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The Reminding Effect: Presentation of Associates Enhances Memory for Related Words in a List

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One aspect of successful cognition is the efficient use of prior relevant knowledge in novel situations. Remindings—stimulus-guided retrievals of prior events—allow us to link prior knowledge to current problems by prompting us to retrieve relevant knowledge from events that are distant from the present. Theorizing in research on higher cognition makes much use of the concept of remindings, yet many basic mnemonic consequences of remindings are untested. Here we consider implications of reminding-based theories of the effects of repetition on memory (Benjamin & Tullis, 2010; Hintzman, 2011). Those theories suggest that the spacing of repeated presentations of material benefits memory when the later experience *reminds* the learner of the earlier one. When applied to memory for *related*, rather than *repeated*, material, these theories predict a *reminding effect*: a mnemonic boost caused by a nearby presentation of a related item. In 7 experiments, we assessed this prediction by having learners study lists of words that contained related word pairs. Recall performance for the first presentation in related pairs was higher than for equivalent items in unrelated pairs, while recognition performance for items in related pairs did not differ from those in unrelated pairs. Remindings benefit only the recollection of the retrieved episodes.

Keywords: reminding, study-phase retrieval, spacing effect, lag effect

Efficiently using prior knowledge to guide our current understanding and behavior allows us to thrive in a complex world. *Remindings*, stimulus-guided retrievals of specific past events, can link relevant prior knowledge to current situations. Remindings allow us to notice and identify the common characteristics of related stimuli across time and distance. For example, remindings may allow us to compare sequentially distant instances of a category in order to distinguish critical commonalities from irrelevant differences, contrast between experiences, and generalize across events. Recognizing meaningful patterns across experiences in order to solve problems and generate inferences may also rely upon remindings.

The importance of remindings has occasionally been of interest in memory research, most specifically with regard to the spacing effect (Benjamin & Ross, 2010; Benjamin & Tullis, 2010; Hintzman, 2010; Jacoby, 1974; Thios, 1972), and even more so in higher level cognition (Medin & Schaffer, 1978; Reeves & Weisberg, 1994; Ross & Bradshaw, 1994; Tullis, Braverman, Ross, & Benjamin, 2014). However, the mnemonic consequences of remindings on individual episodes in a reminding pair remain underexplored. The goal of this article is to investigate the mnemonic consequences of remindings in basic word-learning tasks.

Why has reminding not been more broadly considered in basic memory research? One possibility is that traditional memory experiments go to some length to render encoding and retrieval as individual and separate processes, so much so that some authors have even argued that learners need to be in a distinct "retrieval mode" in order to retrieve memories (Lepage, Ghaffer, Nyberg, & Tulving, 2000). The idea that episodic retrieval takes place during encoding complicates experiments by blurring the boundaries between encoding and retrieval (Benjamin & Ross, 2010; Hintzman, 2011; Mace, 2007). Yet evidence for retrieval during study is abundant and widely known. For example, Rundus (1971) asked learners to overtly rehearse during a study list of categorized and uncategorized items. He showed that presentations of members of a category triggered learners to actively rehearse previously studied items from that same category, even when those items had already been dropped from the active rehearsal list. Category members reminded learners of earlier studied category members and brought earlier studied items back into conscious rehearsal.

We aim to directly measure how remindings during encoding impact memory for individual instances in associated pairs. Theoretical suggestions about how and when reminding operates in basic memory tasks have been offered (Benjamin & Tullis, 2010; Hintzman, 2010; Rundus, 1971), and here we test the most basic prediction of such views: that memory for a word is enhanced when an associate of that word is presented at another point in the study list. Pinning down exactly when and where such enhancements arise turns out be methodologically tricky; across the ex-

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periments presented here, we use a combination of different types of tests to do so.

Reminding in Memory and Higher Order Cognitive Functions

Reminding is thought to play a role in a wide variety of cognitive skills, including classifying new items (Medin & Schaffer, 1978; Ross, Perkins, & Tenpenny, 1990), interpreting ambiguous events (Ross & Bradshaw, 1994; Tullis, et al., 2014), generalizing across episodes (Gick & Holyoak, 1983; Ross & Kennedy, 1990), solving novel problems (Reeves & Weisberg, 1994), and even representing number (Hintzman, 2008). Remindings may even influence answers on personality inventories via attribute substitution effects (Kahneman & Frederick, 2002).

Within memory research, reminding has been theorized to play a role in recency judgments (Hintzman, 2010; Tzeng & Cotton, 1980; Winograd & Soloway, 1985), spacing judgments (Friedman & Janssen, 2010; Hintzman, Block, & Summers, 1973; Hintzman, Summers, & Block, 1975), judgments of frequency (Hintzman, 2004), and determining output order in free recall (Howard & Kahana, 2002; Howard, Kahana, & Wingfield, 2006). The effects of remindings may even play a role in false memory paradigms, where remindings during encoding may cause generation of the critical lure and prompt its subsequent recall (Roediger & McDermott, 1995). In recent work, Benjamin and Tullis (2010) outlined a way in which reminding might help explain a number of enigmatic phenomena in research on the spacing effect. Here we consider what that theoretical viewpoint has to say about memory for related words, rather than repetitions.

In that view of reminding, which emphasizes the role of retrieval, stimuli can remind the learner of previously seen stimuli, with the probability of reminding related to how well the previously seen stimulus is remembered and how associated the two stimuli are. When reminding leads a previously seen item to be retrieved, memory for the reminded item is enhanced. The model specifies a trade-off between *likely* reminding and *potent* reminding. Reminding is less likely to happen at longer delays due to forgetting of the earlier item. It is also less likely to occur for more distantly related stimuli. However, less likely remindings engender a more laborious retrieval process, and when they are successful, laborious retrievals enhance memory more than easy retrievals (e.g., Benjamin, Bjork, & Schwartz, 1998). The most basic implication of the theory is a memory enhancement for the first presentation (P1) in a related pair. Others have made similar claims (Appleton-Knapp, Bjork, & Wickens, 2005; Thios & D'Agostino, 1976; Toppino, Hara, & Hackman, 2002), but those prior studies examined memory for information that was repeated across first and second presentations, so they provide no measure of the specific effects of individual presentations and no clear route to evaluating the central claim of the reminding view that a later event enhances memory for an earlier event. In the current set of studies, we use materials that allow us to examine separately memory for P1 and P2, and do so while fully controlling for item and position effects.

A related view to that of Benjamin and Tullis (2010) is provided by the *recursive reminding* theory of Hintzman (2010), which suggests that later episodes incorporate earlier episodes into their memory traces when reminding occurs. There are several potential implications of this claim for memory for individual instances. The memory strength of P1 may be enhanced by incorporation into the memory trace for P2, P1 may remain unchanged while memory for the second presentation (P2) is enhanced, or P1 may even be "deleted" when reconsolidated with P2. Recent evidence supports this view by showing that memory for the relationships between related items, as indicated by list discrimination and recency judgments, are improved when learners are reminded of the first episode at the time of the second (Jacoby & Wahlheim, 2013; Jacoby, Wahlheim, & Yonelinas, 2013).

Research about the mnemonic effects of reminding on the memory traces of individual presentations is scarce because the relevant research primarily utilizes spacing paradigms, which vary the lag between P1 and P2 but almost invariably use repetitions or partial repetitions (like A–B, A–C word pairs) rather than related stimuli. In such a paradigm, it is impossible to determine the independent contributions of P1 and P2 to memory performance. Research using associated pairs, instead of identity repetitions, can provide insight into the basic mnemonic consequences of reminding because (a) remindings are theorized to occur across related pairs just as in identity repetitions (though with a lower probability of reminding) and (b) memory performance for individual items in an associated pair can be measured independently.

Memory for Individual Instances in Related Pairs

Past research utilizing pairs of associated items, rather than repetitions, hints at the mnemonic consequences of remindings during study. Several studies have demonstrated that related items in a list are remembered better than unrelated items (for a review, see Kausler, 1974, pp. 345–390). However, these studies (e.g., Braun & Rubin, 1998; Hyde & Jenkins, 1969; Puff, 1970; Walker, 1971) suffer from two major shortcomings. First, they typically use different items in the related and unrelated conditions, thus confounding the manipulation with item characteristics associated with those words. Second, they rely exclusively upon tests of free recall, where the effects of manipulations at study on final test performance are confounded by list-strength and output order effects (Delaney, Verkoeijen, & Spirgel, 2010). In a slightly different paradigm that circumvented these confounds, Jacoby (1974) manipulated learners' awareness of relationships across items by instructing some learners to "look back" across prior items in order to draw connections between them. Relatedness among items greatly improved cued recall performance when learners were instructed to look back through related items, but did not help when learners did not look back through earlier related items. In a different paradigm, learners studied word pairs where the cue word was sometimes repeated across presentations (*knee–bend*, *knee–bone*; Wahlheim & Jacoby, 2013). During test, learners were given the cue (*knee*) and instructed to recall the target from the second presentation (*bone*). When learners reported thinking of the first presentation first (*knee–bend*), recall for the second presentation was enhanced. When learners did not remember the first presentation first, recall of the second presentation suffered from proactive interference. Cued recall for the second presentation in a pair was enhanced when learners were aware of the relationships between the first and second presentation.

Instead of instructing learners to look back through a certain portion of the study list, recent research has sought to measure the effects of more naturally occurring remindings. In Tullis et al. (2014), learners studied a list of homographs that were sometimes preceded by biasing context cues. The interpretation of the homograph was used as an index of reminding; when the homograph was interpreted in a manner consistent with the preceding biasing context cue, a reminding likely occurred. Free recall of the biasing context cues was only enhanced when the homographs were interpreted in a manner consistent with the preceding biasing context cue (when a reminding likely happened).

Others have investigated how the lag between related events affects memory. Glanzer (1969) presented subjects with weakly associated word pairs (*coal . . . stove*) across lags and found a decrease in free recall as the spacing between the associated items increased, which he labeled a "reverse spacing" effect. Similarly, Hintzman et al. (1975) showed a decrease in recognition for related items as the lag between their presentations increased. The decrease in performance with lag can be explained by a very low probability of reminding across weakly associated items at long lags, and is predicted in a straightforward way by the Benjamin and Tullis (2010) model (see Benjamin & Ross, 2010, Figure 4.2). However, none of these prior studies were primarily concerned with the mnemonic effects of reminding; therefore, none report the memory performance for both P1 and P2 separately, nor do they compare performance on these items with a set of control items equated in every regard save for the later presentation of a related item. The other major impediment to inferring the presence of reminding in these studies is the uncontrolled influence of reminding during the memory test. As we will outline throughout the experiments presented here, testing must be controlled in order to assure that reminding during testing does not influence mnemonic performance.

Braun and Rubin (1998) analyzed memory separately for P1 and P2 and showed that the spacing effect exists for both P1 and P2 in free recall tests. However, in their experiments, reminding was promoted during testing by encouraging learners to recall both P1 and P2 in response to a shared cue. Greene (1990, Experiment 5) more effectively controlled reminding during testing by using a recognition paradigm. Recognition of synonym pairs decreased with greater spacing between the members. He reported performance separately for P1 and P2, and showed that P1 was better recognized than P2. However, no comparison between single presentations and associated items was reported, limiting what can be said about the presence of reminding in this case. Only one study, to our knowledge, has examined memory performance for single words that were either followed by a later associate or not (Sahakyan & Goodmon, 2007). Because the focus of their study was the influence of directed forgetting, they did not control precisely for the lag between presentations, nor for recency. They did, however, show enhanced recall for both the first and second items in related pairs compared to unrelated items.

Thus, across this wide variety of paradigms, there is the intriguing indication that presentation of associated words seems to enhance memory for individual instances in that pair. However, no study simultaneously (a) controlled the exact stimulus across conditions, (b) controlled the exact serial position and recency of the tested items, (c) separately examined memory for P1 and P2, and (d) controlled for reminding influences during testing. Controlling for item and serial position effects (Delaney et al., 2010) is particularly important here because the effects of relatedness appear to be modest in prior studies. Further, there has been no consideration about what test type might reveal about the processes of reminding. Using recall, cued recall, and recognition tests, we examine whether mnemonic benefits of reminding arise from processes engaged during study, as we predict, or solely from the effects of reminding, list strength, and output order present during free recall tests.

We explicitly seek what we will call the *reminding effect*: the enhancement in memory from study of members of a related pair. We test this enhancement by comparing memory for words in associated pairs with identical words in identical positions when they are in unrelated pairs. The Benjamin and Tullis (2010) reminding model makes clear predictions concerning memory for P1. If P2 reminds the learner of P1, the potent retrieval should improve memory for P1. We also evaluate memory performance for the second presentation of a member of an associated pair. Though the Benjamin and Tullis model only speaks to the effects of reminding on P1, there are reasons to believe that the second item in the associated pair might also enjoy improved memory. If P2 reminds the learner of P1, the reminding may promote interitem associations, for example. Interitem associations should be particularly helpful in free recall where learners can strategically output items based upon their associations to one another (e.g., Howard & Kahana, 2002). Remindings may also prompt an elaboration of P2, whereby the second item incorporates some contextual and semantic information from P1. A more elaborated memory trace of P2 may lead to better memory performance for the second item in an associated pair.

The primary manipulation in these experiments is whether the items are part of an associated pair (in which case we expect some nonzero probability of reminding from P2 to P1) or an unrelated pair (in which reminding is not expected). The lists sometimes contained repetitions so we could compare the benefits of reminding to the benefits of repetition. Further, the experiments sometimes contain a lag variable; we were not specifically interested in the effect of spacing but wanted to increase the likelihood of including a lag at which the effects of reminding are prominent. In fact, the effects were typically similar across lag, and we will simplify our results by collapsing across that variable in all of our experiments. Experiments 1A–1C utilized free recall tests, Experiments 2A–2B utilized recognition tests, and Experiments 3A–3B utilized cued recall tests. Each type of test has inherent benefits and limitations that may reveal the processes underlying reminding, and we will discuss each in turn.

Experiments 1A–1C

In Experiments 1A–1C, free recall of items from associated and unassociated pairs was tested. Learners studied a list of single words; sometimes words were preceded or followed by related words. If a later presentation of a strong associate enhances recall for the earlier item, free recall of first presentations in pairs should be higher than that of the same words in unassociated pairs. We also examine free recall of the second items in related pairs, but make no predictions about their memory performance.

Experiment 1A

Method.

Subjects. Sixty introductory-level psychology students from the University of Illinois at Urbana-Champaign participated in exchange for partial course credit.

Materials. Ninety-six primary associate pairs were collected from the University of South Florida Free Association Norms (Nelson, McEvoy, & Schreiber, 2004). Each word in a pair was the strongest associate of the other. Associated pairs were bidirectionally highly related (mean associative strength = 0.50, *SD* = 0.15) and included synonyms (*dinner*, *supper*), antonyms (*good*, *bad*), male–female counterparts (*king*, *queen*), noun–action pairs (*volcano*, *erupt*), and thematically related words (*salt*, *pepper*). Additionally, 96 words that were not related to any of the primary associate pairs were collected from the same database and were used as unrelated items throughout the lists. Four list structures were created. Each list structure included 12 short lag slots (separated by four intervening items) and 12 long lag slots (separated by 16 intervening items).

At the time of the presentation, words were randomly selected from the list of word pairs and inserted into the list structure. Conditions were assigned such that each list structure contained six primary associate pairs, six repeated items (where one word from a primary associate pair was randomly chosen to be presented twice), six unrelated-first pairs (where the first word in the pair was randomly chosen from a primary associate pair but the second word came from the unrelated word list), and six unrelated-second pairs (where the first word came from the unrelated word list and the second word came from the primary associate list). Half of each type of presentation were shown at short lags (four intervening items), and half were shown at long lags (16 intervening items).

Design. The experiment used a 4 (semantic condition) × 2 (lag) within-subjects design. The four semantic conditions included repetitions, associated pairs, unrelated-first pairs, and unrelated-second pairs. Lag between word pairs was either short (four intervening items) or long (16 intervening items).

Procedure. Subjects were instructed to "do your best to remember the following words for a later memory test" before viewing four study–test cycles of 48 words each. Words were presented singly in the middle of a white computer screen in 50-point black Arial font for 3 s each before being removed from the screen. Between presentations, a blank white screen was presented for 500 ms. After studying each list of presented words, subjects were immediately given a free recall test where they were asked to type in any words they remembered from the immediately prior study list. Subjects decided when they could recall no more words and proceeded to the next study list when they were ready. No time limits during the test phase were enforced, and subjects usually completed the experiment within 30 min.

In order to mitigate against item and order effects, subjects were yoked together in groups of four based upon random assignment of individuals to the testing rooms. If the first subject in a testing room saw a particular associated word pair (*king . . . queen*), the second subject in that room would see an unrelated-first pair (*king . . . radish*) in those same list positions. The third would view an unrelated-second pair (*radish . . . queen*) in the list positions, and the fourth would see a repetition (*queen . . . queen*) in the list positions. In this manner, *king* in the reminding condition (*king . . . queen*) can be compared directly to *king* in the unrelated-first condition (*king . . . radish*) because the same item (*king*) is presented in the exact same study position across the conditions.

Results. Recall performance was averaged across all four study and test lists. Performance was also averaged across the lag variable because performance on P1 did not vary with lag, $t(59) = 0.24$, $p > .80$.[1] Mean recall performance for each semantic condition is displayed in Figure 1. Free recall performance for first presentations in associated pairs was higher than mean recall for the same items in unrelated pairs, $t(59) = 7.80$, $p < .001$, Cohen's $d = 1.01$. A word that was recalled just 30% of the time in an unrelated pair was recalled 43% of the time when its related word was presented later. Second presentations in associated pairs were also better recalled than identical, unrelated items in the same list positions, $t(59) = 8.80$, $p < .001$, Cohen's $d = 1.15$. A word that was recalled 27% of the time in an unrelated word pair was recalled 45% of the time when a related word was presented earlier. Thus, for both P1 and P2, the critical reminding effect was present. Intrusions of related, but not studied, items were very rare and did not vary across repetition or unrelated conditions. Three percent of output items were intrusions of items that were not studied.

Repeated items were recalled more often than both first and second presentations in associated pairs, $t(59) = 7.44$, $p < .001$, Cohen's $d = 0.97$; $t(59) = 6.08$, $p < .001$, Cohen's $d = 0.79$, respectively. However, free recall performance for repetitions cannot distinguish between memory strength arising separately from the first and second studied presentations in the repetition. To compare the benefits of reminding for related material with repetition of material, we sought a principled way of estimating the contributions of the two presentations of a repeated stimulus to performance. Under the simplifying assumption that each presentation contributes to overall performance equally and independently, the equation that relates memory performance for a repetition to each individual presentation is $p_{rep} = 2p_{ind} - p_{ind}^2$, where p_{rep} is the memory for a repetition and p_{ind} is memory for a single, individual presentation. The independent contribution of each presentation for each subject can then be calculated with the quadratic equation. Memory performance as calculated for independent presentations in a repetition was higher than first and second presentations in unrelated pairs, $t(59) = 3.73$, $p < .001$, Cohen's $d = 0.49$; $t(59) = 5.49$, $p < .001$, Cohen's $d = 0.72$, respectively, indicating superadditive effects of repetition. Superadditivity in performance is a hallmark of repetition effects (Benjamin & Tullis, 2010). Memory performance as calculated for independent presentations in a repetition, shown in the dashed box in Figure 1, was surprisingly lower than that for first and second presentations in associated pairs, $t(59) = 4.33$, $p < .001$, Cohen's $d = 0.56$; $t(59) = 5.16$, $p < .001$, Cohen's $d = 0.67$, respectively, suggesting

[1] However, a repeated measures 2 (lag: short or long) × 2 (condition: associated or unrelated) analysis of variance on recall performance for P2 revealed a significant interaction between condition and lag, $F(1, 59) = 5.81$, and a significant effect of condition, $F(1, 59) = 52.96$. A post hoc paired *t* test showed that associated P2s are better remembered at long lags than at short lags, $t(59) = 2.40$. This result did not obtain in Experiments 1B and 1C, so it will not be discussed further.

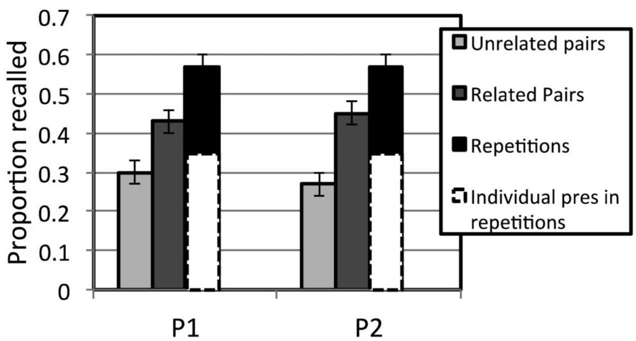

Figure 1. Proportion first (P1) and second presentations (P2) from word pairs recalled in Experiment 1A. Error bars show the within-subjects 95% confidence intervals separately for P1 and P2 (see Benjamin, 2003; Loftus & Masson, 1994). Pres = presentations.

that reminding is a more potent event for enhancing memory than repetition, at least under these conditions.

Because learners had control over the order of output of items during the free recall test, the boost to memory performance for associated pairs may result from reminding that occurred during the test. Recalling P1 may lead learners to remember and output P2, or vice versa. This is an important concern because it implies that the results shown here might not reveal anything about reminding during the study phase of the procedure. To control for reminding at test, we examined only the items output first from within each pair of associated and unassociated items. For instance, if a learner recalled *queen* and later *king*, *queen* would be counted as recalled first, while *king* would be counted as recalled second. Learners can use the first recalled item from a pair as a cue to help in their recall of the second, but the word that is output second cannot influence recall of the first output (unless the items are output in a different order in which they are recalled, a possibility we will concern ourselves with in Experiments 3A–3B). Second-recalled items were discarded in this next analysis because they may be impacted by a learner's strategic use of reminding during testing. As shown in Figure 2, a greater percentage of P1s in associated pairs were output first compared to those same items in unassociated pairs, $t(59) = 3.00$, $p = .04$, Cohen's $d = 0.39$. The amount of P2s output first did not significantly differ between associated and unassociated pairs, $t(59) = 1.37$, $p = .18$, Cohen's $d = 0.18$. This analysis allays some of our concern about the enhancement of memory for associated pairs being due solely to learners' control over testing, since such reminding at test would be unlikely to affect the first-recalled member of a pair of related items.

Experiment 1B

Method. Experiment 1B followed the same procedure as Experiment 1A but used four retention intervals following each study list. Though the original goal of Experiment 1B was to examine whether reminding affects the shape of the forgetting function, our intervals turned out to be too short to elicit enough forgetting to assess those functions. We present the experiment here because, when collapsing across retention interval, it provides a replication opportunity for Experiment 1A.

Subjects. One-hundred and thirty-seven introductory-level psychology students from the University of Illinois at Urbana-Champaign participated in exchange for partial course credit.

Procedure. Experiment 1B utilized the same procedure as Experiment 1A, but varied the retention interval between study and test. After each study block, learners completed double-digit addition problems on the computer for 5, 15, 60, or 180 s before being tested on the studied items. Retention intervals were randomly assigned to the four study blocks. Subjects were yoked together in groups of four, just as in Experiment 1A.

Results. Results were combined across lag and retention interval conditions and replicate those found in the prior experiment. Free recall performance for P1s in associated pairs was higher than mean recall for the same items in unrelated pairs, $t(136) = 9.85$, $p < .001$, Cohen's $d = 0.84$. P2s in associated pairs were also better recalled than identical, unrelated items in the same list positions, $t(136) = 12.71$, $p < .001$, Cohen's $d = 1.09$. Thus, for both P1 and P2, the reminding effect obtained.

Repeated items were also more accurately recalled than both first and second presentations in associated pairs, $t(136) = 9.86$, $p < .001$, Cohen's $d = 0.85$; $t(136) = 9.29$, $p < .001$, Cohen's $d = 0.80$ respectively. Memory performance as calculated for independent presentations in a repetition, as calculated in the prior experiment, was higher than first and second presentations in unrelated pairs, $t(136) = 3.45$, $p < .001$, Cohen's $d = 1.72$; $t(136) = 7.21$, $p < .001$, Cohen's $d = 0.62$, respectively, indicating superadditive effects of repetition. Memory performance as calculated for independent presentations in a repetition, as shown in the dashed box in Figure 3, was again lower than that for first and second presentations in associated pairs, $t(136) = 7.99$, $p < .001$, Cohen's $d = 0.68$; $t(136) = 7.57$, $p < .001$, Cohen's $d = 0.65$, respectively, which suggests once again that reminding is a more potent event for enhancing memory than repetition.

As in Experiment 1A, to mitigate against remindings during testing, we looked separately at items output first from each of the word pairs. As shown in Figure 4, learners output a greater percentage of first presentations in associated pairs first compared to those same items in unassociated pairs, $t(136) = 4.28$, $p < .001$, Cohen's $d = 0.37$. However, the proportion of P2 items output first

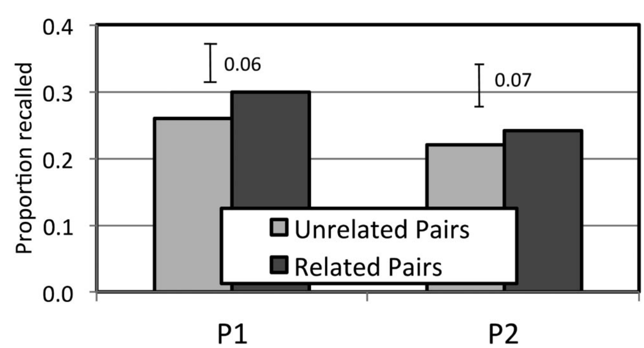

Figure 2. Proportion of first (P1) and second presentations (P2) from word pairs output first in Experiment 1A. Error bars and values show the width of within-subjects 95% confidence intervals of the difference between unrelated and related pairs. Error bars are not placed on the means themselves, because they show the within-subjects variability of the differences between proportions recalled.

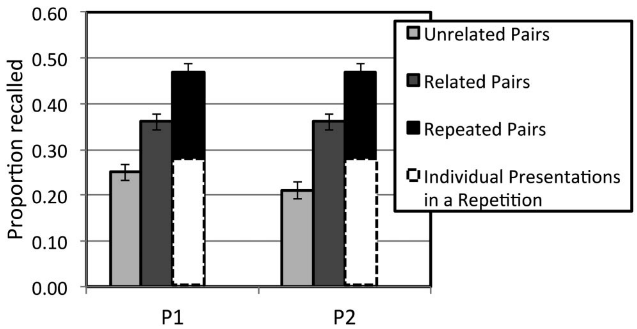

Figure 3. Proportion first (P1) and second presentations (P2) from word pairs recalled in Experiment 1B. Error bars and values show the width of within-subjects 95% confidence intervals of the difference between unrelated and related pairs.

was numerically higher for unassociated than associated pairs, $t(136) = 0.51$, $p = .61$, Cohen's $d = 0.04$.

Experiment 1C

In the third free recall experiment, we utilized the same general procedure as Experiment 1A but included a generation condition. Generation may reduce the amount of processing that happens between associated items and reduce the effects of remindings (Schmidt & Cherry, 1989). In this experiment, half of the second presentations in associated pairs were presented with a missing letter. Learners had to complete the word by generating the missing letter and typing in the whole word. As in Experiment 1B, the new manipulation (here generation) was unsuccessful in eliciting any differences in performance. We included this experiment anyway because it provides yet another replication of the core reminding effects apparent in Experiments 1A and 1B.

Method.

Subjects. Fifty-nine introductory-level psychology students from the University of Illinois at Urbana-Champaign participated in exchange for partial course credit.

Materials. Forty-two of the primary associate pairs from the prior experiments were utilized here. One word from each pair was chosen to be a generate item, and a letter was removed from the middle of each (e.g., *verb*: *ve_b*). A list structure was generated to include 30 pairs of presentations, each with a lag of one intervening item.

The list structure contained 10 associated "read" pairs, 10 associated "generate" pairs, 5 unassociated "read" pairs (where the words came from two associate pairs and the learner read both items from the pair), and 5 unassociated "generate" pairs (where the words came from two different associate pairs and the learner generated the second item).

Design. The experiment used a 2 (semantic condition) × 2 (generate condition) within-subjects design. Pairs were either associated or not, and learners either generated or read the second item in each pair.

Procedure. Subjects were instructed to remember all of the studied words for an upcoming memory test and to type in words that were presented with a missing letter. Words were presented in the middle of a white computer screen in 50-point black Arial font for 4.5 s each before being removed from the screen. Between presentations, a blank white screen was presented for 500 ms. After studying the list of presented words, subjects were asked to type in any words they remembered from the study list.

Pairs in the list were randomly assigned to be associated or unassociated pairs. Subjects were yoked together in groups of two based upon random assignment of individuals to the testing rooms. If the first subject in a testing room read a particular associated word pair (e.g., *noun . . . verb*), the second subject in that room would have to fill in that pair (e.g., *noun . . . ve_b*) in those list positions.

Results. All results found here replicate those found in the prior two experiments. Results were combined across generation conditions because there were no interactions with or effects of generation. Free recall performance for first presentations in associated pairs was higher than mean recall for the same items in unrelated pairs, as shown in Figure 5, $t(58) = 6.01$, $p < .001$, Cohen's $d = 0.89$. Second presentations in associated pairs were also better recalled than identical, unrelated items in the same list positions, $t(58) = 4.35$, $p < .001$, Cohen's $d = 0.58$. Thus, the reminding effect was yet again present for both P1 and P2.

As before, we looked only at items output first from pairs to mitigate against remindings during testing. As shown in Figure 6,

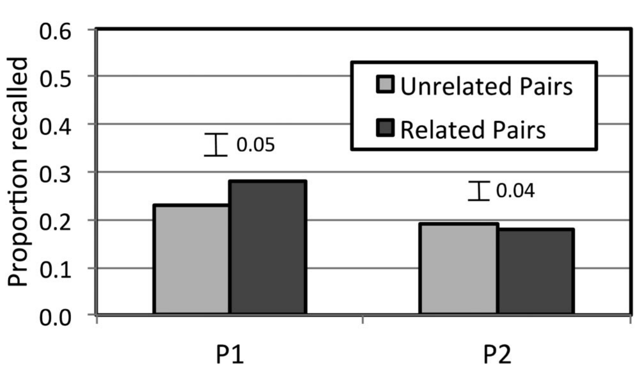

Figure 4. Proportion of first (P1) and second presentations (P2) output first in Experiment 1B. Error bars and values show the width of within-subjects 95% confidence intervals of the difference between unrelated and related pairs.

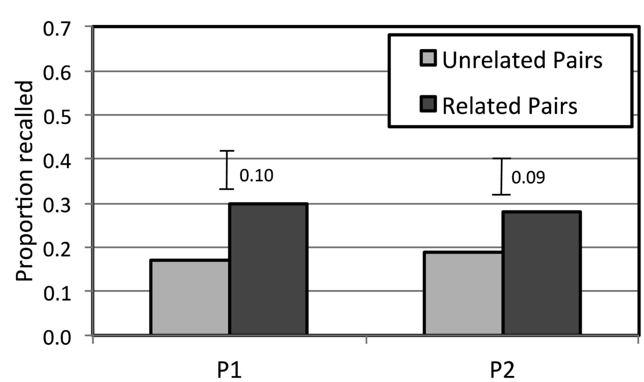

Figure 5. Proportion of first (P1) and second presentations (P2) recalled in Experiment 1C. Error bars and values show the width of within-subjects 95% confidence intervals of the difference between related and unrelated pairs.

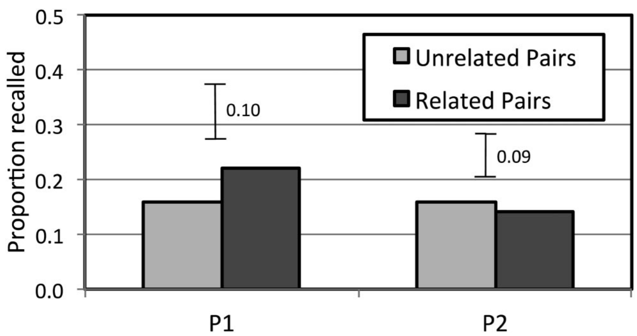

Figure 6. Proportion of first (P1) and second presentations (P2) output first in Experiment 1C. Error bars and values show the width of within-subjects 95% confidence intervals of the difference between unrelated and related pairs.

learners output a greater percentage of P1s in associated pairs first compared to those same items in unassociated pairs, $t(58) = 2.43$, $p = .02$, Cohen's $d = 0.44$. However, the proportion of P2 items output first was not significantly higher for associated than unassociated pairs; in fact, the trend was in the opposite direction, $t(58) = 0.60$, $p = .55$, Cohen's $d = 0.18$.

Discussion. Items are recalled better if followed by related items than if followed by unrelated items. Additionally, an item that is preceded by a related item is recalled better than when it is preceded by an unrelated item. The memory benefit for presentations in associated pairs provides strong evidence for the reminding effect, a mnemonic boost caused by a nearby presentation of an associated item. Reminding theory suggests that this effect arises because later presentations prompt retrieval, and thereby enhance memory, for earlier items. There was weak evidence that the second items in associated pairs are better remembered due to reminding during testing. Across all three experiments, when looking only at first-output items, the effect of relatedness on memory for P1 was considerable (Cohen's $d = 0.35$) but not apparent for P2 (Cohen's $d = 0.005$).

Impressively, remindings in this experiment appeared to be even more beneficial than repetitions; memory for individual items in associated pairs was better than memory for individual presentations in repetitions. Separating repetitions of words in time is very beneficial to memory, as shown in the spacing effect (Melton, 1970); the results here suggest that separating words in semantic space may lead to analogous enhancements in performance. However, these results are based on the assumption that the two presentations of a repeated item make separate and independent contributions to memory, and this assumption is questionable. We take this result as a provocative suggestion but by no means definitive.

The results reported from Experiment 1 are tempered by the limitations of free recall (Delaney et al., 2010). Free recall may be subject to list-strength and output order effects (e.g., Shiffrin, Ratcliff, & Clark, 1990), which confounds poor memory for more weakly remembered items with output order effects. For example, recall of P2 may suffer because P1s are remembered better and are output first. P2s are recalled after learners output P1s and this artificially increases the retention interval for P2s, which may mask the mnemonic benefits that P2s receive from remindings. Further, recall of one item may cause learners to strategically recall associates of that item (Howard & Kahana, 2002). To more fully control strategies utilized during testing, list-strength effects, and output order effects, we conducted a new set of experiments using recognition testing. Recognition testing controls the output order of items and should negate concerns about the effects of item strength.

Experiments 2A–2B

In Experiments 2A and 2B, learners once again studied a list of associated and unassociated word pairs. However, instead of taking a free recall test, learners completed a recognition test for the studied items. The recognition tests allow us to better control the strategies that subjects use during the test. If memory performance for P1 is still enhanced on a recognition test, the benefits of reminding are not caused solely by the freedoms provided by free recall testing.

Experiment 2A

Method.

Subjects. One-hundred and eighty-three introductory-level psychology students participated in exchange for partial course credit.

Materials. The list of 96 primary associate pairs from Experiment 1A was reduced to include only 60 primary associate pairs. Primary associate pairs were selected in order to ensure a diversity of relationships between items and included a mixture of synonyms, antonyms, gender roles, noun–verb pairs, and thematic relationships. Forty-eight unrelated, single words were selected from the pool of 96 from Experiment 1A. Additionally, eight unrelated words were selected for use as primacy and recency buffers. One list structure of 96 total presentations was created. As in the previous experiments, words and conditions were randomly selected to fill the list structure, and the same counterbalancing scheme as Experiment 1A was utilized. The list structure comprised 12 pairs of associates, 12 repetitions, 12 first unrelated pairs (where a primary associate word was followed by an unrelated word), and 12 second unrelated pairs (where an unrelated word was followed by a primary associate word). Half of each set of pairs were shown at short lags (four intervening words), and half were shown at long lags (16 intervening words).

Procedure. The presentation and timing of items during the study list occurred as in Experiment 1A. Subjects in this experiment participated in a recognition task immediately following the study phase. During the recognition task, single words were presented on the screen, just as during the study session, and subjects rated how well they recognized each item on a scale of 1–4, where 1 indicated *I am certain I have not seen that word*, 2 indicated *I think I have not seen that word*, 3 indicated *I think I have seen that word*, and 4 indicated *I am certain I have seen that word*. Subjects rated 168 words during the recognition task, half of which they had seen and half of which they had not seen. All studied items were tested. The composition of the list of distractors mirrored the composition of the list of studied words: It included 24 unstudied words from the unrelated word list, both words from 12 unstudied associated pairs, and 36 unstudied words from associated pairs where only one associated item was studied. The order of test items was determined randomly for each subject.

Results. Results are collapsed across lag, as the pattern of results across lag was consistent. Ratings of 3 and 4 were considered endorsements of having seen a studied word. Average hit rate and false-alarm rates are shown in Figure 7. Hit rates were marginally higher for first presentations in associated pairs than for the same items in unassociated pairs, $t(182) = 1.87$, $p = .06$, Cohen's $d = 0.17$. Hit rates were significantly higher for second presentations in associated pairs than for the same items in unassociated pairs, $t(182) = 1.98$, $p = .05$, Cohen's $d = 0.13$. We calculated two kinds of false alarms: endorsements to words from associated pairs that were never seen and endorsements to words from associated pairs where only the paired related item was seen. False alarms were significantly greater to items when a related word was studied than when no related words were studied, $t(182) = 4.84$, $p < .001$, Cohen's $d = 0.28$.

The higher hit rates and false-alarm rates to associated items over unassociated items may indicate a shift in response criteria that needs to be accounted for in an analysis of overall recognition sensitivity. To account for changes in both hit rates and false alarms, we computed d_a, a signal-detection theoretic value of memory performance that treats confidence ratings as response criteria (Green & Swets, 1966). We computed d_a for associated items by using the hit rates for items in associated pairs and false-alarm rates to items when only its associate was studied. We computed d_a for unassociated items by using the hit rates to related word pairs where only one word was studied and false-alarm rates to words from related word pairs that were not studied at all. This analysis controls for the differential false-alarm rates between presentations of related items. Frequencies of ratings from each subject were transformed into reverse cumulative proportions, which were used to construct receiver operating curves. We computed d_a values from this rate of change for each subject using maximum-likelihood estimation (see Figure 8). The d_a values reveal a slight numeric advantage for items from unassociated pairs over those from associated pairs for both P1, $t(182) = 1.56$, $p = .12$, Cohen's $d = 0.11$; and P2, $t(182) = 0.43$, $p = .66$, Cohen's $d = 0.03$, thus providing no evidence for reminding. This experiment had very high power to detect differences with small effect sizes (power = .98). We will return to these results after presenting a replication in Experiment 2B.

Experiment 2B

To verify that remindings do not influence performance on recognition tests, we measured the influence of association on recognition performance in a slightly new paradigm that was designed to enhance the likelihood of reminding during study by interleaving study and test trials. In Experiment 2B, learners engaged in a continuous recognition paradigm, in which they judged whether each presented word had been presented earlier. Incorporating the memory test into the study phase (and thereby eliminating the separate test phase) should encourage learners to look back continuously and should thus promote remindings (Jacoby, 1974). If we find no evidence of enhancements related to remindings, even when we are prompting learners to constantly look back through their study list, this would provide even stronger evidence that remindings do not influence recognition performance.

Method.

Subjects. Fifty-one introductory-level psychology students participated in exchange for partial course credit.

Materials. Ninety-two strongly associated word pairs and 160 single words were used in this experiment. In the list structure, related and unrelated word pairs were separated by four intervening items, and the second presentation of each item (the test of the item) followed the initial presentation of the item after 80 intervening items. Eight conditions existed in the list structure, which had 404 total presentations. We will represent each of the conditions by a sequence of four letters, where each letter represents the presentation of an item. "A" represents one word from a related pair, "B" represents the other word from a related pair, and "X" represents an item from the single word list. The second presentation of a letter indicates a test for that word. The different conditions are as follows: ABAX (test hits for A when intervening related B is presented), ABXB (test hits for B when preceded by related A), AXAX (test hits for A when intervening item is unrelated), XBXB (test hits for B when preceded by an unrelated item), AXXB (test false alarms to B when preceded by a related item), XBAX (test false alarms to A when preceded by related item), XXAX (test false alarms to A when not preceded by related items), XXXB (test false alarms to B when not preceded by related items). Words were randomly selected to fill the list structure, and the conditions were selected such that each condition was used N times before any condition was used $N + 1$ times, until each condition was used 10 times. Throughout the list, filler items from the single list were also used to maintain appropriate spacing between presentations and to maintain a mixture of seen and unseen word presentations.

Procedure. Learners were given detailed instructions about the continuous recognition procedure before beginning and were

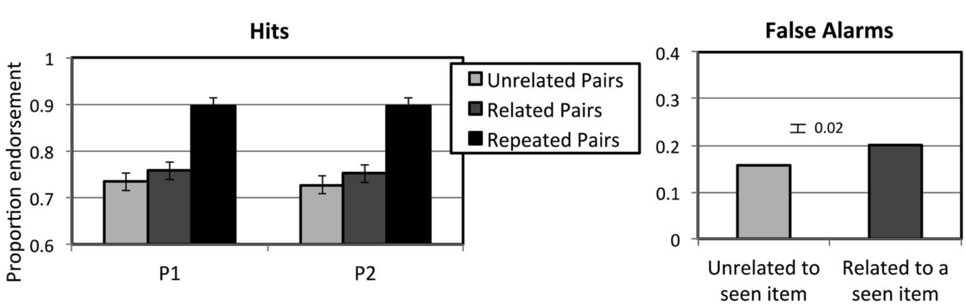

Figure 7. Hits (left) and false alarms (right) to words in related, unrelated, and repeated pairs in Experiment 2A. Error bars show the within-subjects 95% confidence intervals separately for first (P1) and second presentations (P2).

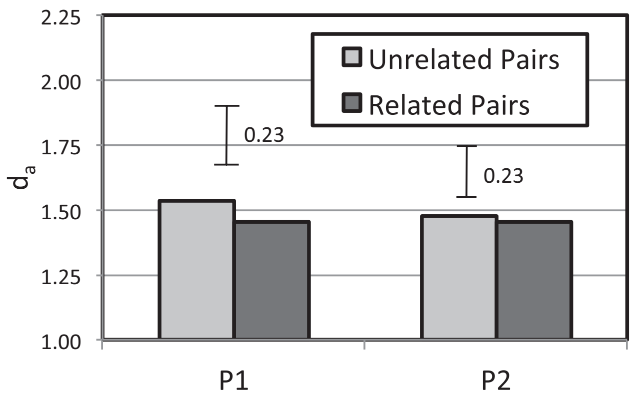

Figure 8. Discrimination (d_a) for words from associated and unassociated word pairs in Experiment 2A. Error bars and values show the width of within-subjects 95% confidence intervals of the difference between unrelated and related pairs. P1 = first presentation; P2 = second presentation.

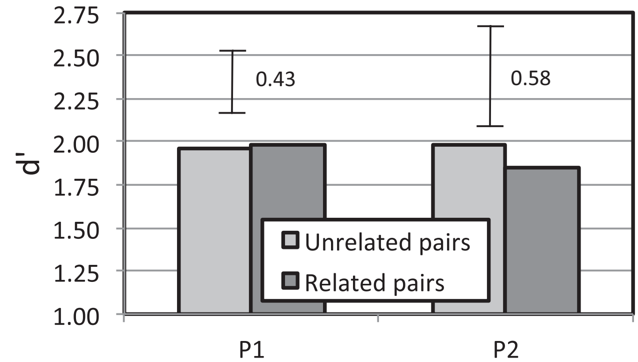

Figure 10. Discrimination (d') for words from associated and unassociated word pairs in Experiment 2B. Error bars and values show the width of within-subjects 95% confidence intervals of the difference between unrelated and related pairs. P1 = first presentation; P2 = second presentation.

presented with an example series of words. After learners read the instructions, words were presented on the screen one at a time for 3 s. During the 3 s, learners were required to respond if they had seen that word before or not. If learners failed to respond during that time, an error message was displayed for 3 s that asked learners to please respond to every presented item.

Results. Subjects failed to respond to less than 1% of trials, and those trials were removed from all analyses. Subjects' hit rates and false-alarm rates are displayed in Figure 9. Subjects had numerically higher hit rates to related P1s and P2s compared to unrelated items, $t(50) = 1.79$, $p = .08$, Cohen's $d = 0.25$; $t(50) = 1.23$, $p = .23$, Cohen's $d = 0.17$, respectively. However, subjects also had higher false alarms to items related to studied items than items unrelated to anything studied, $t(50) = 3.48$, $p = .001$, Cohen's $d = 0.49$.

To account for both hits and false alarms, we computed d' to determine memory strength across the conditions as in the prior recognition study (Green & Swets, 1966). Because perfect hit and false-alarm rates cannot be used to compute d', one half of an item was subtracted from any perfect hit rates and one half of an item was added to any perfect false-alarm rates to allow computation of d' (Snodgrass & Corwin, 1988). The d′ values are displayed in Figure 10 and reveal no significant benefits to recognition memory performance for associated pairs over unassociated pairs for both P1, $t(50) = 0.15$, $p = .88$, Cohen's $d = 0.02$; and P2, $t(50) = 1.09$, $p = .28$, Cohen's $d = 0.15$. The power to detect a small effect of association on memory performance was medium (power = .55).

Discussion. The results from the recognition experiments reveal dramatic differences from the results of the free recall experiments. Experiments 2A–2B indicate that items in associated pairs do not elicit superior recognition than items from unassociated pairs once differences in response bias are taken into account. The differences between the results of Experiments 1A–1C and Experiment 2A–2B may be explained in two different ways. First, in free recall experiments, learners have complete control over output order, which can lead to reminding during testing or strategic choices that use output order and list-strength effects to yield the appearance of reminding. The advantage of associated pairs in free recall may be an effect of reminding during subject-controlled output. This interpretation suggests that the reminding effect is not real and that it only appears in Experiments 1A–1C because of uncontrolled confounds at test.

Another possibility is that standard recognition testing does not tap aspects of memory that are enhanced by the act of reminding. Reminding may only benefit recall tests because retrieval is known to have larger effects on later recall than recognition (Chan & McDermott, 2007). The effects in Experiments 1A–1C may reflect

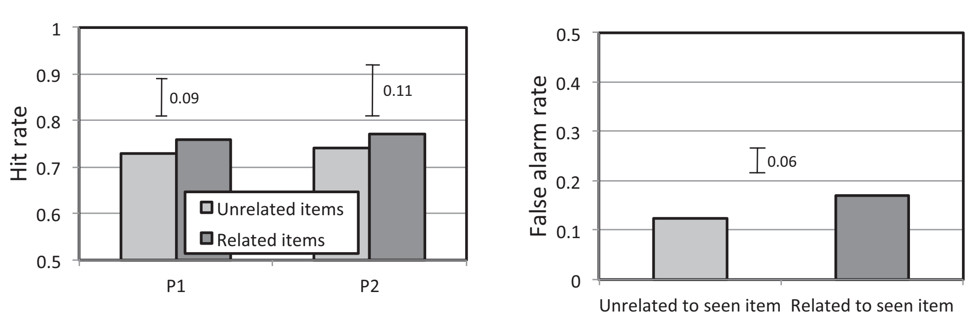

Figure 9. Hits (left) and false alarms (right) to words in associated and unassociated pairs in Experiment 2B. Error bars and values show the width of within-subjects 95% confidence intervals of the difference between unrelated and related pairs. P1 = first presentation; P2 = second presentation.

some degree of reminding at study that are not replicated in Experiments 2A–2B because recognition tests do not reveal the benefits of prior retrieval. Alternatively, the recognition tests utilized in Experiments 2A–2B may not assess recognition in a manner that remindings have the potential to influence. Remindings may create relationships among studied items, and standard recognition tests prevent learners from using these relationships during testing. Influences of remindings might be revealed on other types of recognition tests. For instance, associative recognition tasks (or compound recognition tasks; see Cohn & Moscovitch, 2007) may better assess memory for the relationship between two studied, related items than the standard and continuous recognition tasks utilized here.

In the final set of experiments, we sought a balance between the merits of the two prior procedures. We wanted a test in which we could control the order of output—thereby limiting output order effects, list-strength effects, and opportunities for reminding at test—and that would also be sensitive to the mnemonic effects of reminding-induced retrieval. We used an independent-probe cued recall test, introduced below.

Experiments 3A–3B

In the third series of experiments, we attempted to tease apart the two major differences in the prior experiments—control over output order and sensitivity to the benefits of retrieval—by using a modified cued recall task. In this study, as in the previous studies, learners studied a list of associated pairs. At the time of the test, learners received an extralist cue that uniquely cued a single item from the study list and were required to recall the appropriate target item. In this manner, output order was completely controlled, but learners still had to recollect the studied items. Theories suggest that the influence of list strength should be minimized in an extralist cuing procedure (Bäuml, 1997; Ratcliff, Clark, & Shiffrin, 1990). Further, independent probes allowed us to utilize the similar associate pair stimuli as in the previous experiments while controlling remindings during test. They also allow us to test memory for a specific individual presentation in a related pair because independent test probes that point uniquely to one specific studied item should not influence the memory for the related item.

Experiment 3A

Method.

Subjects. Fifty-nine introductory-level psychology students participated in exchange for partial course credit.

Materials. Forty associate pairs from the previous experiments were included in the study list. Associate pairs were selected so that no pair had any association to others, according to the South Florida Free Association Norms. Further, pairs were selected such that each word in a pair could be uniquely cued by an extralist word. For example, *pancakes* and *syrup* were included because *stack* cues *pancakes* without cuing *syrup* and *sticky* cues *syrup* without cuing *pancakes*. Sixty-four unrelated, single words that had no association to any of the associated pairs or cues were collected. One list structure of 68 total presentations was created. The list included four single presentations and 32 pairs of slots separated by two intervening items. As in the previous experiments, words and conditions were randomly selected to fill the list structure. As in Experiment 2B, the constraint existed that N presentations of each condition had to occur before $N + 1$ of any condition could occur. Sixteen pairs of associated items and 16 pairs of unassociated items were presented during the study list. Unassociated pairs were created by using one item from the associate pair list and an unrelated item from the single word list. Half of the associated pairs had the word from the associated list occur in the P1 position, and half had the associated word occur in the P2 position. We controlled for potential recency differences across conditions by testing half of each type of item in the first half of the test and the other half of each type of item during the second half of the test. Words from the unrelated word list were never tested.

Procedure. Subjects viewed the list of single items at a rate of 4 s per item with a 500-ms interstimulus interval. Following the study list, learners completed a spatial reasoning task, similar to the game Bejeweled, for 4 min. Then learners took a cued recall test on all of the studied items from the associated list. During the cued recall test, an extralist cue was presented on the screen with the first letter of the target word and blank slots that equaled the number of letters in the target word (*stack–p_ _ _ _ _ _ _*). Learners typed in the full target item and moved through the test list at their own pace.

Results. The results from Experiment 3A are shown in Figure 11. Cued recall performance for first presentations in associated pairs was higher than recall for the same items in unrelated pairs, $t(58) = 2.20$, $p = .03$, Cohen's $d = 0.29$. Second presentations in associated pairs were not significantly better recalled than identical, unrelated items in the same list positions, $t(58) = 0.73$, $p = .47$, Cohen's $d = 0.10$. Thus, as in the more controlled analysis in Experiments 1A–1C, the reminding effect was present only for P1.

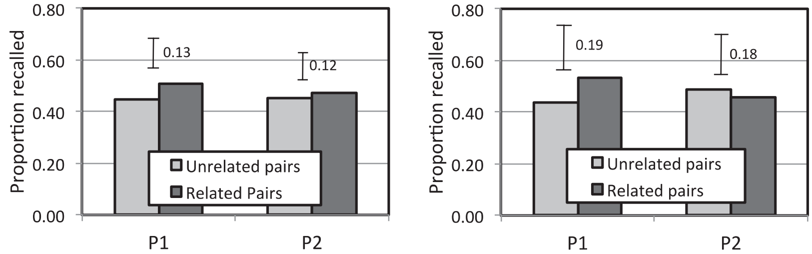

Figure 11. Cued recall performance from Experiment 3A for all items (left) and items only tested first (right). Error bars and values show the width of within-subjects 95% confidence intervals of the difference between unrelated and related pairs. P1 = first presentation; P2 = second presentation.

To mitigate against remindings during testing, we analyzed the data from the words that were tested first from each pair. As shown in Figure 11, when P1 was tested first, learners recalled a greater percentage of P1s in associated pairs compared to those same items in unassociated pairs, $t(58) = 2.25$, $p = .03$, Cohen's $d = 0.30$. When P2s were tested first, the proportion of P2 items recalled was numerically higher for unassociated pairs than associated pairs, $t(58) = 0.68$, $p = .50$, Cohen's $d = 0.09$. Thus, this most controlled analysis replicates all the effects present in the original analysis. We will discuss the implications of these results after providing a replication in Experiment 3B.

Experiment 3B

Experiment 3B replicates Experiment 3A with one exception: During study, learners judged how likely they would be to remember each presented word at the time of the test. Judgments of learning (JOLs) may be influenced by earlier presentations of related items and therefore serve as an unobtrusive index of reminding during study. Further, it is unlikely that JOLs place any demand characteristics on learners to be reminded of prior items and should not encourage more remindings than those produced naturally by the stimuli.

Method.

Subjects. Ninety-eight introductory-level psychology students participated in exchange for partial course credit.

Procedure. The experiment used the same materials and followed the same procedure as the previous study, with one exception. During study, learners judged how likely they would be to remember each of the presented words at the time of the test. Words were presented for 1 s after which subjects rated how likely they would be to remember that word on an upcoming memory task. Learners made their JOLs on a scale of 1 to 4, with 1 indicating that they believed they would definitely not remember the word at the time of the test and 4 indicating that they believed they would definitely remember the word later. JOLs were self-paced. JOLs may indicate when a reminding occurs without affecting how often they do occur. Higher judgments may indicate a greater likelihood that a reminding occurred. The cued recall test proceeded just as in the prior study.

Results. As shown in Figure 12, and as expected, JOLs were not significantly different for P1s in associated pairs compared to those same items in unassociated pairs, $t(97) = 1.29$, $p = .20$, Cohen's $d = 0.13$. JOLs were significantly greater for second presentations of items in associated pairs than for those same items in unassociated pairs, $t(97) = 6.05$, $p < .001$, Cohen's $d = 0.61$. When a related word preceded an item, learners rated P2 as more memorable. JOLs to P2s increased as memory performance of prior associated words increased, as shown in Figure 13, but were unaffected by memory performance of unassociated P1s. The signal detection theoretic measure of resolution (Benjamin & Diaz, 2008; Masson & Rotello, 2009) between the JOL for P2 and memory performance for P1 was greater for related P2s ($d_a = 0.22$) than in the unrelated condition ($d_a = -0.02$), $t(95) = 2.90$, $p = .005$. JOLs for P2 were equally related to recall of P1, as were JOLs of P1 ($d_a = 0.19$).

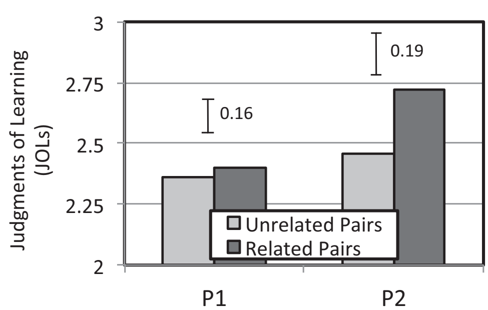

Figure 12. Judgments of learning for associated and unassociated word pairs in Experiment 3B. Error bars and values show the width of within-subjects 95% confidence intervals of the difference between unrelated and related pairs. P1 = first presentation; P2 = second presentation.

The memory performance results are shown in Figure 14, and replicated those found in Experiment 3A. Cued recall performance for first presentations in associated pairs was higher than recall for the same items in unrelated pairs, $t(97) = 3.02$, $p = .003$, Cohen's $d = 0.30$. Second presentations in associated pairs were not significantly better recalled than identical, unrelated items in the same list positions, $t(97) = 1.72$, $p = .09$, Cohen's $d = 0.17$.

We narrowed our scope of analysis to eliminate reminding during testing by excluding data from words from associated pairs tested second, as in prior experiments. As shown in Figure 10, when P1s were tested first, learners recalled a greater percentage of P1s in associated pairs compared to those same items in unassociated pairs, $t(97) = 2.10$, $p = .04$, Cohen's $d = 0.21$. When P2s were tested first, the proportion of correctly recalled P2 items did not differ between associated and unassociated pairs, $t(97) = 1.26$, $p = .21$, Cohen's $d = 0.13$.

In an analysis collapsing over Experiments 3A–3B, we found a mnemonic advantage for related P1s over unrelated P1s for items tested first, as shown in Figure 15, $t(157) = 2.14$, $p = .03$, Cohen's $d = 0.17$. Cued recall performance for P2s tested first was unaffected by relations to other words, $t(157) = 0.58$, $p = .56$, Cohen's $d = 0.05$.

Discussion. Across both cued recall experiments, learners showed a significant memory advantage for items that were later followed by related items compared to those same items when not followed by a related item. Memory performance did not differ for items preceded by a related item compared to items not preceded by a related item. Relations during learning, then, enhance the cued recall of the first presentation in a related pair. Higher JOLs to the second item in related pairs provides further evidence that the reminding effect happens during the later presentation of a related item. Processing of P2 is affected by earlier related P1s, and this change in processing during P2 improves memory performance for P1. Changes in JOLs at P2 may reflect conscious reminding processes (where learners consciously think back to prior related items) or more implicit reminding processes (where P2 is processed more fluently in reminding cases than in unrelated cases without a subject's conscious awareness). These data cannot differentiate between explicit or implicit reminding accounts. The reminding effect is still present in Experiments 3A and 3B, even though the confounding influence of output order effects, list-strength effects, and test-time reminding are severely reduced by the independent-probe cued recall procedure. The reminding effect, in this form, is a result of mnemonic processes that happen during encoding.

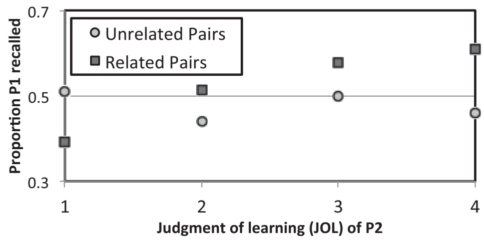

Figure 13. Cued recall performance of the first presentation (P1) in associated and unassociated pairs as a function of judgments of learning to the second presentation (P2) in those pairs in Experiment 3B.

General Discussion

The reminding effect reveals that memory for the first member of a pair of related items in a word list is enhanced by the presentation of the second member. In the first-output analyses of Experiments 1A–1C, and in the first-tested independent-probe cued recall Experiments 3A–3B, in which the opportunity for reminding to occur at test is eliminated, the result still obtained. This result indicates that the reminding effect is not likely due to any number of things that could be happening at the time of the test, including list-strength effects, the effects of control over output order, or simple reminding during the test (when in retrieval mode) but not at study. Test performance for the second presentation in a related pair appears to be enhanced only when learners have control over output order at test, and therefore probably reflects strategies or reminding that occur during the test. No evidence was found for the enhancement of memory for related items across recognition tests, even though we had very high power to detect the difference (Experiment 2A) and we encouraged learners to consistently look back through their study list (Experiment 2B).

The benefits of reminding appear to be limited to tasks that involve retrieval. This may be an example of transfer-appropriate processing (Morris, Bransford, & Franks, 1977): Reminding is, in some sense, unintentional retrieval practice and thus might promote more efficient later retrieval. There is evidence that suggests that retrieval practice has a much larger impact on later memory tasks that tap retrieval than on tasks that rely upon familiarity (Chan & McDermott, 2007). Because remindings are practice retrieving a specific episode, they may only influence the ability to retrieve the episode in the future, which may influence mnemonic performance on recall tests.

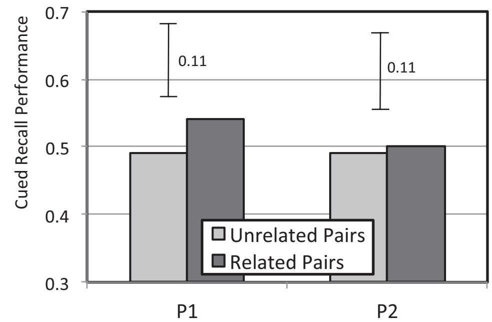

Figure 15. Cued recall performance across Experiments 3A and 3B for items tested first. Error bars and values show the width of within-subjects 95% confidence intervals of the difference between unrelated and related pairs. P1 = first presentation; P2 = second presentation.

Benefits to the second presentation in related pairs may occur during free recall due to learners' output strategies. Access to the first item in a related pair during test can lead learners to recall the second item from a related pair, even if no reminding occurred during the study list. The ability to bootstrap one's way to recall of the second presentation in a related pair from the first presentation may explain why both P1 and P2 are enhanced in free recall tasks, but not in tasks where the output order is strictly controlled. Using recall of one item to elicit recall of an associated item is a core component of major theories of free recall (e.g., Howard & Kahana, 2002). Instead of overlapping temporal context driving the output order of items, here we suggest that overlapping semantic knowledge and associations enable recall of the second presentations from related pairs.

When list-strength and output order effects were well controlled, no significant differences were found for memory of P2 in related and unrelated pairs. Relationships among studied items may alter the first but not the second presentation in a pair for at least three reasons. First, upon studying P2, learners elaborate on P2 by usually thinking of other things. When those other things are related, earlier items, the memory for the earlier items is enhanced. However, processing of P2 is no different when there was an earlier related item or not, so the memory for P2 is unaltered by an earlier related presentation. Second, processing of P2 in a related

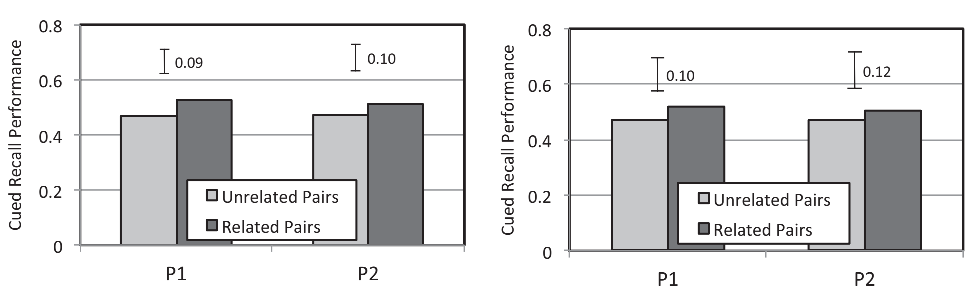

Figure 14. Cued recall performance in Experiment 3B for all items (left) and only items tested first (right). Error bars and values show the width of within-subjects 95% confidence intervals of the difference between unrelated and related pairs. P1 = first presentation; P2 = second presentation.

pair is more relational and deeper than processing of P2 in unrelated pairs. The extra relational processing that learners exert during related P2s, however, is counteracted by some displaced processing to P1, thus making those benefits more difficult to detect. Third, processing of related P2s is qualitatively different from processing of unrelated P2s, but the differences are not revealed by the types of tests utilized in our experiments. Future research will be needed to evaluate to these three possibilities.

The reminding effect, and its accompanying boundary conditions, has important implications for theories of reminding. While the action of reminding happens during the second presentation of a reminded pair, the important consequences of reminding change the memory only for the first presentation. Further, the memory enhancement is only present in tests that rely primarily upon retrieval. Although several reminding theories predict the enhancement of the first item in a reminded pair, they offer different suggestions as to the underlying mechanisms by which that enhancement arises. Rundus (1971) offered a pure rehearsal explanation of the benefits seen in P1. In his view, later items prompt increased conscious rehearsal of earlier items and the extra rehearsal causes the mnemonic benefits for the first presentation. Hintzman (2010) suggested that later presentations recursively remind learners of earlier episodes. Through recursive reminding, earlier episodes are incorporated into the memory traces for later episodes, and consequently the memory traces are enhanced. Benjamin and Tullis (2010) suggested yet another explanation of the benefits of remindings, arguing that the effortful retrieval of the earlier item at the time of the related item enhances memory for the first item. No extant models, including the simplest versions of the rehearsal (Rundus, 1971), recursive reminding (Hintzman, 2011), and retrieval explanations (Benjamin & Tullis, 2010) make clear predictions about the effects of reminding on memory for P2. Hintzman's recursive reminding view may suggest that the memory trace for P2 becomes elaborated through reminding. Using P2 to retrieve P1 may enhance memory for the second item by producing more interitem associations and a more complex, elaborated memory trace for the second item. The retrieval view does not suggest that the memory for P2 should be changed by the reminding; if anything, the increased attention and effort toward retrieval of P1 during the presentation of P2 may slightly impair the memory for P2. All theories of reminding, however, ultimately rely upon retrieval of the earlier episode at the time of the second and suggest that this retrieval benefits memory.

The results presented here begin to constrain the theories that explain what happens during reminding. While further experimentation will be needed to precisely determine the contributions of retrieval, elaboration, and active rehearsal to enhancements in memory for P1, the retrieval view seems the most able to explain why enhancements in memory performance are seen only for P1s and only in recall tasks. The benefits of remindings may arise from the effortful retrieval of a prior episode, which may only benefit tests that require intentional retrieval search. Further, because it is only a retrieval of the first presentation, memory performance for the second member of a pair remains unaltered.

The results presented here blur the boundaries between encoding and retrieval phases in traditional memory experiments: Semantic relationships between separated items during encoding induce a particular type of retrieval that we call reminding and this retrieval changes memory performance. The results hint that prior studied items are retrieved later during the study phase and that learners do not need to be in a retrieval mode to access prior episodes. For many reasons, traditional memory research has actively discouraged making connections across study material by presenting learners with lists of unrelated, unassociated words. We have shown that this choice ignores the connections that learners naturally make when learning new material. Theory has typically compartmentalized memory into three distinct phases (encoding, storage, and retrieval), but in doing so has ignored the important interactions between those processes. Learners are constantly engaged in encoding and retrieval, often using retrieval of prior knowledge to help with ongoing encoding. Connecting new knowledge to prior knowledge or personal experiences beneficial for acquiring new knowledge (McNamara & Kintsch, 1996; Rogers, Kuiper, & Kirker, 1977). Here we show that connecting new knowledge to prior knowledge also enhances memory for the old, previously learned information. However, we theorize that the processes for forward and backward enhancement are different. Connecting new knowledge to old knowledge may help memory for new knowledge by providing organization and structure with which to elaborate upon it. According to reminding theory, memory for prior knowledge may be enhanced just through its effortful retrieval at the time of the second presentation.

Though the reminding effect is the most basic consequence of the reminding processes outlined here, the mnemonic benefits of reminding are broader than what we have reported here. Remindings aid in judging the distance between presentations of related material (Hintzman et al., 1975), list discrimination (Jacoby et al., 2013), and temporal order judgments (Hintzman, 2010; Jacoby & Wahlheim, 2013; Tzeng & Cotton, 1980). These results suggest that remindings enhance not only item-specific memories for the first presentation in a related pair, but also create or enhance memory for the relationship between the items in the pair.

Remindings are a basic building block of cognition; they allow us to bring past experiences to the present, to generalize across similar experiences, and to contrast between different experiences. Remindings determine not only what is learned (Ross et al., 1990), but how well it is learned. Remindings may serve an adaptive function because they may occur during (and therefore enhance memory for) events that are meaningfully related to our past experiences. When we can relate distant experiences to one another, we can use our memory to do more than retain old information—we may be able to generate new knowledge.

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