 1961; Martin & Dean, 1964; Postman & Stark, 1964; Shapiro, 1970). For example, interference was reduced in the A–B, A–B′ design when B and B′ were primary associates (Postman & Stark, 1964). Overall, it appears that related items can reduce both directed forgetting and interference.

Although Conway et al. (2000) did not examine interference levels in their study, it is reasonable to suspect that related items across the lists reduced RI and hence eliminated the directed forgetting costs. It is interesting that Conway et al. reported significant directed forgetting benefits, despite the lack of costs. The dissociation of costs and benefits is hard to reconcile with a single-process account like retrieval inhibition, because it is unclear why uninhibiting List 1 items did not reinstate PI on List 2 in the forget condition. Perhaps related items in Conway et al.'s study reduced RI to a greater extent than PI. If we assume that the size of the directed forgetting costs is more closely related to the degree of RI, whereas the benefits are tied more to the degree of PI, then the findings of Conway et al. can be explained.

The goal of the current article was to manipulate different types of item relatedness in order to explore the relationship between directed forgetting costs and benefits, and RI and PI. Although there are different approaches to indexing item relatedness, in the current article we used associative probabilities obtained from free association norms because they imply not only the strength of the relationship but also the direction of the associative relationship. On the basis of the evidence described in the next section, we propose to examine associative direction as an important factor that can mediate the influence of item relatedness on directed forgetting and interference.

Associative Direction as a Determinant of Item Relatedness

Modern research on associative variables demonstrates that words can be related in several different ways because they are embedded in associative networks (for reviews, see Nelson & McEvoy, 2005; Nelson, McKinney, Gee, & Janczura, 1998). Saying that word A is related to word B might mean different things if in addition to the strength with which they are related (e.g., probability of producing each other in free association), one considers also the direction of associative relationship as indexed by free association norms. For example, two words may share a *forward* (A $\rightarrow$ B) *unidirectional* relationship, such that word A elicits word B in free association, but B does not elicit A when it is independently normed. Alternatively, two words may share a *backward* (A $\leftarrow$ B) *unidirectional* relationship such that word B produces word A in free association, but A does not elicit B. If the two words mutually produce each other in free association when independently normed, they share a *bidirectional* (A $\longleftrightarrow$ B) relationship, although the strength of the backward and forward

[1] Alternative accounts of directed forgetting were also proposed and are discussed in greater detail in the General Discussion section.

associations is not necessarily identical. Finally, A and B may not be directly related to each other, but they may be indirectly connected to each other via mediators or other shared associates. In studying and identifying associative relationships, Nelson and McEvoy (2005) and Nelson et al. (1998) have demonstrated that the direction of the linking connections as well as their strength affects memory, with some connections facilitating memory more than others. For example, cues that share bidirectional associations with the target are more effective in retrieving the target than the cues that have only a forward connection to the target, which in turn are better than the cues with only a backward connection (e.g., Nelson & Goodmon, 2003).

Given that related items influence both interference and directed forgetting, and given that items can be related to each other in multiple ways, it is important to explore how different types of item relatedness, defined in part in terms of directionality, influence these effects. To the best of our knowledge, this is the first attempt to examine the influence of pre-existing directional relationships on the magnitude of interference and directed forgetting. Although many paired-associate studies have investigated how directional associations impact interference, these questions were primarily addressed by comparing forward (A–B) and backward (B–A) recall in a given paired-associate paradigm (e.g., A–B, A–C) to determine which conditions lead to interference or facilitation (for reviews, see Ekstrand, 1966; Horowitz, Norman, & Day, 1966; Kahana, 2002). In other words, earlier work has focused on examining the strengths of forward and backward episodic associations formed during the study of an A–B pair and their influence on interference (Asch & Ebenholtz, 1962). Our investigation, on the other hand, is aimed at examining how pre-existing directional relationships across the lists influence both interference and directed forgetting.

Current Studies

In two experiments, we varied four types of associative relationships between the two study lists to investigate their influence on directed forgetting and interference. We held one of the study lists constant (called the target list) and created four additional lists such that the items on these lists shared (a) a bidirectional relationship with the items on the target list, (b) a unidirectional forward relationship (List 1 → List 2 items), (c) a unidirectional backward relationship (List 1 ← List 2 items), or (d) were unrelated to the items on the target list. We implemented the target list, along with one of the four associative lists, in the list-method directed forgetting design. The main goals were to examine how different types of item relatedness influenced the magnitude of the directed forgetting effect, RI, and PI. In addition, we explored whether the conditions that influenced the magnitude of interference observed on a given list (RI on List 1 and PI on List 2), influenced the directed forgetting components in a similar way.

Experiment 1

Method

Participants

Participants were 192 undergraduate psychology students, who participated in exchange for course credit. They were tested individually.

Materials

The study materials were partly drawn from lists created and used by Nelson et al. (1998). Sixteen words were chosen to serve as the target list items. Four additional lists of 16 new items were selected, and each of these new lists along with the target list served as the study stimuli. Stimuli were presented to participants in lowercase letters with bold typeface. Each participant studied two 16-item lists, one of which was always the target list, whereas the second list contained items that shared one of the following four types of associative relationships with the target list:

1. Bidirectional condition. Each item on the second list shared a bidirectional relationship with an item on the target list (e.g., *chip* ←→ *potato*). The strength of the relationship in both directions was equated to the nearest extent possible; the average forward strength was .14, and backward strength was .15, according to free association norms (Nelson, McEvoy, & Schreiber, 2004).

2. List 1← List 2 condition. Every item on the second list had a unidirectional backward association with an item on the target list (e.g., *chip* ← *chisel*). The average forward strength was .00, whereas backward strength was .12.

3. List 1 → List 2 condition. Every item on the target list had a unidirectional forward association with an item on the second list (e.g., *chip* → *wood*). The average forward strength was .12, whereas backward strength was .00.

4. Unrelated condition. The words on both lists were unrelated to each other (e.g., *chip–guitar*). Both forward and backward strengths were .00.

Item properties. Although we manipulated between-list associations, we tried to minimize the within-list associations. Items on each list were unrelated to the remaining items on that list as well as the items on the next list (with an exception of their related item in the related conditions). We also controlled other pre-existing associative variables known to affect item memorability, such as associative set size, connectivity, and resonance, as well as item characteristics such as word frequency and concreteness. The lists and item characteristics are shown in Appendix A.

Procedure and Design

The procedure followed the standard list-method of directed forgetting. Each participant studied two lists of words that shared one of the four types of associative relationships with each other: They were either unrelated, bidirectional, related by forward List 1 → List 2 association, or by backward List 1 ← List 2 association. The target list served equally often as the first or the second study list. Note that counterbalancing the position of the target list produced four similar types of associative conditions, despite the reversal of the associative direction in the unidirectional conditions (see Figure 1).

Participants were tested individually. They were told to read each word aloud and to remember as many words as possible for a later test. Words appeared one at a time on a computer screen at a rate of 4 s per word. The presentation order of the items within the lists was randomized for each participant. After studying List 1, participants in the forget condition were informed that the first list was only for practice to familiarize them with the task and make them comfortable with the list length and presentation rate. They were told that there was no need to remember the items and

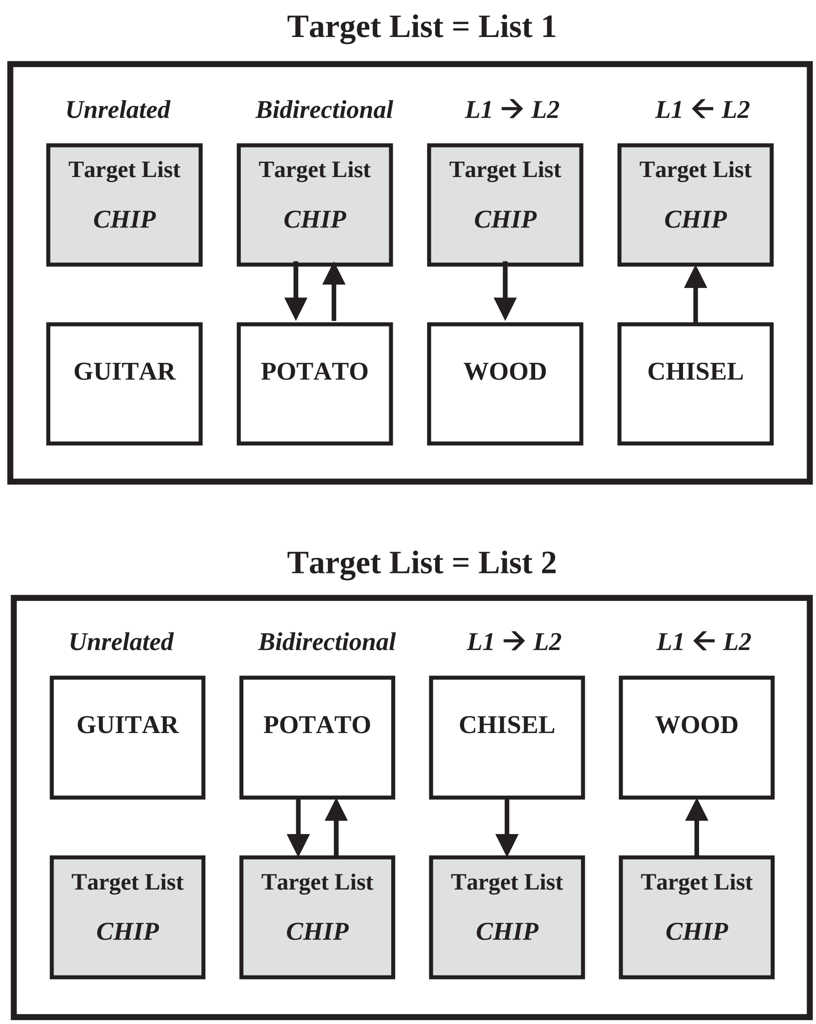

Figure 1. Design and experimental lists used in Experiment 1. L1 = List 1; L2 = List 2.

were encouraged to forget them. Participants in the remember condition were told that the list they studied was only the first half of the items, and they were told to try to remember it for a later test. Then both conditions studied the second list, which was followed by a filler task that involved counting backwards out loud by threes from a fixed predetermined number for 90 s. Upon completion of the filler task, participants were asked to recall the first list, followed by the second list. Recall of each list was carried out on separate sheets of paper, and participants were given 90 s to recall each list.

The design of the study thus formed a Cue (forget, remember) × Associative Direction (unrelated, bidirectional, List 1 → List 2, and List 1 ← List 2) × Study List (List 1, List 2) × Target List Position (first list, second list) mixed factorial, with the cue, associative direction, and target list position manipulated between-subjects and List varied within-subjects.

Results

In all reported analyses, the probability of Type I error was set at .05. Recall was scored by ignoring cross-list confusions, which did not occur frequently enough to permit meaningful analyses (the modal number of intrusion errors was 0 in all conditions).

To evaluate the influence of associative direction on recall, we conducted a Cue (forget, remember) × Associative Direction (unrelated, List 1 → List 2, List 1 ← List 2, bidirectional) × Target List Position (first list, second list) × Study List (List 1, List 2) mixed factorial analysis of variance (ANOVA), with study list as the only within-subjects factor. The target list position variable did not produce a main effect nor did it interact with any other variables in the study (all *F*s < 1). We therefore collapsed the data across this variable in all future analyses. The results are displayed in Table 1.

There was a significant Study List × Cue × Associative Direction interaction, $F(3, 184) = 2.96$, $MSE = 0.012$, $\eta^2 = .05$. Typically, the directed forgetting effect (e.g., the costs and the benefits) is captured by a Study List × Cue interaction. However, in the current study this effect depended on the associative direction condition. Therefore, we examined each associative direction condition separately.

Table 1
Proportion Recall as a Function of Cue and Associative Direction in Experiment 1

List	Cue	Unrelated	List 1 → List 2	List 1 ← List 2	Bidirectional
1	Forget	.20 (.02)	.23 (.02)	.25 (.02)	.38 (.03)
	Remember	.32 (.03)	.33 (.02)	.33 (.02)	.39 (.02)
2	Forget	.35 (03)	.38 (.03)	.35 (.03)	.37 (.03)
	Remember	.28 (.02)	.30 (.02)	.28 (.02)	.35 (.02)

Note. Values in parentheses are standard error of the mean.

Associative Direction and Directed Forgetting

In the unrelated lists condition, there was a significant Study List × Cue interaction, $F(1, 46) = 14.20$, $MSE = 0.016$, $\eta^2 = .24$. Follow-up tests revealed significant directed forgetting costs for List 1 recall, $t(46) = 3.42$ (.20 in the forget condition vs. .32 in the remember condition). There were also significant directed forgetting benefits for List 2 recall, $t(46) = 2.07$ (.35 in forget vs. .28 in remember).

In the List 1 → List 2 condition, there was a significant Study List × Cue interaction, $F(1, 46) = 14.60$, $MSE = 0.013$, $\eta^2 = .24$. Follow-up tests revealed significant directed forgetting costs for List 1 recall, $t(46) = 3.49$ (.23 in forget vs. .33 in remember). There were also significant directed forgetting benefits for List 2 recall, $t(46) = 2.39$ (.38 in forget vs. .30 in remember).

In the List 1 → List 2 condition, there was a significant Study List × Cue interaction, $F(1, 46) = 17.60$, $MSE = 0.008$, $\eta^2 = .28$. Follow-up tests revealed significant directed forgetting costs for List 1 recall, $t(46) = 3.37$ (.25 in forget vs. .33 in remember). The benefits for List 2 approached significance, $t(46) = 1.95$, $p = .06$ (.35 in forget vs. .28 in remember).

Finally, in the bidirectional condition, there were neither main effects nor an interaction (all Fs < 1), indicating that there were neither directed forgetting costs nor directed forgetting benefits in this condition.

Associative Direction and Interference

The next set of analyses was aimed at examining how associative direction influenced recall of List 1 and List 2 in the remember condition, because the latter serves as the baseline against which the effects of directed forgetting are compared. Recall of each list in the remember group might differ across associative direction conditions, presumably because of the varying amount of interference acting on the target list from the other list. Thus, we could examine how the associative direction influenced the magnitude of RI acting on List 1 and the magnitude of PI acting on List 2 in the remember condition.

RI. To evaluate the degree of RI, we subjected proportion List 1 recall in the remember condition to factorial ANOVA, using associative direction (unrelated, List 1 → List 2, List 1 ← List 2, bidirectional) and target list position (first list, second list) as the between-subject factors. The target list position produced neither main effects nor an interaction (Fs < 1), so the data were collapsed across this variable. Significant differences emerged in List 1 recall as a function of associative direction, $F(3, 92) = 2.66$, $MSE = 0.010$, $\eta^2 = .08$. Post hoc tests using Fisher's least significant difference (LSD) of .04 revealed that the bidirectional group recalled significantly more List 1 items (.39) than the unrelated group (.32), the List 1 → List 2 group (.33), and the List 1 ← List 2 group (.33). The last three groups did not differ from each other. These results indicate that there was significantly less build-up of RI in the bidirectional group compared with all remaining groups, which accumulated equivalent levels of RI.

PI. Similar analyses were performed on List 2 recall to evaluate the magnitude of PI. Significant differences emerged in List 2 recall as a function of associative direction, $F(3, 92) = 2.70$, $MSE = 0.012$, $\eta^2 = .08$. Post hoc tests using Fisher's LSD of .04 revealed that the bidirectional group recalled significantly more List 2 items (.35) than the unrelated group (.28), the List 1 → List 2 group (.30), and the List 1 ← List 2 group (.28). The last three groups did not differ from each other. Overall, it appears that there was less build-up of PI in the bidirectional group compared with the remaining conditions, which accumulated equivalent levels of PI.

Discussion

The results from the bidirectional condition revealed that there was no directed forgetting effect in this condition; neither the costs nor the benefits were significant. Furthermore, both RI and PI were reduced in the baseline remember condition compared with the unrelated condition. In other words, the results from interference analyses paralleled the findings from directed forgetting such that when both types of interference were reduced in the remember condition, the directed forgetting costs and benefits were not observed.

Although the bidirectional associations improved memory overall, the unidirectional associations were less successful in doing so. Neither types of interference nor the directed forgetting effect was reduced in the unidirectional conditions and the effects were comparable to what was observed with unrelated lists. However, it is important to note that the strength of the relationship between the words across the two lists was much weaker in the unidirectional conditions compared with the bidirectional condition, because by choosing items with a single associative link we might have inadvertently reduced the strength of the relationship. Thus, the null effect of unidirectional associations on directed forgetting and interference could be due to weaker associative strengths between the lists. To address this issue, in the next experiment we created a new target list along with four new associative direction lists in which we doubled the unidirectional strength.

Experiment 2

Method

Participants and Design

Participants were 432 undergraduate psychology students, who participated in exchange for course credit. They were tested in groups of no more than 5 participants at a time, with 24 participants in each of the 18 experimental conditions (see Figure 2).

The experimental design was identical to the previous experiment except that we included two reference conditions to allow estimating recall rates in the absence of RI and PI. These two reference groups, further referred to as the no-RI group ($n = 24$)

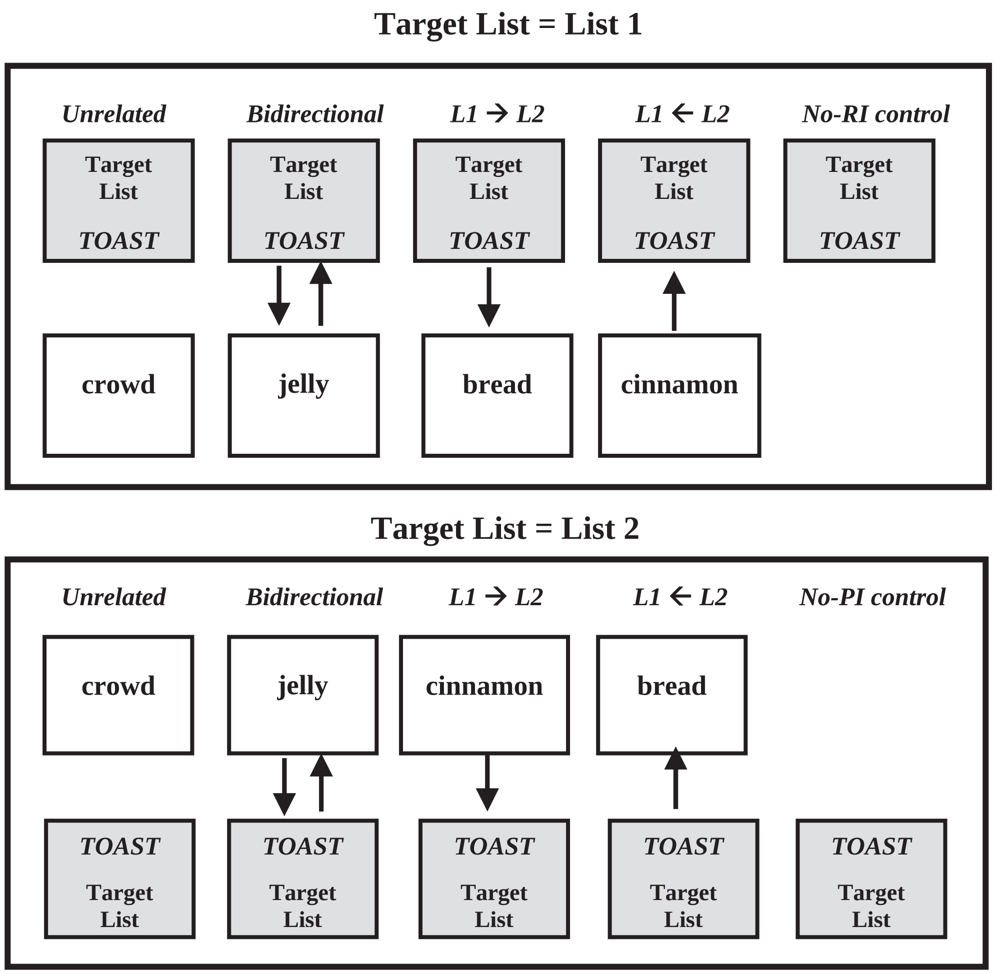

Figure 2. Design and experimental lists used in Experiment 2. L1 = List 1; L2 = List 2; no-RI = no retroactive interference group; no-PI = no proactive interference group.

and the no-PI group (n = 24), studied only the target list and were preoccupied with an unrelated arithmetic task during the time that the remaining participants studied the second list or the first list, respectively.

Materials

The lists were constructed according to the same principles as in Experiment 1, with the exception that we doubled the strength of the unidirectional associations. According to the University of South Florida free association norms (Nelson, McEvoy, & Schreiber, 2004), the bidirectional items had a forward strength of .14 and a backward strength of .13 with their respective targets. In the backward List 1 ← List 2 condition, items on the second list produced their respective targets with an average backward strength of .26 but were not produced by their targets (forward strength was .00). In the forward List 1 → List 2 condition, target items produced second list items with an average forward strength of .19 but were unlikely to be produced in turn by them (backward strength was .02). We increased the forward strength in the List 1 → List 2 condition to the greatest extent possible given the limited pool of related items having a high associative strength in one direction with no association in the reverse direction. Finally, in unrelated lists both forward and backward strengths were .00. As in Experiment 1, the remaining interitem associations both within lists as well as across the lists were minimized. Several preexisting variables known to affect item memory including set size, connectivity, resonance, word frequency, and concreteness were equated across the lists. The lists and their item characteristics are shown in Appendix B.

Procedure

The procedures were identical to Experiment 1, except that two additional reference conditions were tested to assess recall in the absence of PI and RI. The no-RI group studied only the target list using the standard remember instruction and was preoccupied with an unrelated arithmetic task while the remaining participants studied the second list. After performing the filler task involving counting backwards by threes for 90 s, the no-RI participants were asked to recall the items they studied. Similarly, the no-PI participants were first preoccupied with an unrelated arithmetic task while the remaining participants studied the first list and then proceeded to study only the second (target) list. Upon completion of the filler task, participants in the no-PI condition were asked to recall the items. The experimental lists (each followed by forget and remember instructions) are shown in Figure 2.

Results and Discussion

In all reported analyses, the probability of Type I error was set at .05. Recall was scored by ignoring cross-list confusions (the modal number of intrusion errors was 0 in all conditions). To evaluate the influence of associative direction on recall, we performed a Cue (forget, remember) × Associative Direction (unrelated, List 1 → List 2, List 1 ← List 2, bidirectional) × Target List Position (first list, second list) × Study List (List 1, List 2) mixed factorial ANOVA, with study list as the only within-subjects factor. The results are displayed in Figure 3 (top panel shows List 1, bottom panel shows List 2).

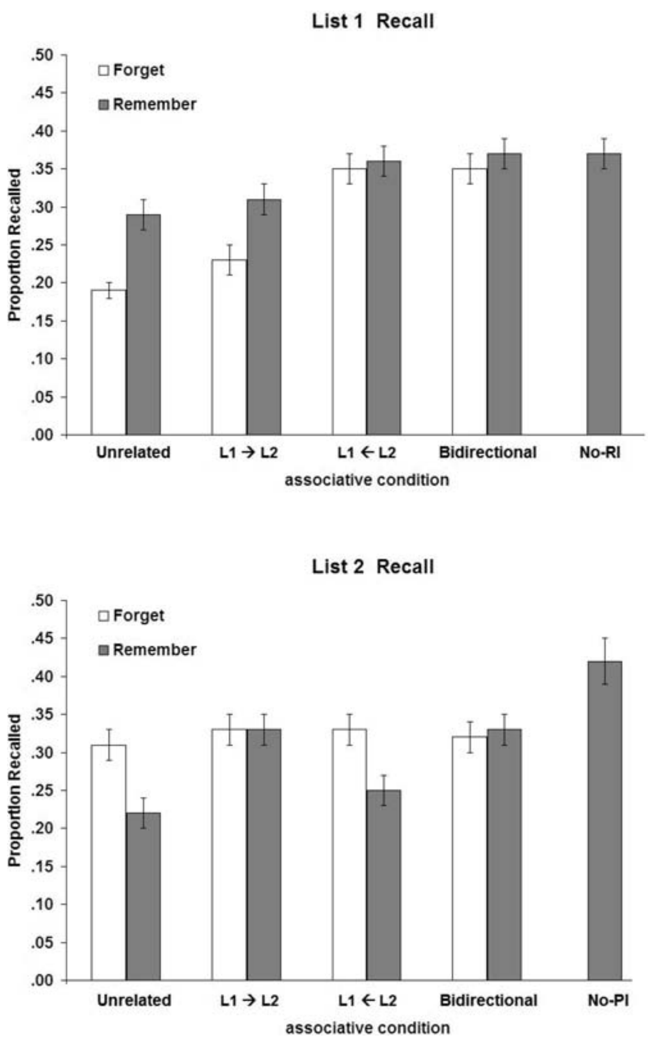

Figure 3. Proportion List 1 recall (top panel) and List 2 recall (bottom panel) by cue and associative condition in Experiment 2. In all conditions, List 1 was tested before List 2. Error bars represent standard error. L1 = List 1; L2 = List 2; no-RI = no retroactive interference group; no-PI = no proactive interference group.

There was neither a four-way interaction nor a three-way interaction involving the target list position (Fs < 1), but there was a significant Study List × Cue × Associative Direction interaction, $F(3, 368) = 4.96$, $MSE = 0.014$, $\eta^2 = .04$. The three-way interaction suggested that the directed forgetting effect depended on the associative direction. To further evaluate the interaction, we performed separate Study List × Cue analyses for each associative direction condition.

Associative Direction and Directed Forgetting

In the unrelated condition, the results revealed a significant Study List × Cue interaction, $F(1, 94) = 38.18$, $p < .001$, $MSE = 0.013$, $\eta^2 = .29$. There were significant directed forgetting costs for List 1 recall, $t(94) = 4.74$ (.19 in the forget condition vs. .29 in the remember condition), and also significant directed forgetting benefits for List 2 recall, $t(94) = 3.94$ (.31 in forget vs. .20 in remember).

In the bidirectional condition, there was no Study List × Cue interaction ($F < 1$). There were neither directed forgetting costs ($t < 1$; .35 in forget vs. .37 in remember) nor directed forgetting benefits ($t < 1$; .30 in forget vs. .29 in remember).

In the List 1 → List 2 condition, there was a significant Study List × Cue interaction, $F(1, 94) = 4.67$, $MSE = 0.017$, $\eta^2 = .05$. There were significant directed forgetting costs, $t(94) = 3.49$ (.23 in forget vs. .31 in remember). However, there were no directed forgetting benefits ($t < 1$; .33 in forget vs. .33 in remember).

Finally, there was also a significant Study List × Cue interaction in the List 1 ← List 2 condition, $F(1, 94) = 7.72$, $MSE = 0.014$, $\eta^2 = .08$. There were no directed forgetting costs ($t < 1$; .35 in forget vs. 36 in remember). However, the benefits of directed forgetting were significant, $t(94) = 2.95$ (.33 in forget vs. .25 in remember).

To summarize, we observed significant directed forgetting costs and benefits with unrelated lists. With bidirectional lists, however, neither the costs nor the benefits were significant. However, the unidirectional associative conditions revealed a double dissociation: In the List 1 → List 2 condition, there was a significant directed forgetting cost, but no significant benefits, whereas in the List 1 ← List 2 condition, there were significant directed forgetting benefits, but no significant costs.

Associative Direction and Interference

Given that certain associative direction conditions differentially affected the costs and benefits of directed forgetting, sometimes eliminating one component but not the other, it would be informative to examine how associative direction influenced interference in the remember condition. This would allow assessment of whether the magnitude of RI and PI in the remember condition parallels the results from the costs and benefits of directed forgetting.

RI. To evaluate the impact of associative direction on RI, we performed factorial ANOVA on proportion List 1 recall in the remember condition, using associative direction (unrelated, List 1 → List 2, List 1 ← List 2, bidirectional) and target list position (first list, second list) as between-subjects factors. The target list position produced neither a main effect, $F(1, 184) = 1.37$, $p = .24$, nor an interaction ($F < 1$), and therefore the data were collapsed across this variable.

There were significant differences in List 1 recall as a function of associative direction, $F(4, 207) = 4.01$, $MSE = 0.016$, $\eta^2 = .07$. Post hoc tests using Fisher's LSD of .05 showed that compared with the single-list no-RI group (.37), List 1 recall was significantly worse in the unrelated group (.29) as well as in the List 1 → List 2 group (.31), implying significant build-up of RI in the latter two conditions. Furthermore, the unrelated group and the List 1 → List 2 group did not significantly differ from each other. In contrast, both the bidirectional group (.37) and the List 1 ← List 2 group (.37) escaped from RI: Both groups were not significantly different from the no-RI group or from each other. Note that in the directed forgetting analyses reported above, the directed forgetting costs were found only in the conditions in which there was significant RI in the remember condition (i.e., unrelated and List 1 → List 2 conditions), but there were no costs in the conditions in which RI was eliminated (i.e., bidirectional and List 1 ← List 2 conditions).

PI. To evaluate the influence of associative direction on PI, we performed similar analyses on List 2 recall. There was a significant main effect of associative direction, $F(3, 184) = 10.57$, $MSE = 0.013$, $\eta^2 = .15$. There was also a significant main effect of the target list position, $F(3, 184) = 8.17$, $MSE = 0.013$, $\eta^2 = .04$, indicating that the target list was a slightly more difficult list compared with the remaining lists that served in the second study list position. List 2 recall was slightly worse when it was estimated from the target list items (.25) compared with when it was estimated from other lists that served in the second study list position (.29).

To more accurately estimate the amount of PI on List 2 across the associative conditions, we limited subsequent analyses to a subset of participants who studied the target list as their second list (see the bottom portion of Figure 2). Significant differences emerged across associative directions, $F(4, 115) = 13.41$, $MSE = 0.013$, $\eta^2 = .32$. Post hoc tests using Fisher's LSD of .05 showed that compared with the single-list no-PI group (.42), List 2 recall was significantly worse in the unrelated group (.20) and in the List 1 ← List 2 group (.22). The latter two groups did not significantly differ from each other, implying that they accumulated equivalent amounts of PI on List 2. In contrast, List 2 recall was significantly higher in the bidirectional group (.27) and in the List 1 → List 2 group (.28) compared with the unrelated group (.20), suggesting that PI was significantly reduced in these conditions. However, although PI was reduced compared with the unrelated group, it was not completely eliminated compared with the no-PI group. Note that the directed forgetting analyses above showed that the benefits of directed forgetting were observed in the conditions that accumulated significant PI (i.e., the unrelated group and the List 1 ← List 2 group), but there were no directed forgetting benefits in the conditions that showed reduced PI (i.e., the bidirectional group and the List 1 → List 2 group).

Mechanisms Relating Associative Direction and Directed Forgetting

In all associative conditions, the pattern of interference in the baseline remember group paralleled the presence or absence of the directed forgetting subcomponents (i.e., the costs and benefits). The unrelated lists, which produced significant RI and PI (compared with a single-list condition), yielded the standard directed forgetting effect: Both the costs and benefits were significant. In contrast, the bidirectional lists, which reduced both forms of interference, also eliminated the entire directed forgetting effect: Neither the costs nor benefits were significant. The unidirectional lists produced list-specific effects. That is, backward associations in the List 1 ← List 2 condition reduced memory effects associated with List 1 (e.g., RI and the directed forgetting costs), without influencing List 2 recall in the remember or forget conditions. In contrast, forward associations in the List 1 → List 2 condition reduced memory effects associated with List 2 (e.g., PI and the directed forgetting benefits), without affecting List 1 recall.

The mechanism by which backward associations improved List 1 memory must have operated at the time of List 2 learning (as opposed to the final test), because at the time of the final test, List 1 items were always recalled before List 2 items. This means that any memory advantage that List 1 items had gained from backward associations must have occurred before the final test. On the other hand, the mechanism by which forward associations improved List 2 recall could have operated either at the time of encoding or at the time of test (or both). When participants first encoded List 1 items, they likely automatically and implicitly activated their related concepts in memory (see Nelson & McEvoy, 2005), one of which was later encountered as a List 2 item. This implies that any List 2 item was potentially activated twice: once implicitly (during the study of List 1) and once explicitly (during the study of List 2). Implicit activation from forward associations at the time of learning could be one source of List 2 memory improvement. Alternatively, forward associations could have also improved List 2 memory at the time of final test, because List 1 items were always tested before List 2 and could prime and facilitate the retrieval of List 2 items (i.e., *retrieval facilitation).*

To better evaluate the mechanism by which forward associations enhanced List 2 memory, in the same semester we collected additional data from 96 participants using the reverse test order, in which we asked participants to recall List 2 first, followed by recall of List 1. We followed the same procedures as before and used the lists from the List 1 → List 2 condition (*cinnamon* → *toast*) and the bidirectional condition (*jelly* ←→ *toast*). Because forward associations were present not only in the List 1 → List 2 condition but also in the bidirectional condition, we also evaluated the bidirectional condition using the reverse test order. If bidirectional links improved memory by a simple combination of the effects produced by each of its unidirectional links, then the same mechanism responsible for the effects of the forward link in the unidirectional condition could operate also in the bidirectional condition: List 2 improvement could emerge at the time of learning from implicit activation or at the time of test from retrieval facilitation. Reversing the test order was aimed at evaluating these mechanisms. The unrelated and backward List 1 ← List 2 associative conditions were not evaluated with the reverse test order because (a) we were primarily interested in evaluating the mechanism of forward link, and (b) we detected significant directed forgetting benefits in unrelated and backward List 1 ← List 2 conditions using a more conservative test order, because prior research indicates that the benefits are much larger when List 2 is tested before List 1 (e.g., Golding & Gottlob, 2005).

A Cue (forget, remember) × Associative Direction (bidirectional, List 1 → List 2) × Test Order (recall List 2 first, recall List

2 second) factorial ANOVA on proportion List 2 recall revealed a significant three-way interaction, $F(1, 184) = 4.50$, $MSE = 0.014$, $\eta^2 = .03$ (see Figure 4). To follow up this interaction, we examined the List 1 → List 2 condition and the bidirectional condition separately.

Forward List 1 → List 2 condition. There was a significant Cue × Test Order interaction in the List 1 → List 2 group, $F(1, 92) = 9.67$, $MSE = 0.013$, $\eta^2 = .10$ (see left panel of Figure 4). The additional data with the reverse test order revealed that when List 2 was tested first, the directed forgetting benefits became significant, $t(46) = 3.99$. This is in contrast to what we found earlier (i.e., no benefits), when List 1 was tested first. The difference in findings was partly due to the remember group, who showed significantly worse List 2 recall when they retrieved List 2 first, compared with when they retrieved List 2 after List 1, $t(46) = 2.39$. Because the benefits are estimated in reference to the remember group, List 2 recall in the remember group is critical for detecting or masking the presence of directed forgetting benefits. The findings with the new test order are important because they suggest that the lack of directed forgetting benefits that was observed with the previous test order was due to retrieval facilitation aiding List 2 recall in the remember group. However, in the absence of help from List 1 items at the time of test, List 2 recall in the remember group did not improve and was comparable to the recall in the unrelated condition reported earlier. Another factor that contributed to detecting significant directed forgetting benefits with the reverse test order was the improved List 2 recall in the forget group: List 2 items were remembered better when they were tested first (.35) compared with when they were tested after List 1 (.28), $t(46) = 2.09$.

Although our central goal was to examine List 2 recall, for completeness we also analyzed List 1 recall. The costs of directed forgetting were significant as evidenced by poorer List 1 recall in the forget group (.20) compared with the remember group (.27), $t(46) = 2.02$. In other words, the directed forgetting costs were detected regardless of the test order.

To summarize, when List 2 was tested before List 1, both the costs and the benefits were significant in the List 1 → List 2 condition. However, when List 2 memory was tested after List 1, there was dissociation between the directed forgetting costs and benefits (significant costs, but no benefits). Overall, this pattern of data suggests that forward associations do not influence directed forgetting, unless at the time of final test certain testing orders create List 2 advantage for the remember group, reducing the directed forgetting benefits.

Bidirectional condition. There was no significant Cue × Test Order interaction in List 2 recall in the bidirectional condition ($F < 1$; see left panel of Figure 4). There was also no main effect of cue ($F < 1$), suggesting that the benefits of directed forgetting were not significant. Also, there were no significant directed forgetting costs in List 1 recall ($t < 1$; .33 in forget and .35 in remember). In other words, regardless of the test order there was no directed forgetting effect in the bidirectional condition.

Prior analyses showed that List 2 recall in the remember group improved (compared with the unrelated lists) when it was tested after List 1. Current analyses indicate that when List 2 was tested first, its recall remained the same and did not suffer. This is contrary to what was observed in the forward List 1 → List 2 condition, in which List 2 recall in the remember group suffered when it was tested first. We therefore conclude that the bidirectional associations must have benefited memory at the encoding stage rather than at the time of test, because reversing the testing order did not produce a List 2 memory decrement. These results also suggest that the simultaneous presence of both types of unidirectional links in the bidirectional condition produced an effect that is more than the sum of the effects attributable to each link independently.

General Discussion

In this article, we examined how cross-list directional associations influenced directed forgetting and the degree of interference observed on each list. Recall in the forget condition was related to the magnitude of interference observed in the remember condition. Furthermore, associative direction predicted the type of interfer-

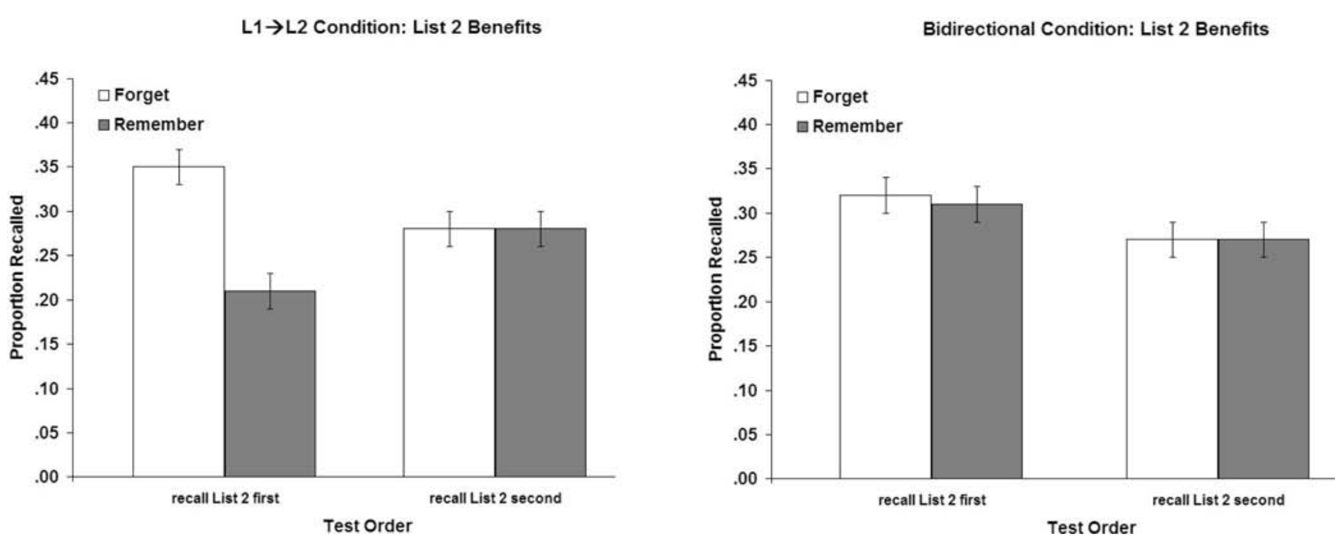

Figure 4. Proportion List 2 recall in forward List 1 → List 2 (L1 → L2) condition (left panel) and bidirectional condition (right panel) by cue and test order in Experiment 2. Error bars represent standard error.

ence and the component of the directed forgetting effect that was affected.

Compared with unrelated lists, bidirectional lists reduced both RI and PI in the baseline condition and also eliminated the entire directed forgetting effect: Neither the costs nor the benefits were significant. These results were obtained in both experiments by means of different materials and different testing orders. Unidirectional lists, on the other hand, affected recall differently in the two experiments. In Experiment 1, in which unidirectional strength was low, the results resembled those from the unrelated condition: Both the costs and benefits were significant, and neither RI nor PI was affected. However, doubling the strength of the unidirectional associations in Experiment 2 dissociated the costs and benefits, and it also eliminated either RI or PI. For example, backward List 1 ← List 2 associations reduced RI and the costs without affecting PI or the benefits, which remained significant. In contrast, forward List 1 → List 2 associations reduced PI and the benefits, but did not affect RI or the costs, which remained significant. Thus, the directed forgetting costs were related to the degree of RI, whereas the directed forgetting benefits were related to the degree of PI observed in the baseline condition.

The results of Experiment 1 imply that associative strength mediates the observed effects because weakly related lists did not influence recall. However, associative direction played an equally important role in Experiment 2. Doubling the unidirectional links' strength produced list-specific effects with unidirectional lists, whereas bidirectional links improved memory on both lists. Thus, both the strength and the direction of associative relationship were important.

Although the bidirectional condition seemingly reflects the sum of effects connected with forward and backward links, in fact the links contributed interactively rather than independently. If each link independently influenced recall, then eliminating one of them should not have eradicated the influence of the remaining link. However, when one link was eliminated from bidirectional items to create unidirectional lists in Experiment 1, the entire influence of associations disappeared and the effects resembled those obtained with unrelated lists. Furthermore, manipulating the test order in Experiment 2 dissociated the forward unidirectional condition and the bidirectional condition by affecting the former but not the latter. If the forward and backward links behaved independently in the bidirectional condition, then an experimental manipulation should have influenced both conditions rather than only the forward condition. Taken together, these results suggest that the simultaneous presence of both links in the bidirectional condition influences recall interactively.

Mechanisms of Influence of Directional Associations

In this section, we propose some mechanisms by which directional associations could have influenced recall.

Backward Associations

Compared with unrelated lists, backward associations enhanced List 1 recall in the List 1 ← List 2 condition and the bidirectional condition of Experiment 2. Not only did they reduce RI in the remember group, but they also eliminated the directed forgetting costs in the forget group.

If backward associations from List 2 reminded participants of List 1 items, they may have explicitly retrieved List 1 items during List 2 encoding. Retrieval could enhance the strength of List 1 items and increase their resistance to interference. In many memory models, the strength of the relationship between an item and the context in which it occurred is critical because it is related to the probability of retrieving that item in free recall (e.g., Gillund & Shiffrin, 1984). If List 1 items are retrieved during List 2 learning, they will become experienced in the contexts of both lists: once in List 1 and then again in List 2. Given that context serves as a retrieval cue in free recall, List 1 items are recalled with a greater probability in the List 1 ← List 2 condition or the bidirectional condition because they have a contextual advantage. Thus, the mechanism by which backward link enhances memory might be similar to the mechanisms that produce the benefits of spaced item presentations. Research has shown that repeated spaced presentations of an item enhance the strength of that item as well as the strength of contextual information encoded along with that item (Malmberg & Shiffrin, 2005).

Even if List 1 items are not explicitly retrieved, they may be implicitly reactivated during List 2 study. Research has shown that processing a familiar word activates its related concepts whether or not participants are consciously aware of this activation (for a review, see Nelson & McEvoy, 2005). Furthermore, implicitly activated memories are linked to context just like the consciously experienced items (Nelson, Goodmon, & Akirmak, in press). Therefore, even if List 1 items were only implicitly reactivated during List 2 learning, their recall could nonetheless benefit from the same processes described earlier.

Finally, if we assume that context is not fixed but rather fluctuates and drifts over time, producing natural forgetting (e.g., Mensink & Raaijmakers, 1988), then List 2 items may remind and reinstate the context of List 1, diminishing the degree of natural context drift between the two list episodes. In other words, the two list contexts may end up being more similar in the bidirectional and List 1 ← List 2 condition than in the unrelated condition, reducing forgetting caused both by directed forgetting and RI.

Forward Associations

Forward links enhanced List 2 memory only when something reminded people of List 1 items. In some cases, this happened during encoding and in other cases during test. During encoding, forward links alone did not enhance memory, as evidenced by equivalent List 2 recall in the List 1 → List 2 and unrelated condition, when List 2 was tested first. However, when forward link was present along with backward link, it significantly improved List 2 memory. For example, in the bidirectional condition, List 2 recall was better than in the unrelated condition, even when it was tested first. This implies that List 2 must have incurred memory advantage during encoding. If backward associations prompted retrieval of List 1 items during List 2 learning, then List 1 items could in turn prime List 2 items because of forward associations. Thus, the influence of forward associations during encoding was contingent on the presence of backward link, because the latter likely prompted retrieval of List 1 items.

During the test, forward link by itself significantly improved List 2 recall via retrieval facilitation: List 2 recall was significantly better in the List 1 → List 2 condition than in the unrelated condition, when List 1 items were retrieved first and facilitated List 2 recall. These findings are consistent with other research demonstrating that retrieval can occasionally improve rather than impair recall (Chan, McDermott, & Roediger, 2006; Nairne, Ceo, & Reysen, 2007). Overall, these results suggest that forward link can enhance memory only when it can capitalize on the presence of List 1 items, which must be highly accessible to facilitate List 2 memory.

Implications for Directed Forgetting Mechanisms

We now discuss the implication of the findings from the bidirectional conditions of both experiments and the unidirectional conditions of Experiment 2 for directed forgetting theories.

Bidirectional Condition

The overall absence of a directed forgetting effect in the bidirectional conditions is consistent with both single-factor and the dual-factor accounts of directed forgetting. According to the selective rehearsal account, the forget group stops rehearsing List 1 items, which leads to the costs of directed forgetting (Benjamin, 2006; R. A. Bjork, 1970; Sheard & MacLeod, 2005). Even if the forget group stopped rehearsing List 1 items, backward associations could nonetheless remind of List 1 items, thereby reversing the consequences of rehearsal termination. These findings are consistent with research demonstrating that related items also prevented the item-method directed forgetting (Golding, Long, & MacLeod, 1994), which is an effect attributed to selective rehearsal. In selective rehearsal account, the benefits occur because the forget group rehearses only List 2, whereas the remember group tries to maintain both lists in memory, which negatively impacts its List 2 encoding. If List 1 items are retrieved (or reactivated) during List 2 learning, they in turn strengthen List 2 items because of forward associations. The net result is an improvement in both lists and the elimination of the directed forgetting costs and benefits.

According to the retrieval inhibition account, List 1 items are inhibited in the forget group to overcome interference on List 2. The interference analyses showed that List 1 items were less likely to exert PI on List 2 items in the bidirectional condition, diminishing the need to invoke an inhibitory process, which could explain the absence of overall directed forgetting effect.

The null directed forgetting findings are also consistent with the dual-factor account, which explains the costs via a context-based mechanism and explains the benefits via a strategy-change mechanism (Sahakyan & Delaney, 2005). Backward associations from List 2 could retrieve and reinstate the context of List 1 items, thereby reducing contextual differentiation between the lists, and this could account for the lack of costs in the forget group. The strategy-based component of the dual-factor account attributes the directed forgetting benefits to better encoding of List 2 by the forget group (Sahakyan & Delaney, 2003). Note that List 2 recall in the remember group improved compared with the unrelated condition, whereas List 2 recall in the forget group remained unchanged between the unrelated and bidirectional conditions ($t < 1$). This suggests that the mechanisms that normally produce the benefits of directed forgetting were unaffected by bidirectional associations. However, because the benefits are typically estimated in reference to the remember group, they were not detected, because high List 2 recall in the baseline condition did not leave much room for detecting improvement in the forget group.

Forward List 1 → List 2 Condition

Forward associations did not influence the costs of directed forgetting, which were significant regardless of the test order. The benefits, on the other hand, were either significant or they were eliminated, depending on the test order. When List 1 was tested first and could facilitate the retrieval of List 2, there were no directed forgetting benefits because List 2 recall improved in the remember group (compared with unrelated lists) and did not leave much room for detecting the benefits in the forget group. In contrast, when List 2 was tested first, the directed forgetting benefits reemerged because List 2 recall in the remember group suffered. Overall, all existing accounts of directed forgetting are consistent with the findings in the List 1 → List 2 condition because forward associations did not influence directed forgetting unless at the time of test List 1 items were tested first and could improve List 2 recall in the remember group, thereby eliminating the benefits.

Backward List 1 ← List 2 Condition

Backward associations dissociated the directed forgetting costs and the benefits: The costs were eliminated, but the benefits remained significant. In the List 1 ← List 2 condition, we always tested List 1 first, and we did not use the reverse test order because prior research has demonstrated that the benefits are much stronger when List 2 is retrieved first (Golding & Gottlob, 2005). In other words, we detected significant benefits with a more conservative test order and so suspect that the benefits would have been even larger had we asked participants to retrieve List 2 first. It is interesting that Conway et al. (2000), using primary associates across the study lists, also reported no costs but significant benefits in their study. One could speculate that their primary associates might have had stronger backward strengths than forward strengths, and the absence of costs despite significant benefits would be consistent with the current findings.

The dissociation between the costs and benefits poses a challenge for single-process accounts that invoke the same underlying process to explain both components of directed forgetting. It is unclear why the benefits were significant even without forgetting List 1 items. According to the inhibitory account, the benefits are a consequence of reduced PI from inhibited List 1 items. However, why would PI not be reinstated when List 1 items were uninhibited? Similarly, on the basis of the selective rehearsal account it is unclear why retrieving List 1 items during List 2 learning did not hurt List 2 encoding in the forget group. If during rehearsal of List 2 items, backward associations prompted retrieval of List 1 items, the quality of List 2 rehearsal should have suffered in the forget group. However, the benefits remained significant although the costs were eliminated.

Because the dual-factor account attributes the costs and benefits to different mechanisms, it can explain the dissociation in the List 1 ← List 2 condition without additional assumptions. In the dual-factor account, the benefits do not depend on the presence or absence of costs because they are attributed to better encoding strategies, whereas the costs are considered a retrieval phenomenon emerging from contextual changes.

Conclusions

The current results reveal that associative relationships affected List 1 recall in both the forget and remember groups; conditions that eliminated RI in the remember condition also eliminated the directed forgetting costs. In contrast, associative relationships did not affect List 2 recall in the forget group, which remained unchanged across the associative conditions. This implies that the mechanisms that normally produce the directed forgetting benefits were unaffected. However, certain conditions improved List 2 recall in the remember group (i.e., reduced PI), thereby eliminating the benefits of directed forgetting, because the latter are estimated in reference to the remember group. Finally, the presence or absence of costs was not related to the presence or absence of benefits, suggesting that they have different underlying mechanisms (Sahakyan & Delaney, 2005).

Whether RI and directed forgetting costs stem from the same underlying mechanism or are simply correlated is not known for certain. However, the present results suggest that a variable that influenced RI also affected directed forgetting costs, implying that they may involve a shared mechanism. One possible shared mechanism involves context, which has been proposed as an explanation of both interference (e.g., Mensink & Raaijmakers, 1988) and directed forgetting (e.g., Sahakyan & Kelley, 2002).

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Appendix A

Item Characteristics and Stimulus Materials From Experiment 1

Table A1
Experiment 1 Associative Strengths and Item Characteristics Known to Affect Item Memory

List	Fsg	Bsg	Set size	Connm	Reso	Frequency	Concrete
Target							
M			15.44	1.37	.52	76.06	4.45
SD			4.98	1.02	.17	68.11	1.32
Bidirectional							
M	.15	.14	12.50	1.58	.54	104.56	4.68
SD	.07	.09	5.14	0.60	.15	203.62	1.89
Forward List 1 → List 2							
M	.11	.00	14.88	1.80	.34	53.19	4.73
SD	.06	.00	5.14	0.62	.21	109.08	1.27
Backward List 1 ← List 2							
M	.00	.12	14.19	1.49	.60	144.20	4.73
SD	.00	.05	5.10	0.65	.22	101.97	1.00
Unrelated							
M	.00	.00	15.75	1.90	.34	45.56	5.65
SD	.00	.00	4.70	0.73	.18	94.78	0.98

Note. Forward strength (Fsg), backward strength (Bsg), set size, connectivity (Connm), resonance (Reso), and concreteness (Concrete) values are taken from University of South Florida free association norms. Frequency values were taken from Kučera and Francis (1967).

(*Appendixes continue*)

Table A2
Study Items Used in Experiment 1

Target	Bidirectional	List 1 → List 2	List 1 ← List 2	Unrelated
chip	potato	wood	chisel	guitar
cover	blanket	book	wrap	gym
create	make	art	design	highway
cut	knife	pain	razor	hug
deny	admit	lie	forbid	item
hole	dig	ground	cave	driver
morning	early	night	breakfast	exit
paint	draw	color	smear	adventure
peace	calm	love	justice	bacteria
prison	cell	bar	dungeon	barn
puppy	kitten	love	pound	business
rose	petals	beauty	stem	calendar
stove	oven	cook	pot	jaw
sugar	spice	tea	cinnamon	knuckle
sun	beach	hot	squint	strain
zero	none	one	less	telescope

Appendix B

Item Characteristics and Stimulus Materials from Experiment 2

Table B1
Experiment 2 Associative Strengths and Item Characteristics Known to Affect Item Memory

List	Fsg	Bsg	Set size	Connm	Reso	Frequency	Concrete
Target							
M			12.69	1.67	.40	29.88	5.53
SD			4.67	0.59	.23	34.20	1.16
Bidirectional							
M	.13	.14	14.44	1.52	.45	36.19	5.71
SD	.10	.16	5.09	0.52	.16	64.36	0.50
Forward List 1 → List 2							
M	.26	.00	14.38	1.54	.21	18.69	5.52
SD	.08	.00	4.72	0.54	.16	20.40	1.08
Backward List 1 ← List 2							
M	.02	.19	14.38	1.48	.58	99.38	5.51
SD	.03	.17	4.79	0.69	.12	63.29	1.04
Unrelated							
M	.00	.00	12.88	1.65	.42	27.81	5.16
SD	.00	.00	3.50	0.33	.17	18.68	0.99

Note. Forward strength (Fsg), backward strength (Bsg), set size, connectivity (Connm), resonance (Reso), and concreteness (Concrete) values are taken from University of South Florida free association norms. Frequency values were taken from Kučera and Francis (1967).

Table B2
Study Items Used in Experiment 2

Target	Bidirectional	List 1 → List 2	List 1 ← List 2	Unrelated
bronze	medal	gold	copper	limb
cave	bat	dark	cavern	tie
chisel	tool	hammer	marble	accomplish
construction	building	build	builder	remedy
dungeon	dragon	prison	chamber	autumn
dust	rag	dirt	lint	tub
justice	court	peace	liberty	engine
log	fireplace	fire	cabin	moon
pound	ounce	dog	weigh	straw
razor	blade	cut	electric	hunt
sheet	blanket	bed	linen	choir
squint	glasses	eye	glare	gift
stem	flower	rose	root	sidewalk
tennis	racket	ball	racquetball	envelope
toast	jelly	bread	cinnamon	crowd
vegetable	broccoli	fruit	cauliflower	signal

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