Journal of Experimental Psychology:
Learning, Memory, and Cognition
2010, Vol. 36, No. 4, 920–937

0278-7393/10/$12.00 DOI: 10.1037/a0019338

Theoretical Implications of Extralist Probes for Directed Forgetting

Lili Sahakyan and Leilani B. Goodmon
University of North Carolina at Greensboro

In 5 experiments, the authors examined the influence of associative information in list-method directed forgetting, using the extralist cuing procedure (Nelson & McEvoy, 2005). Targets were studied in the absence of cues, but during retrieval, related cues were used to test their memory. Experiment 1 manipulated the degree of resonant connections from associates of the target back to the target. Experiment 2 varied the degree of connectivity of associates of the target. Experiment 3 varied the size of the associative neighborhood of the target. Experiment 4 varied the direct target-to-cue strength, and Experiment 5 varied the indirect strength between the cue and the target. Reliable directed forgetting impairment emerged in all experiments. Furthermore, directed forgetting reduced the effects of the associates contributing to the target activation strength (Experiments 1–2), and it also reduced the effects of the associates contributing to the cue–target intersection strength (Experiments 3–5). Together, these results support the context account and challenge the inhibitory interpretation of directed forgetting.

Keywords: directed forgetting, context change, cued recall, independent probes

Memory researchers have always been interested in the fundamental act of forgetting and the mechanisms by which memories become attenuated. Traditionally, the investigation of the forgetting processes has emphasized passive forms of forgetting, which arise unintentionally in response to changes in the environment or because of the accumulation of more traces in memory (for a review, see M. C. Anderson & Neely, 1996; Postman, 1971). In the past decade, however, there has been growing interest in the ability to retrieve appropriate memories and exclude inappropriate ones. Any system that uses memory must be able to identify some memories as more relevant than others and must be able to reduce the accessibility of unwanted information. Research on intentional forms of forgetting has shifted focus from viewing forgetting as a passive process that happens to people to viewing forgetting as a process over which people can exert control.

In the laboratory, intentional forgetting has been studied with a variety of paradigms, including the think/no-think (e.g., M. C. Anderson & Green, 2001), retrieval practice (e.g., M. C. Anderson, Bjork, & Bjork, 1994), and directed forgetting paradigms (e.g., R. A. Bjork, LaBerge, & LeGrand, 1968). In this article, we used the directed forgetting paradigm. However, instead of the more established free recall or recognition tests, we assessed directed forgetting in a novel way that involved the use of unstudied cues to test memory for the information that participants were instructed to forget. Such an approach allowed us to evaluate the leading theories of directed forgetting.

In directed forgetting studies, participants study some information and are subsequently told to forget certain portions of it. In the *list-method* version of the procedure, participants are told to forget an entire block of the items they studied earlier, whereas in the *item-method* version, participants are told to forget or remember on an item-by-item basis (e.g., Basden, Basden, & Gargano, 1993; MacLeod, 1999;). This article utilizes the list-method design, which typically involves presenting two lists of items to study for a later memory test. Following the first list, some participants are told to forget the first list because it was the practice list, whereas others are told to remember it because it was the first half of the study list. Everyone encodes the second list, which is followed by a memory test for both lists. Directed forgetting instructions impair recall of List 1 items and enhance recall of List 2 items in the forget group compared with the remember group; these are termed the *costs* and the *benefits* of directed forgetting, respectively (for reviews, see E. L. Bjork, Bjork, & Anderson, 1998; Johnson, 1994; MacLeod, 1998).

The aim of this article was to evaluate the two major theoretical explanations of directed forgetting—the inhibitory account and the context-change account. According to the inhibitory account, the forget instruction inhibits List 1 items, impairing their recall without altering their availability in memory (e.g., E. L. Bjork & Bjork, 1996, 2003; R. A. Bjork, 1989; Geiselman, Bjork, & Fishman, 1983). "Inhibition merely limits retrieval by reducing activation of unwanted items" (M. C. Anderson, 2009, p. 224). As List 1 items become inhibited, they interfere less with List 2 items, thereby producing the benefits of directed forgetting. The proponents of the inhibitory view have argued that inhibition can be released with the provision of appropriate cues. For example, the absence of directed forgetting on recognition tests or implicit fragment completion tests was interpreted as evidence of release of inhibition resulting from the re-exposure of to-be-forgotten (TBF) items on these tests (Basden et al., 1993; E. L. Bjork & Bjork, 1996). Also, in some studies, a free recall test was

---

Lili Sahakyan and Leilani B. Goodmon, Department of Psychology, University of North Carolina at Greensboro.

We are grateful to Alyson Gurr, Alexandra Kueider, Steven Minor, Cory Viklund, Catherine Patteson, and Nathaniel Foster for their help in data collection and scoring.

Correspondence concerning this article should be addressed to Lili Sahakyan, Department of Psychology, University of North Carolina at Greensboro, 296 Eberhart Building, P.O. Box 26170, Greensboro, NC 27402-6170. E-mail: l_sahaky@uncg.edu

administered both before and after some intervening activities, and depending on the nature of the intervening task, directed forgetting was occasionally released on the final test compared with the initial test (e.g., Basden et al., 1993; E. L. Bjork & Bjork, 1996). For example, an intervening recognition test that included TBF items as distractors released directed forgetting on the subsequent recall test (Basden et al., 1993; E. L. Bjork & Bjork, 1996). In contrast, when recall was delayed by intervening arithmetic (Basden et al., 1993; E. L. Bjork & Bjork, 1996) or by an implicit fragment completion task that included TBF items (E. L. Bjork & Bjork, 1996), then directed forgetting was not released. E. L. Bjork and Bjork (1996) noted that it is not the mere exposure to TBF items that releases them from inhibition but rather the processes initiated by the intervening task; these processes reverse directed forgetting if they redirect attention to the original study episode. Thus, a recognition test is an explicit test that directs attention to the study episode as opposed to the implicit fragment completion test, which does not invoke such processes. These observations suggest that the reinstatement of contextual information associated with encoding of TBF items might be the key factor underlying the release phenomena.

Indeed, another theoretical explanation of directed forgetting invokes contextual factors rather than inhibition as the basis of directed forgetting. According to the context-change account of directed forgetting, the forget instruction encourages participants to change their mental context between the lists, thereby segregating the two lists as separate events (Sahakyan & Kelley, 2002). The impairment arises because at the time of test, context better matches the context that was prevalent during the encoding of List 2 than List 1, producing forgetting of List 1 items in the forget group. The benefits of directed forgetting arise because contextual differentiation reduces interference between the lists. Although many studies have not obtained directed forgetting in recognition, recently there have been several reports of significant effects in recognition (e.g., Benjamin, 2006; Sahakyan & Delaney, 2005), particularly when the conditions of recognition promoted the importance of contextual information (e.g., Lehman & Malmberg, 2009; Sahakyan, Waldum, Benjamin, & Bickett, 2009). In contrast, when contextual information is irrelevant to the task, as is the case with implicit memory tests, then directed forgetting is not obtained (e.g., Basden et al., 1993; E. L. Bjork & Bjork, 1996). Thus, the presence or absence of directed forgetting in recognition or implicit tests can also be explained in terms of the conditions that encourage utilization of contextual information. Likewise, the release of directed forgetting from certain types of intervening tests can be explained by reinstatement of the context associated with encoding of TBF items. In prior research, mentally reinstating the episodic context of TBF items before the final test reduced directed forgetting even in the absence of any re-exposure to TBF items (e.g., Sahakyan & Kelley, 2002).

In this article, we utilized a novel procedure for examining the directed forgetting theories, by using the extralist cuing technique, pioneered by Nelson, McEvoy, and their colleagues (for a review, see Nelson & McEvoy, 2005). The technique involves presenting target words for study and later testing people with cue words that are related to the targets but were not studied with them—hence the name *extralist*. For example, participants may study the target word *dinner* and receive the test cue *lunch* to help them retrieve *dinner*. Performance on this task is influenced both by the target characteristics and the cue characteristics (for reviews, see Nelson, McKinney, Gee, & Janczura, 1998; Nelson & Zhang, 2000). Extralist cuing allows us to independently manipulate the cue characteristics while holding the target characteristics constant (or vice versa). This aspect of the procedure is appealing because it enables us to contrast the inhibitory account and the context account of directed forgetting. The two accounts make opposing predictions for our experiments, and we describe them in greater detail in the sections that follow.

To date, little is known about how directed forgetting might behave in extralist cued recall. Only one study so far has used an extralist cuing procedure in directed forgetting (Basden et al., 1993). Participants studied the second word of associatively related word pairs and later received the first word as a cue to help them retrieve the second word. Basden et al. (1993) reported better recall for to-be-remembered (List 2) compared with TBF (List 1) items in the forget group; there was no remember group included in the design. Although in the past some investigators have assessed directed forgetting by comparing recall between the lists in the forget group, this method confounds directed forgetting with numerous other factors, including recency (for a review, see M. C. Anderson, 2005), and it does not allow for the estimation of directed forgetting costs and benefits because assessing these effects requires comparisons with the remember group. In other words, because the costs and the benefits cannot be evaluated without the remember group, it remains an empirical question whether they can be obtained with extralist cued recall. In the sections that follow, we briefly review the research on the implicit variables that we manipulated in this article. Some of the variables describe the properties of the targets, whereas others refer to the properties of the test cues. To set the stage for the predictions of directed forgetting theories, we first discuss the processes implicated in extralist cued recall, including how disruptions of episodic context influence performance on this task.

Implicit Associations and Their Influence in Extralist Cued Recall

Much evidence shows that encoding a familiar word implicitly activates its related concepts from past experiences (e.g., J. R. Anderson, 1983; Kintsch, 1988; Nelson, Schreiber, & McEvoy, 1992). Although the associates of the target are not consciously experienced, they produce systematic effects in memory (for reviews, see Nelson & McEvoy, 2005; Nelson et al., 1998; Nelson & Zhang, 2000). Nelson et al. (1998) used free association to measure the associative structures of many words and have shown that words differ in how many associates they have and in the patterns of connections among them. The probability that any word is produced in response to another word in free association is taken as a measure of relative strength between the words.

Free association measurements may or may not be representative of the associative structure of a single individual (e.g., Bilodeau & Howell, 1968; Fox, 1968; Simpson & Voss, 1967). Clearly, there is variability both between people because of differing experiences (e.g., heavy drinkers have stronger associations to the word *alcohol* than light drinkers; Reich & Goldman, 2005) and within a given individual as a result of recent experience. However, the norms are not used to predict individual participant data but rather performance of similar groups of participants. Research suggests that free association measures capture the key aspects of preexisting lexical experience with high reliability (Nelson, Dyrdal, & Goodmon, 2005; Nelson, McEvoy, & Dennis, 2000) and that they are useful in predicting free recall (Deese, 1965), cued recall (Bahrick, 1970), recognition (Nelson et al., 1998), and false memories (Deese, 1959; McEvoy, Nelson, & Komatsu, 1999).

Implicit Variables

Several robust findings have emerged from research on preexisting associations. We limit the discussion to five variables that were examined in relationship to directed forgetting (for additional variables, see Nelson et al., 1998). The number of associates that the target produces in free association (known as the size of the network) affects extralist cued recall, with targets with smaller networks having a recall advantage compared with targets with larger networks of associates (Nelson & Friedrich, 1980; Nelson et al., 1998; Nelson & Schreiber, 1992). Also, targets whose associates are more connected to each other are more likely to be recalled than targets whose associates are less connected to each other (Nelson, Bennett, Gee, Schreiber, & McKinney, 1993). Finally, targets whose associates produce them as a response in free association are better recalled than targets whose associates are less likely to produce them (Nelson et al., 1998). In addition to the target characteristics, cue characteristics also affect extralist cued recall. For instance, associates that are strongly activated by the target during encoding are more effective retrieval cues for that target compared with weakly activated associates (e.g., Nelson & McEvoy, 1979). Furthermore, indirect connections between the test cue and the target also affect cued recall (e.g., Nelson et al., 1998).

The most critical finding that motivated the experiments in this article concerns the effect of contextual disruptions on implicitly activated information. In particular, conditions that block or disrupt the retrieval of episodic contextual information were shown to reduce the influence of implicit variables on memory. For example, set size effects and connectivity effects are reduced after contextual disruptions (Nelson, Goodmon, & Akirmak, 2007; Nelson, McEvoy, Janczura, & Xu, 1993; Nelson et al., 1998) and so are the effects of direct and indirect connections between the target and the cue (Nelson & Goodmon, 2002). In some studies, access to context was manipulated by giving the test in a new physical location (Nelson & Goodmon, 2002; Nelson, Goodmon, & Ceo 2007) or by introducing test delays of increasing durations (Nelson, Goodmon, & Akirmak, 2007). Other studies have used tests that discourage the use of context during the test, such as primed free association (Goodmon & Nelson, 2004; Nelson, Goodmon, & Akirmak, 2007). In all of these studies, the effects associated with implicit variables were reduced.

Explaining Extralist Cued Recall

To explain these findings, Nelson and colleagues developed a theoretical model, according to which two key processes are involved in extralist cued recall—the target activation process and the cue–target intersection process (for computational details, see Nelson, Goodmon, & Ceo, 2007). Target activation is an *integrating* process that involves parallel activation of the target's associates and the links that connect the associates to one another when the target is initially processed. It is described by adding the strengths of all the links in the associative network (i.e., the strengths of target-to-associates connections, associates-to-target connections, and associate-to-associate connections). Higher values indicate stronger target activation and lead to better memory. This explains the memorial advantage of targets that have more links between their associates as well as the advantage of targets that have more links from their associates—known as the *connectivity effect* and the *resonance effect.* Both of these effects are thought to emerge during the learning stage, and they are found also in recognition tests (Nelson, Zhang, & McKinney, 2001).

When the test cue is presented at the time of test, it activates its own associates, just as the target did during encoding. During the retrieval stage, a *separating* process selects the target from the associates activated by the cue and the associates activated by the target. The success of the intersection process is influenced by the connections that bind the target and the cue together as well as by the connections that fail to join them. Figure 1 shows examples of linking and nonlinking connections between a hypothetical target and its test cue. Whereas the linking connections between the cue and the target facilitate memory, the nonlinking connections become a source of interference that impairs memory. As the size of the associative neighborhood increases, so does the number of the nonlinking connections in that network, which accounts for the negative effects of the set size (Schreiber, 1998; Schreiber & Nelson, 1998). The model describes the intersection process with a ratio rule, which is a function of contrast between the strength of

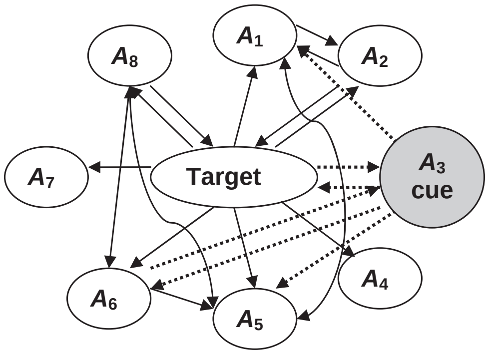

Figure 1. This figure shows the associative network of a hypothetical target, which produces eight associates (A_1–A_8) in free association. The length of links and the distances between the associates are drawn arbitrarily. The dotted lines represent the associative links involving the hypothetical test cue (A_3). Note that associates outside of the target's network can also serve as test cues. Two types of direct connections link the cue and the target together—the target-to-cue association and the cue-to-target association. Increases in strength in both directions independently facilitate recall (Nelson, Fisher, & Akirmak, 2007; Nelson & McEvoy, 1979; Nelson et al., 1998). There are also indirect connections between the cue and the target that can facilitate recall. For example, associates A_1, A_5, and A_6 are *shared associates* because both the target and the test cue produce them. The more indirect associations there are between the cue and the target, the more successful the cue is in retrieving the target (Nelson & Goodmon, 2002, 2003; Nelson & McEvoy, 2002; Nelson et al., 1998). Finally, there are nonlinking connections that do not bind the test cue and the target together. For example, associates A_2, A_4, A_7, and A_8 are unique to the target because they are not linked to the cue. Such associates are *competitors*, and they lower the probability that the target will be chosen in the presence of the test cue (Nelson et al., 1998).

the linking connections relative to the strength of the nonlinking connections.

Finally, to explain the effects of contextual disruptions, the model adopts an interactive cuing assumption. It proposes that the extralist cue and the episodic context cues combine together in a multiplicative way to retrieve the target. Episodic contextual information encoded along with the target is critical in the retrieval process in part because it helps to differentiate the target from other associates activated by the cue.

Current Studies and Predictions of Directed Forgetting Theories

We report five experiments that crossed directed forgetting with several associative variables. The first two experiments manipulated variables that influence the target activation strength, including target resonance (Experiment 1) and target connectivity (Experiment 2). The next three experiments manipulated variables that influence the cue–target intersection strength. These involved varying target set size (Experiment 3), direct target-to-cue strength (Experiment 4), and indirect strength between the target and the cue (Experiment 5). We did not manipulate the explicit encoding strength, because explicit encoding strength (varied through levels-of-processing, study time, or spaced repetitions) does not interact with implicit variables and has only an additive contribution to recall (Nelson, Bennett, et al., 1993; Nelson, Bennett, & Leibert, 1997; Nelson, Fisher, & Akirmak, 2007; Nelson & Goodmon, 2002; Nelson, McEvoy, et al., 1993; Nelson, McEvoy, & Schreiber, 1990; Nelson et al., 1992).

Because episodic contextual disruptions were shown to reduce the effects of implicit variables, these findings have implications for the contextual account of directed forgetting. The latter predicts effects similar to those produced by the disruption of context found in prior studies. That is, implicit associates should show reduced effects in the forget group compared with the remember group, producing an interaction between the manipulated implicit variable and directed forgetting. Furthermore, directed forgetting should interact with all implicit variables regardless of whether the study manipulates the variables involved in the target activation or the cue–target intersection process. This prediction results from the interactive cuing assumption of Nelson, Goodmon, and Ceo's (2007) model, which explains how disruptions in context affect extralist cued recall.

The inhibitory account does not make the same predictions, and one could even argue that it makes the opposite predictions in some experiments, considering its assumptions. For Experiments 1–2, which manipulated the target activation level, it is not obvious why highly activated targets should suffer more from directed forgetting than weakly activated targets (as predicted by the context account). If anything, one would expect the opposite, because highly activated targets may be harder to inhibit. For Experiments 3–5, which manipulated the intersection strength variables, the inhibitory account would predict the opposite of the context account. Whereas the context account predicts a reduced effect of the cue strength in the forget condition compared with the remember condition, the inhibitory account predicts an enhanced effect of the cue strength in the forget condition. This is because the inhibitory account assumes that items can be released from inhibition with appropriate cues. If inhibition can be released, then one would expect that stronger cues would be more effective at releasing the items from inhibition than weaker cues, resulting in a larger effect of the cue strength in the forget than the remember condition. Overall, unlike the context account, the inhibitory account does not predict reduced effects of implicit variables in the forget group in any of the experiments.

Section 1: Target Activation Variables

Experiment 1: Resonance

Words vary in terms of the likelihood that their associates produce them in turn in free association. For some items, most of their associates produce them as a response in free association, whereas for other words, few of their associates produce them as a response. This property of the words has been termed *resonance* (Nelson et al., 1998). Figure 2 shows two hypothetical targets with similar associative set sizes but different degrees of resonant

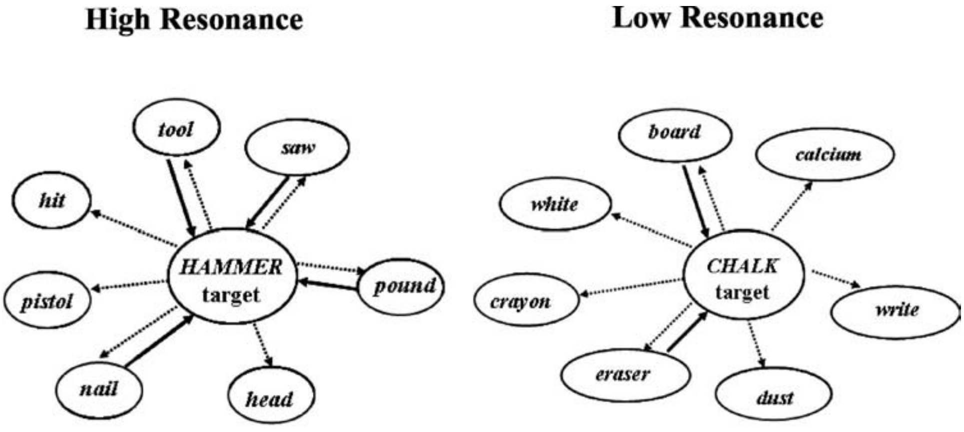

Figure 2. Associative map of targets with high and low resonant connections from the associates back to the target. Resonant links are shown with bold arrows.

connections. The word *CHALK* is a low resonance item because only two of its associates produce it in free association (e.g., *board* and *eraser*), whereas the word *HAMMER* is a high resonance item because four of its associates produce it in free association (e.g., *tool*, *nail*, *pound*, and *saw*). Items with more extreme resonance characteristics also exist, such that either none of their associates produce them in free association (e.g., *airport*) or all of their associates produce them in free association (e.g., *circle*).

Studies have shown that targets with more and stronger resonant links are more likely to be recalled in extralist cued recall (e.g., Nelson et al., 1998). The memorial advantage of items with high resonance is known as the *resonance effect*. Resonance represents a source of target activation strength, and its effect is independent of connectivity of associates in the network of the target (Nelson, McEvoy, & Pointer, 2003).

To the best of our knowledge, there have been no studies examining the effect of contextual disruption on the resonance effect. Thus, it remains an empirical question whether directed forgetting is affected by resonance. On the basis of the context account and the prior research on disruptions of context in the extralist cued recall, we expected an interaction between these variables, with directed forgetting reducing the magnitude of the resonance effect.

Method.

Participants and design. Participants were 72 undergraduates at the University of North Carolina at Greensboro who took part in the study in exchange for course credit. The experimental design was a 2 × 2 mixed-factorial design, with resonance (high, low) manipulated within subjects and instruction (forget, remember) manipulated between subjects.

Materials. We selected 32 words from the University of South Florida Free Association Norms (Nelson, McEvoy, & Schreiber, 1999) to serve as targets for two unrelated 16-item study lists. An additional 32 words served as test cues, one per target item. Targets were unrelated to each other, and cues were unrelated to each other. Each cue word was related only to a single target. In selecting cue–target pairs, we controlled the variables that are known to influence recall except for the associations involved in target resonance. This was accomplished with the help of a computer program called ListChecker. When target resonance was high, the probability that the associates in the target's network produced the target in free association averaged .70 ($SD = .09$), with the sum of associate-to-target strengths averaging 2.49 ($SD = 0.48$). When target resonance was low, the probability of resonant connections averaged .24 ($SD = .06$), with the sum of associate-to-target strengths averaging 1.16 ($SD = 0.15$). Whereas target resonance was varied, other variables were controlled across the resonance conditions. These included target set size ($M = 15.16$, $SD = 2.67$), target competitor strength ($M = .61$, $SD = .14$), target connectivity as indexed by the number of associate-to-associate connections ($M = 1.63$, $SD = 0.52$) and the sum of those connection strengths ($M = 2.96$, $SD = 1.17$), target concreteness on a 1–7 scale ($M = 5.02$, $SD = 1.38$), and target printed frequency ($M = 57.00$, $SD = 40.03$; Kučera & Francis, 1967). We also controlled cue set size ($M = 15.34$, $SD = 2.69$), cue competitor strength ($M = .51$, $SD = .14$), cue concreteness on a 1–7 scale ($M = 5.08$, $SD = 1.26$), and cue printed frequency ($M = 43.44$, $SD = 49.09$). Finally, direct and indirect associations between the cue and the target were also held constant across the resonance conditions. Direct cue-to-target strength averaged .05 ($SD = .02$), and direct target-to-cue strength averaged .04 ($SD = .03$). Indirect strength involving shared associates and mediators was also controlled. Shared associate strength averaged .02 ($SD = .02$) and mediated associate strength averaged .01 ($SD = .02$).

Procedure. Participants were tested individually. Each participant studied two lists of items, with half the items in each list being high-resonance targets and the remaining items being low-resonance targets. The position of the two lists was counterbalanced during presentation. Participants were told to read each word and to try to remember the words for a later unspecified memory test. The words were presented one at a time on a computer screen at a rate of 4 s. The presentation order of high- and low-resonance targets within each list was randomized. After the first list, participants in the forget condition were informed that the first list was only for practice, that there was no need to remember the items, and that they should try to forget them. Participants in the remember condition were told that the list they studied was only the first half of the items and that they should remember them for a later test. Both forget and remember groups then studied the second list of targets. Afterward, all participants received an extralist cued recall test for items from both lists. They were told that meaningfully related cues were going to be presented to help them remember the studied words. They were instructed to use each cue to recall a related item from either the first list or the second list. The experimenter further clarified to the forget group that the first list referred to the practice list and that they should try to retrieve both the practice items and the second list items in response to the test cues. Participants were told that if no word from either list came to mind, they could guess. Guessing instructions are typical in extralist cuing studies because prior research has shown that the magnitude of the implicit variable effects is unaffected by whether the test instructions require, merely encourage, or forbid guessing (e.g., Nelson et al., 1992). Cues for both lists were randomly combined and presented one at a time on the computer screen. Participants made their responses aloud, and the experimenter recorded them. Testing was self-paced. We tested both lists simultaneously rather than separately because the testing procedure was under the control of the experimenter, reducing the potential for output interference at the time of test. In contrast, in free recall, participants could start their recall from List 2 items, thereby confounding directed forgetting with output interference. Therefore, in free recall, each list is usually tested separately, whereas simultaneous testing is more common with other memory tests, such as recognition (e.g., Benjamin, 2006; MacLeod, 1999; Sahakyan & Delaney, 2005), or implicit tests (e.g., Basden et al., 1993; E. L. Bjork & Bjork, 1996).

Results.

Directed forgetting costs. To analyze the costs of directed forgetting, a Resonance (high, low) × Instruction (forget, remember) mixed-factorial analysis of variance (ANOVA) was conducted on the proportion of List 1 recall, with instruction as the between-subjects variable. The results are shown in Figure 3 (top panel). There was a main effect of resonance, $F(1, 70) = 9.27$, $MSE = 0.015$, $p < .01$, $\eta^2 = .12$, indicating better List 1 memory for high-resonance targets (.31) than low-resonance targets (.25). There was also a main effect of instruction, $F(1, 70) = 9.89$, $MSE = 0.016$, $p < .01$, $\eta^2 = .12$, indicating that the remember group participants recalled more List 1 items (.32) than the forget

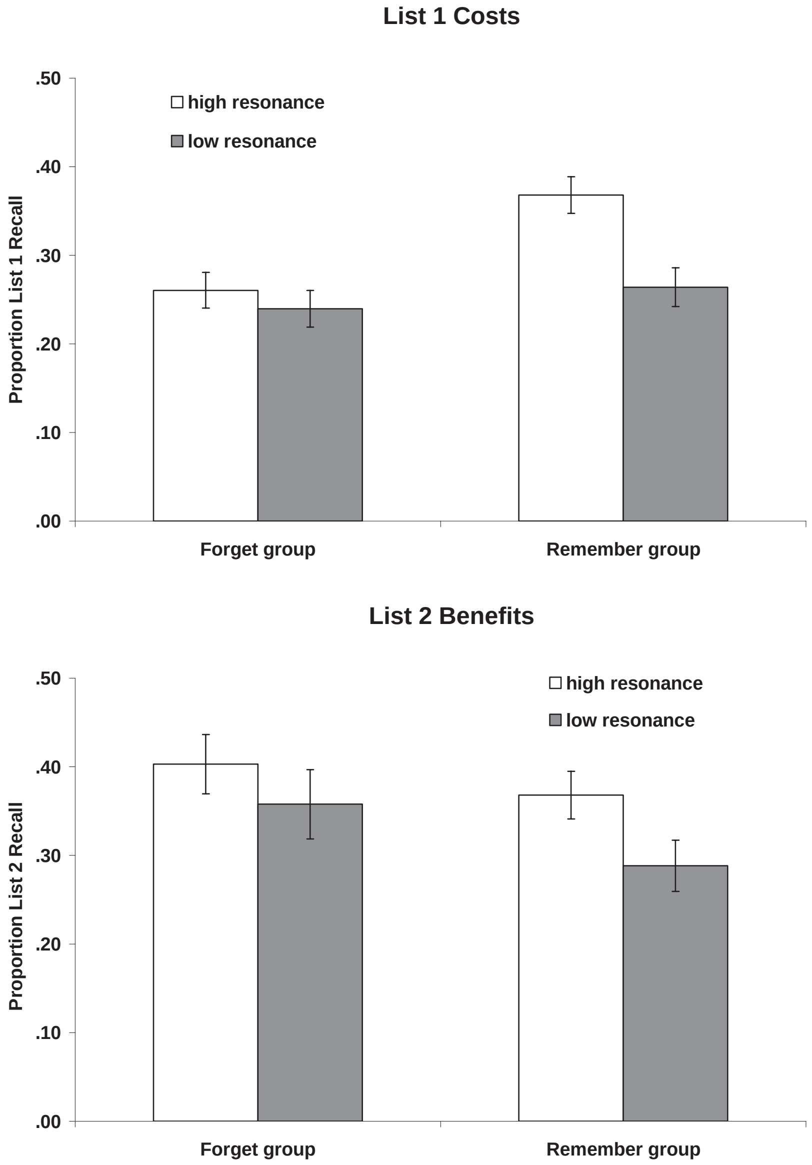

Figure 3. List 1 recall (top) and List 2 recall (bottom) as a function of associative resonance in Experiment 1. Error bars represent standard error of the means.

group participants (.25). The Instruction × Resonance interaction was also significant, $F(1, 70) = 4.12$, $p < .05$, $\eta^2 = .06$. There was an 11% resonance effect in the remember condition, $t(35) = 3.21$, $p < .01$, and a substantially reduced resonance effect (3%) in the forget condition ($t < 1$).

Directed forgetting benefits. To analyze the benefits of directed forgetting, similar analyses were carried out on the proportion of List 2 recall. The results are shown in Figure 3 (bottom panel). There was a main effect of resonance, $F(1, 70) = 6.41$, $MSE = 0.022$, $p < .05$, $\eta^2 = .08$, indicating better List 2 memory for high-resonance targets (.38) than low-resonance targets (.32). There was no main effect of instruction, $F(1, 70) = 1.83$, $p = .18$ (.38 in the forget and .32 in the remember group). There was also no interaction ($F < 1$). These results suggest that regardless of the resonance condition, there were no significant directed forgetting benefits. Although numerically the effect was in the right direction, it was not significant.

Experiment 2: Connectivity

Words vary in terms of the density of connections among the associates in their associative network—that is, the extent to which the associates of a target produce each other when they are independently normed. This property of the word has been termed *connectivity* (Nelson et al., 1998). Figure 4 shows two hypothetical targets with similar associative set size. However, the associates of the target word *POLITE* are more densely connected to each other than the associates of the target word *CORK*. Research has shown

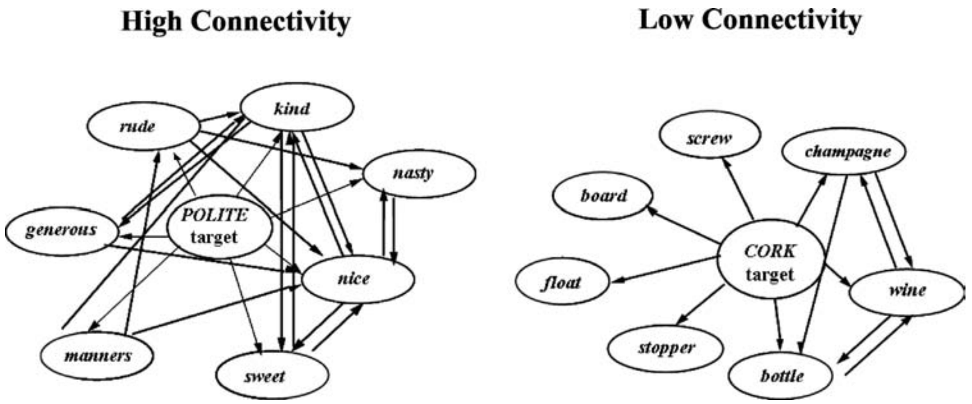

Figure 4. Associative map of targets with high and low connectivity among their associates.

that targets with a densely connected network of associates are more likely to be recalled in extralist cued recall than targets with sparsely connected sets (Nelson, Bennett, et al., 1993; Nelson et al., 1998). Connectivity represents another source of target activation strength, and its effect is independent of resonance (Nelson et al., 2003), word concreteness, frequency, or target set size (Gee, Nelson, & Krawczyk, 1999; Nelson, Bennett, et al., 1993). Of importance, the connectivity effect is reduced by manipulations that reduce accessibility of the episodic context cues (Nelson, Goodmon, & Akirmak, 2007; Nelson et al., 1998); therefore, we expected reduced connectivity effects in the forget group.

Method.

Participants and design. Participants were 48 University of North Carolina at Greensboro undergraduates who took part in the experiment in exchange for course credit. None of them had participated in the previous experiment. The experimental design was a mixed-factorial design, with connectivity (high, low) manipulated within subjects and instruction (forget, remember) varied between subjects.

Materials. We selected 32 words from the University of South Florida Free Association Norms to serve as targets for two unrelated 16-item study lists. An additional 32 words served as test cues, one per target item. Targets were unrelated to each other, and cues were unrelated to each other. Each cue word was related only to a single target. When target connectivity was high, each associate in the target's associative network was connected to an average of 2.36 ($SD = 0.38$) associates, with the sum of associate-to-associate link strengths averaging 4.20 ($SD = 1.00$). When target connectivity was low, each associate was connected to an average of only 0.70 ($SD = 0.14$) associates, with the sum of associate-to-associate link strengths averaging 1.50 ($SD = 0.28$). As in Experiment 1, for each cue–target pair in the high- and low-connectivity conditions, we controlled the variables known to affect recall probability. The controlled variables along with their values are shown in Table 1.

Procedure. The procedures were identical to those used in Experiment 1, except that the manipulated implicit variable was target connectivity instead of resonance.

Results.

Directed forgetting costs. To analyze the costs of directed forgetting, a Connectivity (high, low) × Instruction (forget, remember) mixed-factorial ANOVA was conducted on the proportion of List 1 recall. The results are shown in Figure 5 (top panel). There was a main effect of connectivity, $F(1, 46) = 116.94$, $MSE = 0.010$, $p < .001$, $\eta^2 = .72$, indicating better List 1 memory for high-connectivity targets (.40) than low connectivity targets (.18). There was also a main effect of instruction, $F(1, 46) = 12.58$, $MSE = 0.031$, $p < .01$, $\eta^2 = .22$, indicating that the remember group remembered more List 1 items (.35) than the forget group (.23). These main effects were qualified by a significant Instruction × Connectivity interaction, $F(1, 46) = 10.61$, $MSE = 0.010$, $p < .01$, $\eta^2 = .19$. The connectivity effect was much larger in the remember condition (28%) $t(23) = 9.27$, $p < .001$, than in the forget condition (15%), $t(23) = 5.80$, $p < .001$.

Directed forgetting benefits. To analyze the benefits of directed forgetting, a similar analysis was conducted on the proportion of List 2 recall. The results are shown in Figure 5 (bottom panel). There was a main effect of connectivity, $F(1, 46) = 34.53$, $MSE = 0.022$, $p < .001$, $\eta^2 = .43$, indicating better List 2 memory for high-connectivity items (.38) than low-connectivity items (.20). There was no main effect of instruction ($F < 1$) and no significant interaction ($F < 1$). In other words, there were no directed forgetting benefits regardless of the connectivity condition.

Discussion of Experiments 1 and 2

The first two experiments demonstrated that directed forgetting impairment can be reliably obtained with the extralist cuing procedure. These experiments also confirmed that the manipulation of two independent sources of target activation strength was successful. There was an advantage for targets with high resonance in Experiment 1 and an advantage for targets with high connectivity in Experiment 2 in the remember conditions of the experiments. Of importance, the magnitude of the resonance effect and of the connectivity effect was substantially reduced by the directed forgetting manipulation. Thus, an instructional variable (e.g., "forget the words") produced effects similar to those found in prior studies with extralist cued recall, which manipulated the environmental context or the delay interval. These results were predicted by the contextual account of directed forgetting costs, and they are hard to reconcile with the inhibitory account without additional assumptions.

In contrast to the reliable directed forgetting costs, we did not obtain directed forgetting benefits. Although numerically the

Table 1
Mean Strengths and Standard Deviations of Controlled Variables for Items in Experiments 2–5

Controlled variable	Experiment 2: Connectivity		Experiment 3: Target set size		Experiment 4: Target-to-cue strength		Experiment 5: Shared associate strength	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Direct target-to-cue strength	0.05	0.03	0.02	0.02	—	—	0.02	0.02
Direct cue-to-target strength	0.08	0.02	0.06	0.03	0.04	0.02	0.06	0.04
Shared associate strength	0.01	0.01	0.06	0.07	0.05	0.07	—	—
Mediated strength	0.01	0.02	0.04	0.05	0.02	0.03	0.07	0.10
Target set size	15.58	3.45	—	—	13.84	3.97	12.59	3.66
Target competitor strength	0.54	0.15	—	—	0.46	0.20	0.53	0.14
Cue set size	15.50	5.94	13.28	5.36	14.47	4.34	10.59	2.41
Cue competitor strength	0.49	0.17	0.41	0.24	0.46	0.19	0.38	0.18
No. of associate-to-associate connections	—	—	1.36	0.65	1.36	0.55	1.41	0.59
Sum of associate-to-associate link strengths	—	—	2.37	0.84	2.57	0.80	2.68	1.23
No. of associates-to-target connections	0.44	0.23	0.49	0.22	0.41	0.19	0.49	0.25
Sum of associates-to-target link strengths	1.86	0.82	1.78	0.69	1.44	0.42	1.90	0.66
Target printed frequency (Kučera & Francis)	74.10	58.36	89.94	79.22	33.94	29.81	78.75	72.77
Target concreteness on a scale from 1 to 7	4.71	1.32	5.00	1.19	5.08	1.38	4.89	1.43
Cue printed frequency (Kučera & Francis)	50.95	59.28	38.63	45.94	72.59	95.86	53.63	92.19
Cue concreteness on a scale from 1 to 7	4.65	1.24	4.88	1.18	4.74	1.96	4.74	1.56

Note. Dashes indicate that a variable was manipulated, and the specific values can be found in the Methods section of corresponding experiments.

means were in the correct direction, the effect was not reliable in either experiment. This null effect needs to be treated with caution, and given the new methodology used in these studies, it needs to be replicated.

Section 2: Cue–Target Intersection Variables

Whereas the previous two experiments manipulated implicit variables that affect the target activation strength during encoding, in the next three experiments we introduced implicit variables, the effects of which emerged during the test stage. Namely, we manipulated three variables implicated in the cue–target intersection process while controlling for the target activation levels. In other words, the recall differences were expected to be driven by the strength of the test cues rather than the targets. We varied target set size (Experiment 3), direct target-to-cue strength (Experiment 4), and indirect strength between the target and the cue (Experiment 5).

As described earlier, the two theories of directed forgetting make opposite predictions for this set of experiments. The context account predicts a smaller effect of the cue strength in the forget condition than in the remember condition, because directed forgetting disrupts the context, making the strong cues less effective. In contrast, the inhibitory account predicts a larger effect of the cue strength in the forget condition than in the remember condition, because stronger cues can release the items from inhibition.

Experiment 3: Set Size

Targets that produce fewer associates are recalled better in extralist cued recall than targets with larger associative sets (Nelson & Friedrich, 1980; Nelson et al., 1998; Nelson & Schreiber, 1992). The memorial advantage of small set size items is known as the *set size effect*. Set size effects are obtained regardless of word ambiguity (Gee, 1997), concreteness (Nelson & Schreiber, 1992), or frequency (Nelson & Xu, 1995) and regardless of how well the target has been processed explicitly (e.g., Nelson et al., 1992). They are also independent of connectivity and resonance (Nelson & Zhang, 2000).

Although set size is a property of the target, its effect is driven completely by the selected test cue. In other words, it represents a retrieval phenomenon that arises when one word is used to search the memory for a related word. Set size effects are not found in single item recognition, where the target is used as a cue for itself (e.g., Fisher & Nelson, 2006), but they do have a robust effect in extralist cued recall when the test cue is used to search for the target.

The negative effect of set size is attributed to the increasing number of competitors in the large networks (Schreiber, 1998; Schreiber & Nelson, 1998). In other words, the set size effect is a competitor effect in disguise, with increases in competitor strength decreasing the probability of recall, because they lower the cue–target intersection strength. (For the illustration of competitors, see Figure 1.) Of importance, set size effects are reduced by manipulations that block or disrupt access to contextual cues (Nelson, McEvoy, et al., 1993; Nelson et al., 1998); therefore, we predicted a smaller set size effect in the forget group compared with the remember group.

Method.

Participants and design. Participants were 72 University of North Carolina at Greensboro undergraduates who took part in the study in exchange for course credit. None of them had participated in previous experiments. The experimental design was a 2 × 2 mixed-factorial design, with set size (small, large) manipulated within subjects and instruction (forget, remember) manipulated between subjects.

Materials. We selected 32 words from the University of South Florida Free Association Norms to serve as targets for two unrelated 16-item study lists. An additional 32 words served as test cues, one per target item. Targets in the small set condition had an

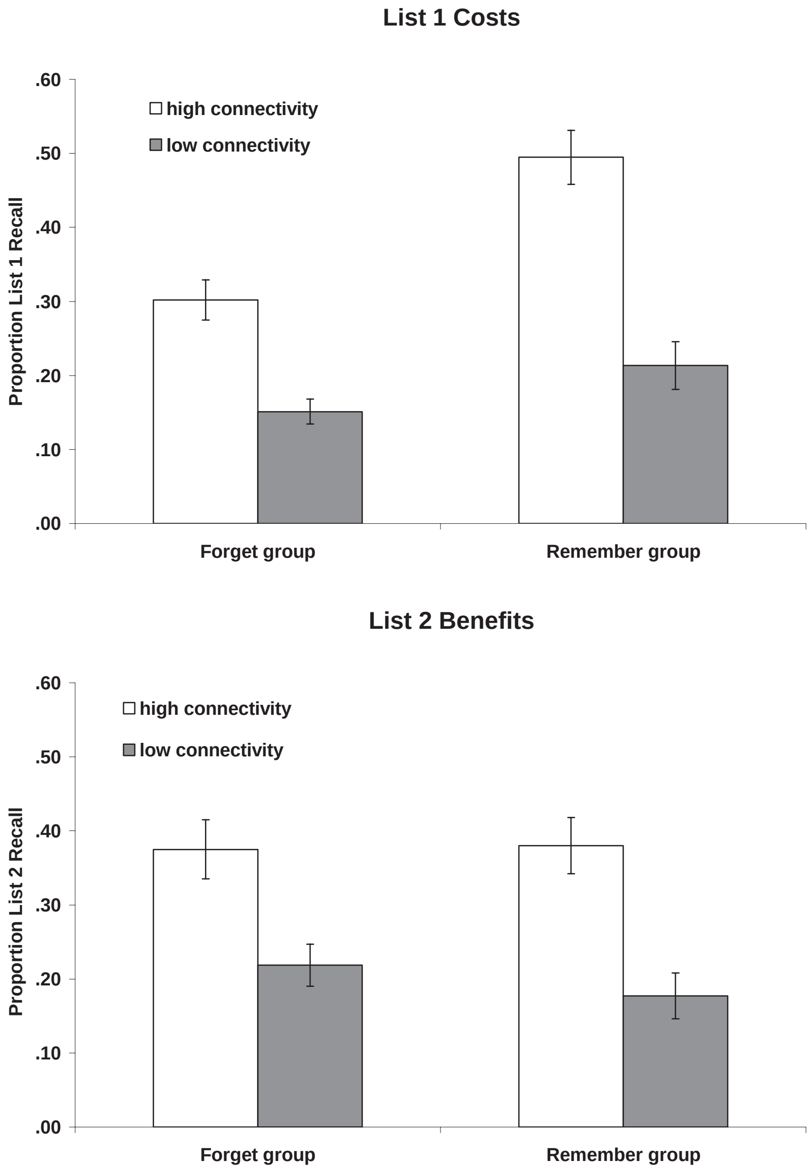

Figure 5. List 1 recall (top) and List 2 recall (bottom) as a function of associative connectivity in Experiment 2. Error bars represent standard error of the means.

average of 6.56 associates (*SD* = 1.59) in their set, whereas targets in the large set condition had an average of 19.88 associates (*SD* = 3.05). There were more competitors in the large set condition (*M* = 16.31, *SD* = 3.89) than in the small set condition (*M* = 4.25, *SD* = 1.77). Hence, competitor strength was higher in the large set, averaging .64 (*SD* = .13), whereas in the small set it averaged .31 (*SD* = .28). The remaining variables were controlled across the set size conditions (see Table 1).

Procedure. The procedure was identical to that of Experiment 1, except that the implicit variable manipulated within subjects involved set size.

Results.

Directed forgetting costs. To analyze the costs of directed forgetting, a Set Size (small, large) × Instruction (forget, remember) mixed-factorial ANOVA was conducted on proportion List 1 recall. The results are shown in Figure 6 (top panel). There was a main effect of set size, $F(1, 70) = 41.80$, $MSE = 0.020$, $p < .001$, $\eta^2 = .37$, indicating better List 1 memory for targets in small sets (.44) than large sets (.29). There was also a main effect of instruction, $F(1, 70) = 7.48$, $MSE = 0.047$, $p < .01$, $\eta^2 = .10$, indicating that the remember group recalled more List 1 items (.41) than the forget group (.31). These effects were qualified by an Instruction × Set Size interaction, $F(1, 70) = 4.63$, $MSE = 0.020$, $p < .05$, $\eta^2 = .06$. The set size effect was larger in the remember condition (20%), $t(35) = 5.70$, $p < .001$, than in the forget condition (10%), $t(35) = 3.29$, $p < .01$.

Directed forgetting benefits. To analyze the benefits of directed forgetting, a similar analysis was conducted on proportion

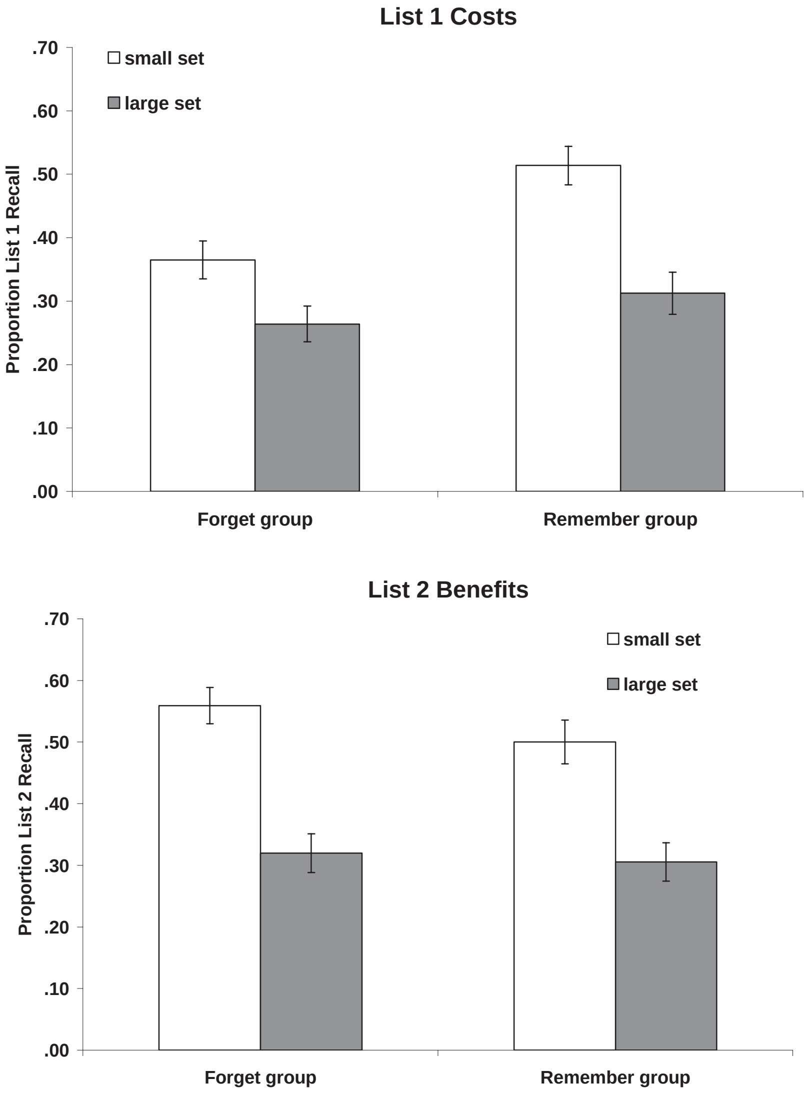

Figure 6. List 1 recall (top) and List 2 recall (bottom) as a function of target set size in Experiment 3. Error bars represent standard error of the means.

List 2 recall (see Figure 6, bottom panel). There was a main effect of set size, $F(1, 70) = 66.05$, $MSE = 0.026$, $p < .001$, $\eta^2 = .49$, indicating better memory for targets in the small set condition (.53) than the large set condition (.31). There was neither a main effect of instruction nor an interaction ($F\text{s} \leq 1$), indicating no directed forgetting benefits in either set size condition.

Experiment 4: Direct Target-to-Cue Strength

In this experiment, we investigated another variable that affects the cue–target intersection by varying the direct target-to-cue strength. The latter describes the probability that the target activates the test cue during learning. This link facilitates recall because it provides direct access from the target to the test cue (Tulving & Thomson, 1973). Prior research shows that associates that are more strongly activated by the target during encoding are more successful as retrieval cues for that target compared with associates that are weakly activated by the target (Humphreys & Galbraith, 1975; Nelson & Goodmon, 2003; Nelson & McEvoy, 1979). The effects of target-to-cue strength are not contingent on how well the target is encoded explicitly (Nelson, Fisher, & Akirmak, 2007; Nelson & Goodmon, 2002). Furthermore, these effects are reduced by manipulations that block or disrupt access to the contextual information encoded about the target during learning (Nelson & Goodmon, 2003; Nelson, Goodmon, & Ceo, 2007). Therefore, we expected that directed forgetting would reduce the target-to-cue strength effect.

Method.

Participants and design. Participants were 72 University of North Carolina at Greensboro undergraduates who took part in the experiment in exchange for extra course credit. None of the participants took part in previous experiments. The experimental design formed a 2 × 2 mixed-factorial design, with target-to-cue strength (high, low) varied within subjects and instruction (forget, remember) varied between subjects.

Materials. We selected 32 words from the University of South Florida Free Association Norms to serve as targets for two unrelated 16-item study lists. An additional 32 words served as test cues, one per target item. Targets were unrelated to each other, and cues were unrelated to each other. During the test, participants received a mixture of high- and low-strength cues, such that some targets were tested with strong cues, whereas the remaining targets were tested with weak cues. Strong cues had an average target-to-cue strength of .15 (*SD* = .02), whereas weak cues had an average target-to-cue strength of .04 (*SD* = .03). The remaining variables that could affect cued recall were controlled across the cue strength conditions (see Table 1).

Procedure. The procedure was identical to that of Experiment 1, except that the within-subjects implicit variable was the direct target-to-cue strength.

Results.

Directed forgetting costs. To analyze the costs of directed forgetting, a Target-to-Cue Strength (high, low) × Instruction (forget, remember) mixed-factorial ANOVA was conducted on proportion List 1 recall. The results are shown in Figure 7 (top panel). There was a main effect of target-to-cue strength, $F(1, 70) = 18.97$, $MSE = 0.025$, $p < .001$, $\eta^2 = .213$, indicating that target recovery was better when target-to-cue strength was high (.41) than when it was low (.30). There was also a main effect of instruction, $F(1, 70) = 11.86$, $MSE = 0.042$, $p < .01$, $\eta^2 = .060$, indicating that the remember group recalled more List 1 items (.42) than the forget group (.30). These effects were qualified by a significant Instruction × Target-to-Cue

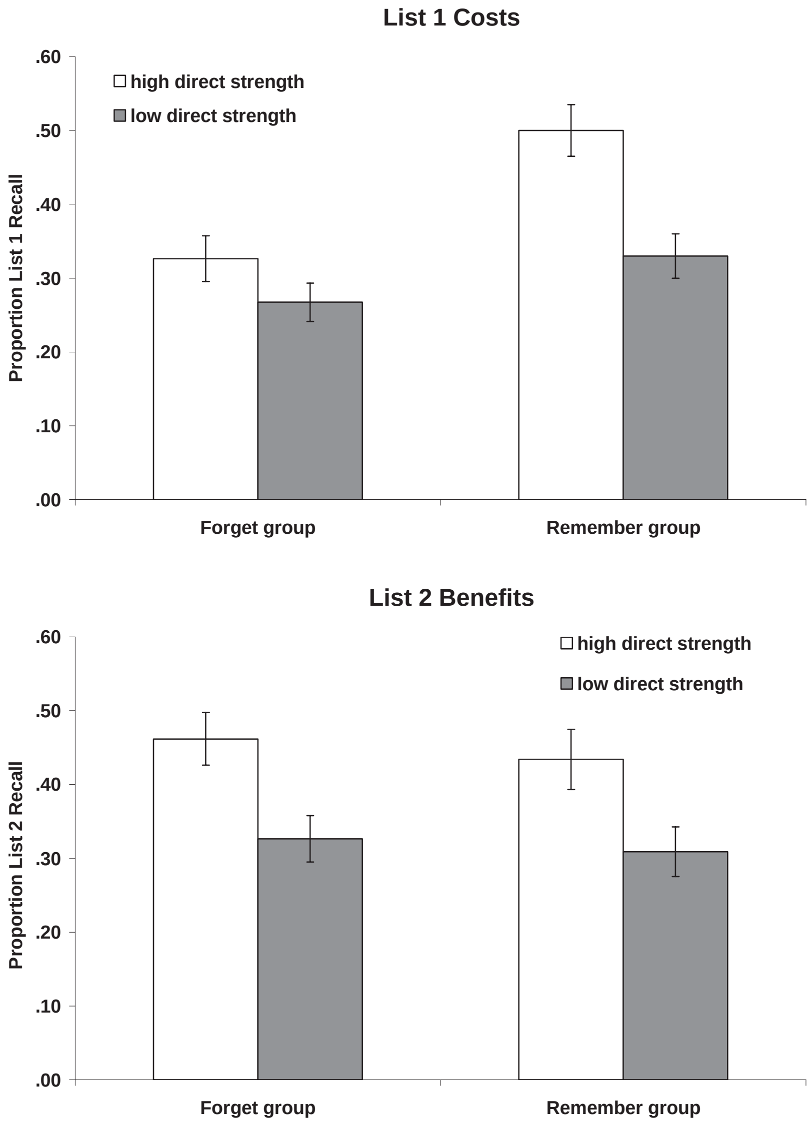

Figure 7. List 1 recall (top) and List 2 recall (bottom) as a function of direct strength from the target to the test cue in Experiment 4. Error bars represent standard error of the means.

Strength interaction, $F(1, 70) = 4.46$, $MSE = 0.025$, $p < .05$, $\eta^2 = .184$. The magnitude of the target-to-cue strength effect was larger in the remember group (17%), $t(35) = 4.92$, $p < .001$, than in the forget group (6%), $t(35) = 1.49$, $p = .15$.

Directed forgetting benefits. To analyze the benefits of directed forgetting, the same analysis was conducted on proportion List 2 recall (see Figure 7, bottom panel). There was a main effect of target-to-cue strength, $F(1, 70) = 17.83$, $MSE = 0.034$, $p < .001$, $\eta^2 = .203$, indicating better recall of targets when target-to-cue strength was high (.45) than when it was low (.32). There was no main effect of instruction ($F < 1$) and no significant interaction ($F < 1$), indicating no directed forgetting benefits in either of the target-to-cue strength conditions.

Experiment 5: Shared Associate Strength

In this experiment, we manipulated the indirect strength between the target and the cue. If the test cue and the target both independently produce one or more common associates (e.g., *CHORUS* → *music* ← *SONG*, where *CHORUS* is the target, *SONG* is the test cue, and *music* is the associate that they share), then the probability of retrieving the target during the test is greater when there are more shared associates between the cue and the target than when there are fewer shared associates between them (Nelson & Goodmon, 2002, 2003; Nelson et al., 1998; Nelson & McEvoy, 2002). The indirect connections between the test cue and the target enhance recall by enhancing the cue–target intersection strength (if not offset by the strength of competitors). Their effects, however, are reduced by contextual disruptions (Nelson & Goodmon, 2003); therefore, we expected reduced effects of the shared associate strength in the forget condition compared with the remember condition.

Method.

Participants and design. Participants were 72 University of North Carolina undergraduates who took part in exchange for extra course credit. None of them had participated in previous experiments. The experimental design formed a 2 × 2 mixed-factorial design, with shared associate strength (high, low) varied within subjects and cue (forget, remember) varied between subjects.

Materials. Thirty-two words were selected from the University of South Florida Free Association Norms to serve as targets for two unrelated 16-item study lists. An additional 32 words served as test cues, one per target item. Targets were unrelated to each other, and cues were unrelated to each other. During the test, participants received a mixture of cues that had high and low shared associate strength. When shared associate strength was high, there was an average of 2.50 ($SD = 0.83$) associates between the target and the cue, with an average shared associate strength of .19 ($SD = .08$). When shared associate strength was low, there was an average of 0.81 ($SD = 1.00$) associates between the target and the cue, with an average shared associate strength of .00 ($SD = .01$). The remaining variables were controlled across the shared associate strength conditions (see Table 1).

Procedure. The procedure was identical that of to Experiment 1, except that the within-subjects implicit variable was shared associate strength.

Results.

Directed forgetting costs. To analyze the costs of directed forgetting, a Shared Associate Strength (high, low) × Instruction (forget, remember) mixed-factorial ANOVA was conducted on the proportion of List 1 recall. The results are shown in Figure 8 (top panel). There was a main effect of shared associate strength, $F(1, 70) = 67.53$, $MSE = 0.014$, $p < .001$, $\eta^2 = .49$, indicating better List 1 memory for targets that were tested with cues that had high shared associate strength with the targets (.39) than for those tested with cues that had low shared associate strength (.23). There was also a significant main effect of instruction, $F(1, 70) = 4.60$, $MSE = 0.042$, $p < .05$, $\eta^2 = .06$, indicating that the remember group recalled more List 1 items (.35) than the forget group (.27). These effects were qualified by an Instruction × Shared Associate Strength interaction, $F(1, 70) = 8.85$, $MSE = 0.014$, $p < .01$, $\eta^2 = .11$. As predicted, the shared associate strength effect was larger in the remember group (22%), $t(70) = 8.57$, $p < .001$, than in the forget group (11%), $t(70) = 3.46$, $p < .01$.

Directed forgetting benefits. To analyze the benefits of directed forgetting, similar analyses were performed on the proportion of List 2 recall (see Figure 8, bottom panel). There was a main effect of shared associate strength, $F(1, 70) = 44.55$, $MSE = 0.020$, $p < .001$, $\eta^2 = .39$, indicating better List 2 recall of targets that were tested with high shared associate strength cues (.38) than for those tested with low shared associate strength cues (.23). There was no main effect of instruction, $F(1, 70) = 1.36$, $p = .25$, and no significant interaction, $F(1, 70) = 1.01$, $p = 30$. In other words, there were no directed forgetting benefits in either condition of the shared associate strength.

General Discussion

Across five experiments, we found that implicitly activated associates had systematic effects on memory. Targets with high resonance from their associates, high connectivity amongst their associates, and smaller associative neighborhoods were better recalled than targets with low resonance, low connectivity, or larger sets. Also, cues that had stronger direct or indirect associations with the targets were more successful at retrieving the targets than cues that had weaker associative links with the target. These findings confirm the results of prior research demonstrating that the associates of the target, albeit not consciously experienced, impact memory in systematic ways. In addition, we found that implicitly activated associates influence directed forgetting. Specifically, the forget cue reduced the effect of target resonance and connectivity as well as the effects of target set size, direct target-to-cue strength, and indirect strength between the target and the cue. In other words, the memory advantage produced by stronger associative links of every type was reduced by directed forgetting. This was obtained regardless of whether the source of the memory advantage was driven by the implicit target activation strength (Experiments 1 and 2) or by the cue–target intersection strength (Experiments 3–5).

These findings were predicted by the context account of directed forgetting, and they were motivated by prior research that investigated how disruptions of episodic context influence performance in extralist cued recall. According to Nelson's model that explains those findings, the extralist cue combines together with the context cue to elicit the episodically primed target (e.g., Nelson, Goodmon, & Ceo, 2007). Providing a specific extralist cue for the target does not diminish the importance of recovering the contextual information encoded about that target. If context cues are unavailable during the test, they diminish the power of the extralist cue to

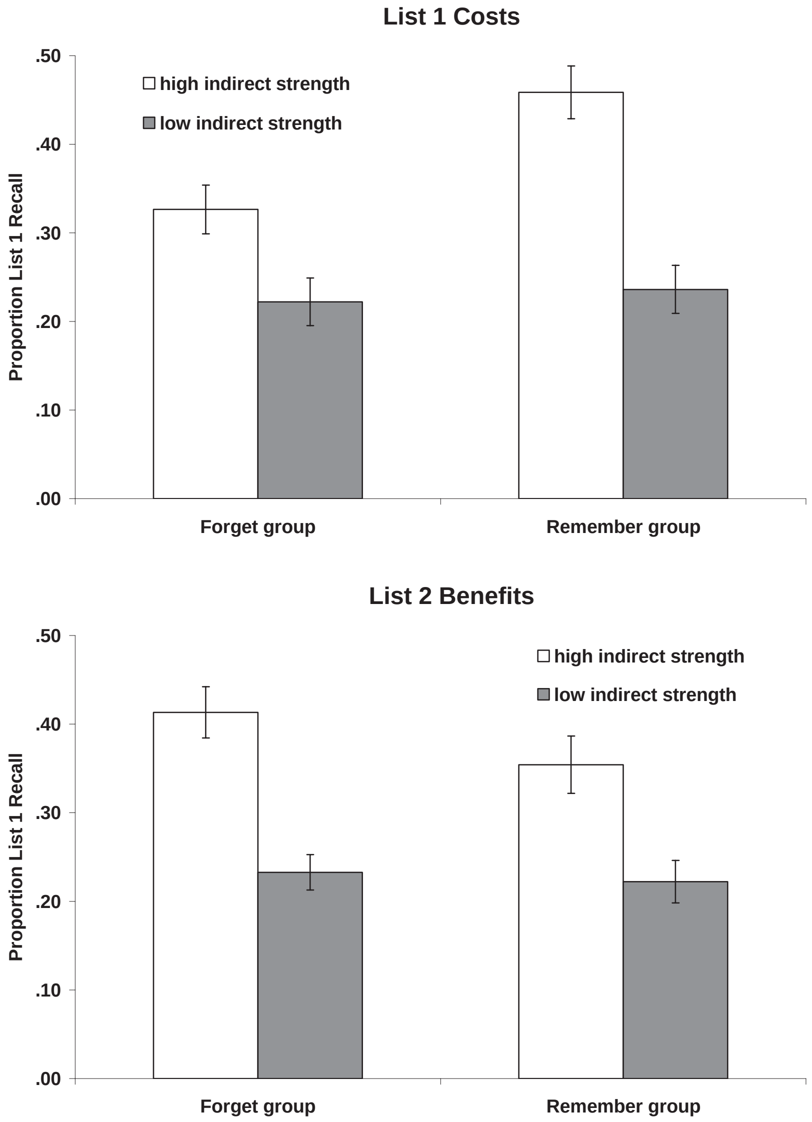

Figure 8. List 1 recall (top) and List 2 recall (bottom) as a function of indirect shared strength between the target and the test cue in Experiment 5. Error bars represent standard error of the means.

differentiate the target from other activated associates of the cue, and the extralist cue loses its ability to restore the former target activation levels. Because the context account uses the mental context change taking place between the two lists to explain directed forgetting impairment, it predicts that effects of the forget cue on implicit variable effects will be similar to those of other forms of disruption of context (e.g., Nelson, Bennett, et al., 1993; Nelson & Goodmon, 2003; Nelson, Goodmon, & Akirmak, 2007 Nelson, McEvoy, et al., 1993; Nelson et al., 1998). Importantly, both the context account and Nelson's model made a strong prediction that directed forgetting would interact with *all* types of implicit variables, regardless of whether they were implicated in the target activation or in the cue–target intersection process. Indeed, implicit variables interacted with directed forgetting in all experiments.

These findings support the contextual account of directed forgetting costs, and they are problematic for the inhibitory account. It is unclear, for example, why in Experiments 1 and 2, the strongly activated targets were inhibited more than the weakly activated targets. To explain these findings, an item-level inhibitory mechanism is needed, as in the retrieval-induced forgetting or think/no-think research (e.g., M. C. Anderson et al., 1994; M. C. Anderson & Green, 2001), along with some untested assumptions. In retrieval-induced forgetting studies, for example, high-frequency exemplars of a category were inhibited more than low-frequency exemplars, presumably because they caused more competition during the retrieval practice stage (e.g., M. C. Anderson et al., 1994). Therefore, it needs to be assumed that strongly activated targets across the lists caused more competition with each other and thus were inhibited to a greater extent than weakly activated targets. We do not know of any empirical evidence that suggests this is the case. Furthermore, a related line of work from our lab has indicated that higher episodic strength by itself is insufficient to cause variable degrees of directed forgetting across the strong and weak items, unless that strength refers to the contextual strength in the memory trace rather than the item strength (e.g., Sahakyan, Delaney, & Waldum, 2008). Thus, it seems unlikely that higher implicit strength of the items could cause greater competition and lead to greater inhibition.

Even more problematic for the inhibitory view are the findings of Experiments 3–5, because those results were driven entirely by the test cue. In fact, as the cue effectiveness was manipulated in those experiments, the target characteristics were fully controlled. Nevertheless, there was greater impairment in the conditions where targets were tested with stronger cues than in those tested with weaker cues. Because inhibition must be aimed at targets before any test cues are presented, it is unclear why inhibition differentially impaired some cue–target pairs more than others. If anything, given the assumption of the release from inhibition, one would expect that strong cues would be more effective at releasing the targets from inhibition and would lead to less forgetting rather than more forgetting in those conditions. To reconcile these findings with the inhibition view, one might try to argue that when the target was inhibited, its entire implicit representation was inhibited, and because of the association with the target, the cues were inhibited along with the target, which would reduce their effectiveness during the test. However, even if the cues were inhibited with the targets, one would expect them to be released from inhibition to their full strength when they were presented during the test. Moreover, this still does not explain why stronger cue–target relationships suffered more from inhibition than weak ones.

Of interest, further examination of the results at the level of individual pairs in Experiments 3 through 5 confirmed the interactions of cue strength with directed forgetting for pairs where the cues were members of the target's set as well as for pairs where the cues were not members of the target's set. Note that for any cue–target pair, the cue may be a member of the target's set, but it may also be any associate outside of the target's network that has a direct or indirect association with the target. We used the target-to-cue strength of .000 as a definition that the cue was not a member of the target's set. These association values show the probability of the target activating the cue in the absence of a study trial. With this definition in mind, we discovered that 40% of the cues used in Experiments 3 through 5 were not members of the target's set. Nevertheless, regardless of the cue status, they all produced interactive effects in directed forgetting, $F(1, 184) = 4.90$, $p < .05$ (see Figure 9). Overall, these results are inconsistent with the inhibitory explanation.

Some researchers have proposed that the context-change account is not inconsistent with the retrieval inhibition account if one assumes that mental context change induced by the forget cue is accomplished by inhibiting the unwanted context (e.g., M. C. Anderson, 2005). Others have argued that directed forgetting is caused by inhibition that induces some form of contextual isolation of List 1 items (e.g., Bäuml, Hanslmayr, Pastotter, & Klimesch, 2008). In other words, both of these proposals attribute the recall impairment to diminished access to the List 1 context along with a tacit assumption about the importance of context in retrieval—claims directly made by the context-change account. However, unlike the context-change account, which makes no claims about the inhibition of context and suggests that the two lists are simply contextually segregated, these interpretations of the inhibition account suggest that List 1 context is inhibited. To the best of our knowledge, there is no empirical evidence demonstrating the inhibition of context in directed forgetting studies, and in the absence of such evidence, the context-change account and the inhibition-of-context account are virtually indistinguishable.

Finally, although the earlier proposed selective rehearsal explanation of directed forgetting (e.g., R. A. Bjork, 1970, 1972) has been dismissed because directed forgetting emerges in incidental

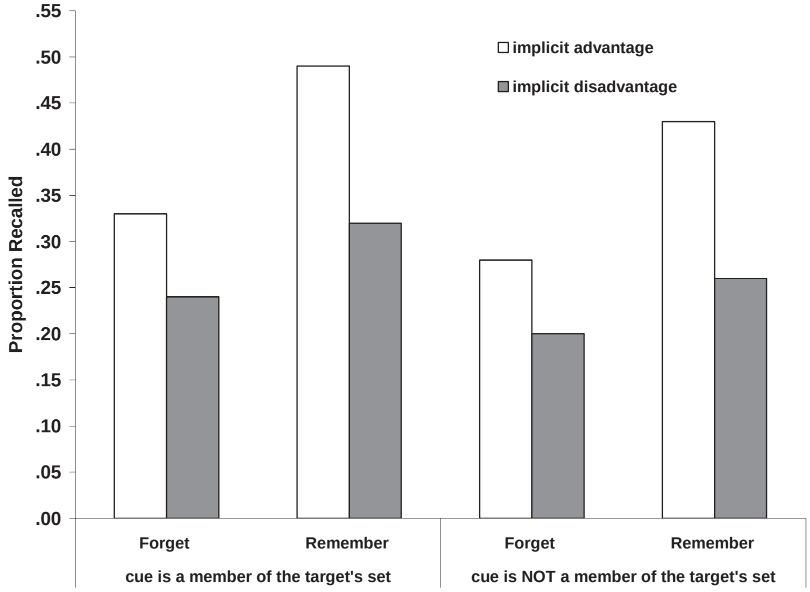

Figure 9. List 1 recall in the remember and the forget groups as a function of implicit variable level (recall advantage vs. disadvantage) and status of the test cue (member vs. nonmember of the target set) in Experiments 3 through 5.

learning as well (e.g., Geiselman et al., 1983; Sahakyan & Delaney, 2005; Sahakyan et al., 2008), some researchers have suggested that it needs to be entertained as a candidate explanation in intentional learning situations (e.g., Benjamin, 2006; Sheard & MacLeod, 2005). We therefore consider our findings from the perspective of the selective rehearsal account, according to which the forget cue encourages participants to terminate List 1 rehearsal and therefore devote extra rehearsal to List 2 items, leading to the costs and benefits, respectively. In all of our experiments, the selective rehearsal account would predict equivalent directed forgetting for items with an implicit advantage and items with an implicit disadvantage. This is because terminating rehearsal should be more detrimental to the explicit encoding strength of the items rather than to their implicit strength, and explicit strength does not interact with implicit variables (Nelson, Bennett, et al., 1993; Nelson et al., 1997; Nelson, Fisher, & Akirmak, 2007; Nelson & Goodmon, 2002; Nelson, McEvoy, et al., 1993; Nelson et al., 1990, 1992). Furthermore, in some experiments, we introduced the implicit variable during testing (Experiments 3–5), whereas in other experiments, we introduced the implicit variable during learning (Experiments 1–2). The rehearsal explanation would predict different results for variables introduced at testing as opposed to learning, yet they all produced the same effect. Therefore, the results are inconsistent with the selective rehearsal account.

Caveats

Despite obtaining directed forgetting impairment in List 1 recall with extralist cuing, we did not observe directed forgetting enhancement in List 2 recall in any of the experiments. The lack of directed forgetting benefits is inconsistent with all existing accounts of directed forgetting, including the dual-factor accounts, which invoke encoding-based mechanisms to explain the benefits (e.g., Bäuml et al., 2008; Sahakyan & Delaney, 2005). When we combined the data across all the experiments, we observed the benefits in List 2 recall, although the effect was modest in magnitude, $F(1, 326) = 3.86$, $p = .05$. Unlike the directed forgetting costs, the benefits did not interact with implicit condition in the combined analyses ($F < 1$). The lack of benefits seemed to be a reliable finding because it emerged repeatedly in all of the experiments. It could be driven by the new testing procedure used in the experiments for as yet undiscovered reasons. In general, the number of reports where the costs and the benefits were not observed together is growing in the literature (e.g., Benjamin, 2006; Conway, Harries, Noyes, Racsma'ny, & Frankish, 2000; Delaney & Sahakyan, 2007; Macrae, Bodenhausen, Milne, & Ford, 1997; Minnema & Knowlton, 2008; Pastötter & Bäuml, 2010; Sahakyan & Delaney, 2003; Sahakyan & Foster, 2009; Sahakyan & Goodmon, 2007; Sahakyan et al., 2009; Whetstone, Cross, & Whetstone, 1996; Zellner & Bäuml, 2006). Our understanding of the factors that produce these dissociations is incomplete, and this inconsistency should become a priority for future research. New research from our lab (Sahakyan & Delaney, 2010) has suggested that even when the recall rates do not signify directed forgetting benefits, there are other diagnostic markers that imply the benefits (e.g., reduced intrusions). Thus, in future investigations, researchers should consider variables beyond the recall rates to infer about the presence or absence of directed forgetting benefits.

Another finding that requires further attention is the absence of directed forgetting for items with an implicit disadvantage. In all experiments, we found greater effects of directed forgetting for items with implicit advantage than for those with disadvantage as predicted by the context account. However, directed forgetting impairment was significant in the strong conditions of the experiments, but it was not significant in the weak conditions of the experiments, although numerically it was in the right direction. When all experiments are combined together, there was significant forgetting in both weak, $t(334) = 2.34$, $p < .05$, and strong conditions, $t(334) = 7.83$, $p < .001$, although the effect is not quite robust in the weak condition. This was not necessarily a predicted finding; nevertheless, it seems reliable given that it was found in all experiments. The null effect of directed forgetting on weak items is reminiscent of findings of prior research on contextual disruptions and set size, which affect the small set items but not the large set items (Nelson et al., 1998). Why this is the case is currently unknown and needs further investigation.

In all experiments, we predicted and observed significant interactions between implicit variables and directed forgetting. Because this interaction is critical for our predictions, one could criticize it by invoking the scaling argument (e.g., Loftus, 1978). Because the recall rates of items in the implicit advantage (IA) and implicit disadvantage (ID) conditions were not the same in the remember condition, the IA items had more room to suffer from directed forgetting than ID items. In other words, the interaction may reflect a measurement problem caused by the underlying function relating implicit strength to the probability of recall. To address this potential concern, we identified the IA and ID items that were recalled at approximately the same level in the remember condition of each experiment and examined the recall of the same items in the forget condition. We determined the median recall values of IA and ID items in each experiment (by pooling the data over participants in the remember condition) and selected the bottom half of the IA items and the top half of the ID items. This selection approximately equated the recall of IA and ID items in the remember condition. (Note that the items were still different normatively on the relevant implicit characteristics.) Next, we evaluated the recall of this subset of items with a factorial ANOVA, using cue (forget vs. remember) and implicit condition (IA vs. ID). The results revealed a significant interaction, $F(1, 156) = 4.36$, $p < .05$ (see the top portion of Table 2). For the analysis, the data from all experiments were combined because individual experiments did not provide enough items to capture a potential interaction. However, the pattern was present numerically in all the experiments (see the bottom portion of Table 2). This analysis suggests that the interaction of directed forgetting with implicit condition was driven by the factors underlying the manipulation of implicit strength.

Conclusions

The results of five experiments demonstrated that directed forgetting can be successfully obtained with extralist cued recall. This is an important first step toward investigating directed forgetting with methods other than free recall and recognition. The extralist cuing procedure not only allowed testing of TBF items with unstudied cues but also enabled independent manipulation of the characteristics of the TBF items and the characteristics of the test

Table 2
Proportion Recall of the Subset of Items Included in the Item-Level Analyses as a Function of Cue and Implicit Condition Across Experiments

Study, implicit condition, and cue	*M*	*SE*
Overall across all experiments		
Advantage		
Remember	.34	.02
Forget	.24	.02
Disadvantage		
Remember	.33	.02
Forget	.30	.02
Experiment 1: Resonance		
Advantage		
Remember	.29	.02
Forget	.20	.04
Disadvantage		
Remember	.31	.02
Forget	.28	.02
Experiment 2: Connectivity		
Advantage		
Remember	.34	.02
Forget	.24	.04
Disadvantage		
Remember	.34	.03
Forget	.31	.03
Experiment 3: Set size		
Advantage		
Remember	.34	.03
Forget	.25	.04
Disadvantage		
Remember	.30	.02
Forget	.31	.05
Experiment 4: Target-to-cue strength		
Advantage		
Remember	.36	.04
Forget	.25	.06
Disadvantage		
Remember	.38	.02
Forget	.32	.05
Experiment 5: Shared associate strength		
Advantage		
Remember	.36	.06
Forget	.26	.03
Disadvantage		
Remember	.33	.02
Forget	.28	.05

cues. This approach allowed us to contrast the leading theories of directed forgetting. The results of these five experiments underscore that the mechanism behind directed forgetting is contextual rather than inhibitory in nature.

References

Anderson, J. R. (1983). *The architecture of cognition.* Cambridge, MA: Harvard University Press.

Anderson, M. C. (2005). The role of inhibitory control in forgetting unwanted memories: A consideration of three methods. In C. MacLeod & B. Uttl (Eds.), *Dynamic cognitive processes* (pp. 159–190). Tokyo, Japan: Springer-Verlag.

Anderson, M. C. (2009). Motivated forgetting. In A. Baddeley, M. W. Eysenck, & M. C. Anderson (Eds.), *Memory* (pp. 217–243). London, England: Psychology Press.

Anderson, M. C., Bjork, R. A., & Bjork, E. L. (1994). Remembering can cause forgetting: Retrieval dynamics in long-term memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20,* 1063–1087.

Anderson, M. C., & Green, C. (2001). Suppressing unwanted memories by executive control. *Nature, 410,* 131–134.

Anderson, M. C., & Neely, J. H. (1996). Interference and inhibition in memory retrieval. In E. L. Bjork & R. A. Bjork (Eds.), *Memory: Handbook of perception and cognition* (2nd ed., pp. 237–313). San Diego, CA: Academic Press.

Bahrick, H. P. (1970). Two-phase model for prompted recall. *Psychological Review, 77,* 215–222.

Basden, B. H., Basden, D. R., & Gargano, G. J. (1993). Directed forgetting in implicit and explicit memory tests: A comparison of methods. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19,* 603–616.

Bäuml, K.-H., Hanslmayr, S., Pastotter, B., & Klimesch, W. (2008). Oscillatory correlates of intentional updating in episodic memory. *NeuroImage, 41,* 596–604.

Benjamin, A. S. (2006). The effects of list-method directed forgetting on recognition memory. *Psychonomic Bulletin and Review, 13,* 831–836.

Bilodeau, E. A., & Howell, D. C. (1968). Stimulated recall of idiosyncratic and cultural free associates. *Journal of Verbal Learning and Verbal Behavior, 7,* 348–350.

Bjork, E. L., & Bjork, R. A. (1996). Continuing influences of to-be-forgotten information. *Consciousness and Cognition: An International Journal, 5,* 176–196.

Bjork, E. L., & Bjork, R. A. (2003). Intentional forgetting can increase, not decrease, residual influences of to-be-forgotten information. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 29,* 524–531.

Bjork, E. L., Bjork, R. A., & Anderson, M. A. (1998). Varieties of goal-directed forgetting. In J. M. Golding & C. M. MacLeod (Eds.), *Intentional forgetting: Interdisciplinary approaches* (pp. 103–137). Mahwah, NJ: Erlbaum.

Bjork, R. A. (1970). Positive forgetting: The noninterference of items intentionally forgotten. *Journal of Verbal Learning and Verbal Behavior, 9,* 255–268.

Bjork, R. A. (1972). Theoretical implications of directed forgetting. In A. W. Melton & E. Martin (Eds.), *Coding processes in human memory* (pp. 217–235). Washington, DC: Winston.

Bjork, R. A. (1989). Retrieval inhibition as an adaptive mechanism in human memory. In H. L. Roediger III & F. I. M. Craik (Eds.), *Varieties of memory and consciousness: Essays in honour of Endel Tulving* (pp. 309–330). Hillsdale, NJ: Erlbaum.

Bjork, R. A., LaBerge, D., & LeGrand, R. (1968). The modification of short-term memory through instructions to forget. *Psychonomic Science, 10,* 55–56.

Conway, M. A., Harries, K., Noyes, J., Racsma'ny, M., & Frankish, C. R. (2000). The disruption and dissolution of directed forgetting: Inhibitory control of memory. *Journal of Memory and Language, 43,* 409–430.

Deese, J. (1959). On the prediction of occurrence of particular verbal intrusions in immediate recall. *Journal of Experimental Psychology, 58,* 17–22.

Deese, J. (1965). *The structure of associations in language and thought.* Baltimore, MD: Johns Hopkins University Press.

Delaney, P. F., & Sahakyan, L. (2007). Effects of working memory capacity on context maintenance: Adding individual differences to the contextual-change account of directed forgetting. *Memory & Cognition, 35,* 1074–1082.

Fisher, S. L., & Nelson, D. L. (2006). Recursive reminding: Effects of repetition, printed frequency, connectivity, and set size on recognition and judgments of frequency. *Memory & Cognition, 34,* 295–306.

Fox, P. W. (1968). Recall and misrecall as a function of cultural and individual word association habits and regulation of the recall environment. *Journal of Verbal Learning and Verbal Behavior, 7,* 632–637.

Gee, N. R. (1997). Implicit memory and word ambiguity. *Journal of Memory and Language, 36,* 253–275.

Gee, N. R., Nelson, D. L., & Krawczyk, D. (1999). Is the concreteness effect a result of underlying network interconnectivity? *Journal of Memory and Language, 40,* 479–497.

Geiselman, R. E., Bjork, R. A., & Fishman, D. L. (1983). Disrupted retrieval in directed forgetting: A link with posthypnotic amnesia. *Journal of Experimental Psychology: General, 112,* 58–72.

Goodmon, L. B., & Nelson, D. L. (2004). Strengthening the activation of unconsciously activated memories. *Memory & Cognition, 32,* 804–818.

Humphreys, M. S., & Galbraith, R. C. (1975). Forward and backward associations in cued recall: Predictions from the encoding specificity principle. *Journal of Experimental Psychology: Human Learning and Memory, 1,* 702–710.

Johnson, H. (1994). Processes of successful intentional forgetting. *Psychological Bulletin, 116,* 274–292.

Kintsch, W. (1988). The role of knowledge in discourse comprehension: A construction–integration model. *Psychological Review, 95,* 163–182.

Kučera, H., & Francis, W. (1967). *Computational analysis of present-day American English.* Providence, RI: Brown University Press.

Lehman, M., & Malmberg, K. J. (2009). A global theory of remembering and forgetting from multiple lists. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 35,* 970–988.

Loftus, G. R. (1978). On interpretation of interactions. *Memory & Cognition, 6,* 312–319.

MacLeod, C. M. (1998). Directed forgetting. In J. M. Golding & C. M. MacLeod (Eds.), *Intentional forgetting: Interdisciplinary approaches* (pp. 1–57). Mahwah, NJ: Erlbaum.

MacLeod, C. M. (1999). The item and list methods of directed forgetting: Test differences and the role of demand characteristics. *Psychonomic Bulletin and Review, 6,* 123–129.

Macrae, C. N., Bodenhausen, G. V., Milne, A. B., & Ford, R. L. (1997). On regulation of recollection: The intentional forgetting of stereotypical memories. *Journal of Personality and Social Psychology, 72,* 709–719.

McEvoy, C. L., Nelson, D. L., & Komatsu, T. (1999). What is the connection between true and false memories? The differential roles of interitem associations in recall and recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 25,* 1177–1194.

Minnema, M. T., & Knowlton, B. J. (2008). Directed forgetting of emotional words. *Emotion, 8,* 643–652.

Nelson, D. L., Bennett, D. J., Gee, N. R., Schreiber, T. A., & McKinney, V. (1993). Implicit memory: Effects of network size and interconnectivity on cued recall. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19,* 747–764.

Nelson, D. L., Bennett, D. J., & Leibert, T. W. (1997). One step is not enough: Making better use of association norms to predict cued recall. *Memory & Cognition, 25,* 785–796.

Nelson, D. L., Dyrdal, G. M., & Goodmon, L. B. (2005). What is preexisting strength? Predicting free association probabilities, similarity ratings, and cued recall probabilities. *Psychonomic Bulletin & Review, 12,* 711–719.

Nelson, D. L., Fisher, S. L., & Akirmak, U. (2007). How implicitly activated and explicitly acquired knowledge contribute to the effectiveness of retrieval cues. *Memory & Cognition, 35,* 1892–1904.

Nelson, D. L., & Friedrich, M. A. (1980). Encoding and cuing sounds and senses. *Journal of Experimental Psychology: Human Learning and Memory, 6,* 717–731.

Nelson, D. L., & Goodmon, L. B. (2002). Experiencing a word can prime its accessibility and its associative connections to related words. *Memory & Cognition, 30,* 380–398.

Nelson, D. L., & Goodmon, L. B. (2003). Disrupting attention: The need for retrieval cues in working memory theories. *Memory & Cognition, 31,* 65–76.

Nelson, D. L., Goodmon, L. B., & Akirmak, U. (2007). Implicitly activated memories get connected to context just like episodic memories. *Memory & Cognition, 35,* 1878–1891.

Nelson, D. L., Goodmon, L. B., & Ceo, D. (2007). How does delayed testing reduce effects of implicit memory: Context infusion or cuing with context? *Memory & Cognition, 35,* 1014–1023.

Nelson, D. L., & McEvoy, C. L. (1979). Encoding context and set size. *Journal of Experimental Psychology: Human Learning and Memory, 5,* 292–314.

Nelson, D. L., & McEvoy, C. L. (2002). How can the same type of prior knowledge both help and hinder recall? *Journal of Memory and Language, 46,* 652–663.

Nelson, D. L., & McEvoy, C. L. (2005). Implicitly activated memories: The missing links of remembering. In C. Izawa & N. Ohta (Eds.), *Learning and memory: Advances in theory and applications* (pp. 177–198). Mahwah, NJ: Erlbaum.

Nelson, D. L., McEvoy, C. L., & Dennis, S. (2000). What is free association and what does it measure? *Memory & Cognition, 28,* 887–899.

Nelson, D. L., McEvoy, C. L., Janczura, G. A., & Xu, J. (1993). Implicit memory and inhibition. *Journal of Memory and Language, 32,* 667–691.

Nelson, D. L., McEvoy, C. L., & Pointer, L. (2003). Spreading activation or spooky action at a distance? *Journal of Experimental Psychology: Learning, Memory and Cognition, 29,* 42–52.

Nelson, D. L., McEvoy, C. L., & Schreiber, T. A. (1990). Encoding context and retrieval conditions as determinants of the effects of natural category size. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16,* 34–41.

Nelson, D. L., McEvoy, C. L., & Schreiber, T. A. (1999). *The University of South Florida word association, rhyme and word fragment norms.* Retrieved from http://www.usf.edu/FreeAssociation/

Nelson, D. L., McKinney, V. M., Gee, N. R., & Janczura, G. A. (1998). Interpreting the influence of implicitly activated memories on recall and recognition. *Psychological Review, 105,* 299–324.

Nelson, D. L., & Schreiber, T. A. (1992). Word concreteness and word structure as independent determinants of recall. *Journal of Memory and Language, 31,* 237–260.

Nelson, D. L., Schreiber, T. A., & McEvoy, C. L. (1992). Processing implicit and explicit representations. *Psychological Review, 99,* 322–348.

Nelson, D. L., & Xu, J. (1995). Effects of implicit memory on explicit recall: Set size and word frequency effects. *Psychological Research, 57,* 203–214.

Nelson, D. L., & Zhang, N. (2000). The ties that bind what is known to the recall of what is new. *Psychonomic Bulletin and Review, 7,* 604–617.

Nelson, D. L., Zhang, N., & McKinney, V. M. (2001). The ties that bind what is known to the recognition of what is new. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 27,* 1147–1159.

Pastötter, B., & Bäuml, K.-H. (2010). Amount of postcue encoding predicts amount of directed forgetting. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 36,* 54–65.

Postman, L. (1971). Transfer, interference, and forgetting. In J. W. Kling & L. A. Riggs (Eds.), *Woodworth and Schlosberg's experimental psychology* (3rd ed., pp. 1019–1132). New York, NY: Holt, Rinehart, & Winston.

Reich, R. R., & Goldman, M. S. (2005). Exploring the alcohol expectancy memory network: The utility of free associates. *Psychology of Addictive Behaviors, 19,* 317–325.

Sahakyan, L., & Delaney, P. F. (2003). Can encoding differences explain the benefits of directed forgetting in the list-method paradigm? *Journal of Memory and Language, 48,* 195–201.

Sahakyan, L., & Delaney, P. F. (2005). Directed forgetting in incidental learning and recognition testing: Support for a two-factor account.

Journal of Experimental Psychology: Learning, Memory, and Cognition, 31, 789–801.

Sahakyan, L., & Delaney, P. F. (in press). Item-specific encoding produces an additional benefit of directed forgetting: Evidence from intrusion errors. *Journal of Experimental Psychology: Learning, Memory, and Cognition.*

Sahakyan, L., Delaney, P. F., & Waldum, E. R. (2008). Intentional forgetting is easier after two "shots" than after one. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 34,* 408–414.

Sahakyan, L., & Foster, N. L. (2009). Intentional forgetting of actions: Comparison of list-method and item-method directed forgetting. *Journal of Memory and Language, 61,* 134–152.

Sahakyan, L., & Goodmon, L. B. (2007). The influence of directional associations on directed forgetting and interference. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 33,* 1035–1049.

Sahakyan, L., & Kelley, C. (2002). A contextual change account of the directed forgetting effect. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 28,* 1064–1072.

Sahakyan, L., Waldum, E. R., Benjamin, A. S., & Bickett, S. P. (2009). Where is the forgetting with list-method directed forgetting in recognition? *Memory & Cognition, 37,* 464–476.

Schreiber, T. A. (1998). Effects of target set size on feelings of knowing and cued recall: Implications for the cue effectiveness and partial-retrieval hypotheses. *Memory & Cognition, 26,* 553–571.

Schreiber, T. A., & Nelson, D. L. (1998). The relation between feelings of knowing and the number of neighboring concepts linked to the test cue. *Memory & Cognition, 26,* 869–884.

Sheard, E. D., & MacLeod, C. M. (2005). List method directed forgetting: Return of the selective rehearsal account. In N. Ohta, C. M. MacLeod, & B. Uttl (Eds.), *Dynamic cognitive processes* (pp. 219–248). Tokyo, Japan: Springer-Verlag.

Simpson, P., & Voss, J. F. (1967). Stability of response hierarchies. *Journal of Experimental Psychology, 7,* 170–174.

Tulving, E., & Thomson, D. M. (1973). Encoding specificity and retrieval processes in episodic memory. *Psychological Review, 80,* 352–373.

Whetstone, T., Cross, M. D., & Whetstone, L. M. (1996). Inhibition, contextual segregation, and subject strategies in list method directed forgetting. *Consciousness and Cognition, 5,* 395–417.

Zellner, M., & Bäuml, K. H. (2006). Inhibitory deficits in older adults: List-method directed forgetting revisited. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 32,* 290–300.

Received September 26, 2009
Revision received February 8, 2010
Accepted February 17, 2010 ■