

JUST A REMINDER: REMINDING INFLUENCES UNDERSTANDING

BY

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THESIS

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ABSTRACT

Reminders have been shown to play an important role in concept learning, problem solving by analogy, and basic memory phenomena such as the spacing effect. However, little research has addressed their role in interpretation and understanding. The current experiment explores that possibility by testing whether reminding caused by semantic and contextual cues can bias the interpretation of homographs. Subjects were shown a list of words that included homographs and cue words related to a non-dominant meaning of each homograph. For each word, they wrote a sentence that was scored to assess how they interpreted the ambiguous homograph. In the *same* condition, the cue appeared several trials prior to the homograph, and they shared a common background image. In the *different* condition, the cue appeared before the homograph, but the two words were presented on different background images. The *reverse* condition, in which the cue appeared after the homograph, served as a baseline. The biasing effect of cue words, as revealed by a non-dominant interpretation of homographs, was higher in the *same* condition than in the *different* or *reverse* conditions. Additionally, non-dominant interpretation in the *same* condition was significantly higher when the background image was correctly recognized as having been previously seen. These findings suggest that reminders caused by a combination of semantic and visual cues can influence word interpretation and understanding more generally.

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INTRODUCTION

Reminders are ubiquitous in everyday life. A bank employee's scowl reminds me of her rudeness on my last visit, so I choose the other teller. I solve a data analysis problem by remembering a similar problem in the textbook and using that as a guide. Research has shown that reminders play a critical role in enhancing memory, fostering concept learning, and even solving problems. The goal of the present research is to evaluate the role of reminding in promoting understanding.

Reminding in higher cognition

As noted by Benjamin and Ross (2010), reminding is the process by which generalization and contrast can be achieved at a distance. These processes can be seen in a number of cognitive domains. For example, reminders foster problem solving by way of analogy, when problem-solvers are reminded of the details of an earlier problem and use that information to solve a new one. These processes have been studied in formal domains, like physics and mathematics. That research has shown that novices are often reminded of possible analogs based on surface similarities. In physics, for example, new students will solve inclined plane problems by reference to other inclined plane problems (Chi, Feltovich, & Glaser, 1981). The goal of advanced instruction in math and physics is to encourage students to think about problems conceptually, and thus use deep conceptual features rather than superficial ones to guide reminding of relevant prior examples. However, even many formal domains include problems for which superficial content is a useful clue for categorizing or solving a problem. Reminders and subsequent generalization over content-similar problems may be one way such useful

dependencies are learned and come to be included in experts' problem schemata (Blessing and Ross, 1996).

Reminders also play a role in some theories of concept learning. Early accounts claimed that people use a summary representation as a basis for classifying new items, with similarity to this prototype determining category membership and typicality (Rosch, 1975). This prototype view eschewed any possibility of using specific category instances in future tasks, divorcing aspects of concept learning and use from memory of specific category members. Later theories, which posited learning of exemplars as the basis for category learning (Medin & Schaffer, 1978; Brooks, 1978), suggested that new instances are categorized based on which previous instance the learner is reminded of. These exemplar-based views accounted for data that prototype views did not, such as the phenomenon that people learn about the correlations of features within categories (Medin, Altom, Edelson, & Freko, 1982). Additionally, there is evidence that reminders that occur when learning a category lead to generalizations about that category, and that the mechanism underlying this ability is an explicit comparison of the current instance with reminded instances (Ross, Perkins, & Tenpenny, 1990).

Reminding and memory

The process of reminding also plays a role in how people remember material. For example, in autobiographical memory, automatic reminders may help people remember the order in which events occurred. Friedman (2007) suggested that whenever one event causes the retrieval of a previous event, a representation for the order of those events is stored in memory. This hypothesis leads to the prediction that people should be more accurate at judging the

temporal order of related than unrelated events, which is empirically supported by several studies (e.g., Nairne & Neumann, 1993; Tzeng & Cotton, 1980; Winograd & Soloway, 1985).

The spacing effect. One domain in which the role of reminding has been considered is in studies of scheduling repetitions of study. The spacing effect is the phenomenon that memory performance is often superior when study opportunities are spaced farther apart in time. There are numerous competing theories of this basic phenomenon, two of which I will review briefly. *Encoding variability theory* states that, the farther apart two presentations of an item are, the greater the variety of contextual elements or encoding processes that item will have experienced. At the heart of this view is the idea that a second encoding opportunity that includes different information from the first is superior, because of the greater diversity of retrieval cues of encoded information that arises. An implication of this view is that the spacing effect can be attenuated (or, more accurately, performance under massed presentations can be enhanced) by intentionally varying the context or salient features between multiple presentations of an item. This has been empirically shown with a variety of different materials. For instance, Bevan, Dukes, and Avant (1966) showed subjects pairs of pictures which represent the same concept but consist of either identical or different examples. For the concept 'shoe', for instance, they saw either two identical pictures of a men's tennis shoe or two different pictures, one a men's tennis shoe and one a woman's high heel. Memory for concepts with varying pictures was greater than for concepts with identical pictures. Bevan et al. also showed the same effect with identical versus varied adjective-noun pairs ("maple tree" twice or "maple tree" and "oak tree"). Dellarosa and Bourne (1985) showed a memory advantage with varying context using spoken sentences. Their subjects heard the same sentence twice with either two different speakers, or the same speaker both times, with memory better in the former condition.

These results all suggest that factors that decrease the relationship between the two presentations of a to-be-learned item enhance recall. However, it is on this very count that encoding variability theory encounters serious problems. Most notably, people do not remember one of two unrelated but spaced items better than two massed unrelated items (Ross & Landauer, 1978). Another complexity for encoding variability theory is evident in the results of Thios (1972). He presented subjects with sentences containing homographs. The homographs were repeated in sentences using the same (“The hi-powered drill entered the masonry blocks” twice), similar (“The hi-powered drill entered the masonry blocks”, and “The electrical drill pierced the stone blocks”), or different (“The hi-powered drill entered the masonry blocks” and “The fire drill cleared the city blocks”) contexts. His results showed that performance did not always increase with increasing spacing between the two events: different context repetitions showed a drop in performance at long lags. Appleton-Knapp, Bjork, and Wickens (2007) found a similar effect using repeated or varied advertisements for the same product. More generally, it appeared as though spacing in these two experiments led to nonmonotonic performance functions. Encoding variability theory cannot explain any drop in performance when lag is increased or when the relationship between item presentations is decreased. That is, encoding variability implies that performance will always continue to increase or asymptote with spacing. These results clearly reveal that this is not the case.

Reminding theory can explain findings that other well established spacing theories, such as encoding variability, cannot (Benjamin & Tullis, 2010). The idea is that, rather than encoding both instances of the item separately, the second instance may remind the learner of seeing it the first time. The reminding thus causes either an enhancement of the strength of the original representation or lays down a new representation. This use of reminding, it should be noted,

suggests a more interactive relation between encoding and retrieval than much traditional memory research. This interactive perspective forms a natural way of understanding why spacing functions are often nonmonotonic—performance reflects a trade-off between the conditions that enhance the effects of reminding (substantial forgetting or weak reminding cues) and those that enhance the probability of reminding (temporal proximity and strong cues).

The current studies

Given the importance of reminders in so many domains of cognition, one expects they also play a role in higher-level, integrative processes, such as understanding and interpretation. Note that, in all the varied research I have gone over here, there has been little emphasis on how a reminding activated by some stimulus might influence understanding of that stimulus at a basic level. For instance, when solving a new problem, reminding may bring to mind a relevant analog, but little research has investigated how reminding shapes the initial representation of the problem. Similarly, the role of reminding has been studied in classifying new category members, as well as making generalizations about a category. And some research (Spalding & Ross, 2000) has shown that reminding learners of previously seen category exemplars can influence the abstract interpretation of a new category member's given features. For instance, reminding can bias whether the given feature "rides a bike to work" is indicative of athleticism or of environmental concern in a person. But little research has addressed whether reminding can influence basic interpretation of category features, as in Medin and Wisniewski (1994), who show that activating category expectations can lead people to interpret the same physical stimulus (a vertical line of dots on a drawing of a person) as a different feature (buttons or a tie).

Reminding may be one mechanism that activates such expectations in real-world category learning.

Understanding can be thought of as operating in stages, as learners continuously build larger, more integrated representations from smaller pieces of information. For text comprehension, word interpretation is an early stage, while comprehension of sentences and longer blocks of text, as well as understanding thematic elements, come later. By focusing on the effect of reminders on the use of material, rather than on understanding it at a basic level, much research has also failed to address early stages of processing.

This can be seen by examining a previous example -- how reminding can influence the inference of abstract category features from given features. In order to make the determination that “rides a bike to work” indicates athleticism, a reader has to construct an integrated representation that combines the meaning of each word into an understanding of the sentence. Only after understanding the sentence as a whole can it bring to mind another individual who also rides a bike to work. If this reminded-of individual is athletic, then it is more likely the present one’s actions will be interpreted as athletic. Thus, reminding at the sentence level acts to bias abstract feature interpretation. If reminding can affect processing at the level of individual words, it would show their influence at an earlier stage.

More importantly, by eschewing a focus on understanding, previous reminding research has avoided the study of quick, non-deliberative processes, such as word interpretation. The fluency displayed by most readers shows that word interpretation occurs very quickly. It is not clear that reminders can have any effect on so quick a process – perhaps words are interpreted much more quickly than reminders occur. If so, quick ambiguity resolution may not be amenable to influence by specific earlier events, but only by more general knowledge and the

current context. This restriction may prevent some potentially non-normative behavior, as when recent experiences have disproportionately high influence, at the cost of performing worse in situations where specific experiences are more relevant than erroneous or incomplete general knowledge.

There has been some empirical support for a role of reminding in the understanding of new material, though at a passage rather than word level. Ross and Bradshaw (1994) had subjects read three stories. The first two were “source” stories, with the first about a retiring reporter reminiscing on the time he covered a jailbreak, and the second about an eccentric who enjoyed watching wrestling on television. The third was an ambiguous story that could be interpreted as being about a jailbreak or about a wrestling match. Each subject saw a superficial cue (“Delaware Daily newspaper” or “Shakespeare”) in the beginning of the ambiguous story, which was originally mentioned in either the jailbreak or the wrestling source story. Despite the superficiality of the cues used, a single reminding of the earlier story was enough to bias interpretation of the ambiguous story. Our goal, in a similar vein, is to extend the research on reminding to include interpretation and understanding of material at a basic level, and at early and quick stages of processing, not just the use of it.

Our experiments evaluate the interpretation of ambiguous homographs by asking subjects to write sentences including those words. To evaluate the effects of reminding, visual background contexts were varied across the stimuli, such that some homographs were preceded by a biasing word presented on either the same or a different background context. The presence of reminding was evaluated by assessing the biasing effect of prior words presented on similar and dissimilar contexts relative to a baseline control condition.

Specifically, participants were shown a list of words (including homographs) with background images, and asked to write a sentence using the word. Prior to the sentence generation, they were asked to evaluate whether they had previously viewed that particular background or not, in an attempt to motivate thinking back to prior episodes in the experiment. Each homograph in the list was paired with a cue word, spaced 3 list positions away, that was semantically related to the homograph's less dominant meaning (e.g., the homograph *shot* and the cue *whiskey*). In the *same* condition, the cue word appeared before the homograph with the same background image. In the *different* condition, the cue word still appeared before the homograph, but with a different background image. Finally, in the *reverse* condition, which served as a baseline control, the homograph appeared before the cue word.

My predictions for the three conditions assume that reminders can influence understanding even for relatively quick processes, such as word interpretation. More specifically, semantically relevant cue words, brought to mind via the repetition of background images, will bias the interpretation of a consequent homograph. The *same* condition should thus show the highest rate of non-dominant homograph interpretation, showing the influence of thinking back to the nearby cue words. The *different* condition, where backgrounds should not elicit any semantically relevant reminding but nearby cues are still available to bias interpretation via priming, should show a lower rate. Finally, the *reverse* condition should show the lowest rate because placing the cues after the homographs precludes any influence they might have on homograph interpretation. Word recognition performance should also be better for conditions with more reminders between members of a critical pair, since reminders constitute rehearsal of one or both items.

EXPERIMENT 1

Method

Subjects

43 University of Illinois undergraduates participated for course credit. However, seventeen subjects' data were discarded, either because they did not finish in time (14) or for failure to follow instructions (3). One subject did not complete the recognition test, so only the word list data were used. All experimental sessions lasted 50 minutes or less.

Design

A within-subjects design was used, with each subject exposed to fourteen critical (cue-homograph) pairs for each condition. When assigning each pair to a condition, the conditions were spread across the whole list, rather than blocking all trials of a condition together. The order by which conditions were spread was counterbalanced using a 3x3 Latin square, resulting in three word list orders. List order served as a between-subjects variable, with each subject seeing one of the three list orders.

The main dependent variable was the proportion of homographs that were interpreted as their normatively less dominant meaning. The *same* condition was expected to show the highest proportion of non-dominant interpretation, due to semantic (cue) and contextual (background) reminding. The *different* condition, where only semantic reminding was possible, was expected to show a lower proportion. The *reverse* condition provides a baseline rate at which the non-dominant interpretation is provided. Two dependent variables of secondary interest are the proportion of non-dominant homograph interpretations contingent on background recognition

response in the word list phase, and the proportion of recognized cues and homographs on the final recognition test.

Materials

Forty-two homographs were chosen for which one meaning was dominant (occurring more often than other meanings, usually by a great margin) according to free association norms (Twilley, et.al., 1994). The dominant meanings occurred between forty and ninety-eight percent of the time, with a mean of seventy-one percent. The non-dominant meanings occurred between one and forty percent of the time, with a mean of nineteen percent. For instance, when asked the first word that comes to mind after hearing “punch,” 52% of responses were related to striking things with one’s fist, the dominant meaning. Only 30% of responses related to fruit punch, a non-dominant meaning. The norms were then used to choose the cue most associated with a non-dominant meaning of each homograph. In this case, *bowl* was chosen as the cue for the homograph *punch*. Forty-two critical cue-homograph word pairs were thus obtained (see Appendix). Due to a programming error, for one critical pair, a cue related to the dominant meaning were used. However, since this cue was used across all conditions, it affects only the item variability and not the overall effect of condition. Additionally, one critical pair did not switch properly between experimental conditions, and its data were discarded.

Word-list presentation. Background images were distinctive images that were found via internet searches. They included nature scenes, animals, buildings, food, statues, and musical instruments. Even when multiple pictures included the same categorical content (i.e., two nature pictures), they differed in color, composition, and so on.

For each list order, the same 113 words were presented: 42 critical pairs, four primacy buffer words, three recency buffer words, and 22 filler words. To control for order effects, all 42 homographs remained in the same list position for all three list orders. However, depending on condition, a homograph's semantically related cue word might be three list positions before (same or different) or three list positions after (reverse). Filler words were inserted into the list in order to better disguise the semantic relationships among the critical stimuli.

For all three list orders, each word was randomly assigned a background image, with the following constraints: 1) the members of each critical pair in the 'same' and 'reverse' conditions shared the same background image, 2) critical pairs in the 'different' condition had different background images, and 3) all background images appeared twice. Each of the three list orders included the same fifty-seven backgrounds, though presented in a different order.

Recognition test. Additionally, a single 168-word list was compiled for the word-recognition phase. The recognition list included all 84 words from the experiment's 42 critical pairs, as well as 84 new words. The new words were selected for being common English words of one to three syllables, characteristics shared by nearly all of the homographs and cue words. The order of items in the recognition list was randomized, and this same order was used for all participants, regardless of which word-background list order they saw earlier.

Procedure

The experiment consisted of two phases: the word list phase and the recognition test.

Word List. The participants were instructed that they would be shown a series of words with background pictures, one at a time. They were told that a good way to remember each word is to write a sentence using the word's meaning. They were instructed to type such a sentence

after each word, and were informed that they would be asked some questions about the backgrounds.

The background image for each word-background pair was shown first. The question, “Have you seen this background before? y/n” was superimposed over the image in size 12 font in the center of the screen. Once participants responded by pressing the “y” or “n” key, the question disappeared, leaving only the background image. The image was displayed for 4 seconds, then the word appeared in the center of the screen in size 48 font (see Fig 1). After 2.5 seconds, the word/image pair was replaced by a blank white screen. The subject then typed a sentence that included the word and pressed enter to indicate completion. After all 113 word-background pairs had been shown, participants were congratulated on finishing phase one of the experiment, and told to press any key to advance to phase two.

Recognition Test. Participants were instructed that they would again be shown a series of words, one word at a time. Their task was to indicate whether they had seen the word earlier in the experiment by pressing y (for yes) or n (for no). They were asked to press any key to begin the task. The words were shown in size 48 black font on a white background.

Results

Homograph Interpretation Results. The homograph interpretation data are summarized in Figure 2. There was a significant main effect for reminding condition, showing that homograph word interpretation was biased by the presence of visual or semantic cues, $F(2, 46) = 14.51, p < .001$. Follow-up tests were performed comparing the means of the three experimental conditions. As predicted, the *same* condition showed a greater proportion of nondominant interpretation than both the *different* condition, $t(25) = 5.47, p < .001$, and the baseline *reverse*

condition, $t(25) = 2.88, p = .024$. The difference between the *different* and *reverse* conditions was significant, though in the opposite direction from that expected, $t(25) = 2.61, p = .045$. In all three cases, Type I error was controlled using the Bonferroni correction. There was no main effect for the counterbalancing variable of list order, $F(2, 23) = .654, p = .529$.

However, there was a significant interaction between reminding condition and list order, $F(4, 46) = 3.156, p = .022$. The simple main effect of reminding condition was assessed for list order. There was a significant effect for reminding condition for two of the list orders, but not the third. The latter showed the same decrease in the *different* condition relative to baseline, but did not show a difference between the *same* and *reverse* conditions. As a whole, these results suggest strong item effects and other methodological issues (see discussion).

Homograph interpretation rates contingent on background recognition response were also tabulated (see Table 1). Because many subjects did not contribute a score to some of the cells in this comparison, no inferential statistics were performed. However, the values from this analysis support the view that reminding is the mechanism by which understanding was influenced: Bias was much greater in the *same* condition following correct recognition of a previously seen background than failed recognition.

Word Recognition Results. Word recognition performance on the final test is shown in Figure 3. There was a significant main effect for condition, $F(2, 48) = 3.217, p = .049$. Pairwise comparisons were made with all three possible pairs of conditions, with Type I error controlled using the Bonferroni correction. Only the difference between the *different* and *reverse* conditions was significant, $t(24) = 2.71, p = .037$, with *reverse* showing a higher hit rate. This pattern mirrors the unexpected difference seen in the interpretation data.

I also tested whether word recognition performance differed between the first- and second-presented items in a critical pair. Figure 4 breaks down word recognition performance by type of word (cue or homograph) in each condition. For both *same* and *different* conditions, the first-presented item was the cue word, and the second-presented item was the homograph. In the *reverse* condition, the order was reversed. There was no main effect for presentation order, $F(1, 24) = .286, p = .598$.

Discussion

The differences in word interpretation between reminding conditions show that the presence of semantic and visual (background image) cues do have an impact on word interpretation. Critically, the repetition of background image, which should have increased the degree to which subjects successfully “looked back” at the relevant previous event, led to substantially more bias in interpretation than any other condition.

An examination of the differences between conditions shows that reminding elicited by repeated background images is the likely cause of the interpretation bias. The *reverse* condition serves as a baseline by placing the cue word after its related homograph, so that thinking back to the cue at time of homograph interpretation is impossible. The higher bias in the *same* condition is in the direction of the cued meaning, so the cue word must be exerting some influence over interpretation. However, it cannot be that the mere presence of the cue word (say, by priming), rather than thinking back to the cue at time of homograph presentation, is responsible for this effect. The *different* condition shows this by placing the cue first, but with a different background as the later homograph, resulting in reliably lower rates of non-dominant

interpretation. This shows that the mere presence of a preceding cue word (without visual reminding cues) is not responsible for the effect.

If reminding is responsible, one would also expect that not recognizing an already seen background would lead to lower interpretation bias, since it implies that the subject did not think back to an earlier background (and thus was not reminded of the earlier cue word). This is consistent with the data shown in Table 1, which shows that non-dominant interpretation rates were much higher when the background was correctly recognized as having been seen before than when it was incorrectly classified as new.

Explaining the different condition

The lower than baseline rate of nondominant homograph interpretation in the *different* condition was puzzling. I expected that these homographs would show an intermediate level of nondominant interpretation. The biasing cue-word was presented first, allowing residual semantic activation from cue-word presentation to affect processing of the later homograph. But without a repeated background, homographs would lack contextual cues for retrieval of and additional influence by the earlier biasing word. Thus, homograph interpretation in the *different* condition should have only been influenced by semantic priming, *not* by reminding.

This effect is likely an artifact, rather than a true difference. To understand why, consider how counterbalancing the assignment of critical pairs to conditions was accomplished in this experiment. Homographs remained in the same list position regardless of what condition they were assigned to. So list order primarily controlled the order in which conditions were assigned to the given homographs (and thus, where their respective cue words were placed.) For every list order, each condition was experienced once before any of them were repeated, using a constant

pattern particular to that list order. For instance, for list order 1, the pattern was *same-different-reverse*. The first homograph was assigned to the *same* condition, the second to the *different* condition, the third to the *reverse* condition, the fourth to the *same* condition again, and so on. Each list order used a different permutation of this pattern. Using this repetitive scheme, rather than randomly assigning conditions, was necessary to ensure collection of enough observations in each condition. A random scheme would have necessitated a much longer list of words to prevent list position conflicts between critical pairs.

The consequence of this counterbalancing scheme is that the forty-two critical pairs were effectively divided into three sets of fourteen, and the words in each set stayed together as they were shuffled between conditions depending on list order. Two main problems thus become apparent, each of which may partially mediate the *different* effect. First, the cohesive sets of homographs seem to have widely varying base rates of nondominant homograph interpretation, a problem exacerbated by the unequal number of subjects in each list order. Second, there was a significant interaction between reminding condition and list order, possibly indicating that the influence of a particular condition on homograph interpretation depended on which set of critical pairs were being tested.

The best estimate of a homograph set's baseline rate of nondominant interpretation is likely its performance in the *reverse* condition. *Reverse* condition homographs are untainted by any influence of their semantically related cue words, which occur after. Here I break down *reverse* performance by cohesive sets of homographs. I arbitrarily refer to these sets of homographs as Groups 1, 2, and 3. There is some variance between these groups: Group 1 ($M = 0.184$) showed the lowest performance, Group 3 ($M = 0.305$) the highest, and Group 2 about halfway between (0.246).

More important than these baseline differences is the significant interaction between reminding condition and list order. It seems that, even if the direction of each manipulation's effects remains constant, its magnitude changes. Some groups of homographs may receive more of a boost in the *same* condition than others. Conversely, some homographs show a stronger decrease from baseline when placed in the *different* condition. Group 1 had the distinction of both having the lowest baseline rates of nondominant homograph interpretation, *and* showing the greatest decrease when placed in the *different* condition.

Selection effects may have helped Group 1 skew the results. Nearly a third of participants were excluded for failing to finish in time. One consequence was an unequal number of subjects between list orders. In fact, the list order which overwhelmingly showed the *different* condition decrease (by virtue of placing Group 1 in the *different* condition) also had the most participants (see Table 2). Unweighted means, which count each list order equally, reduce the discrepancy. See Table 3, which compares weighted and unweighted means of nondominant homograph interpretation.

The data suggest the results were skewed by differing base rates of nondominant interpretation between the groups of homographs. Although free association norms were originally used to select groups of homographs with similar base rates, the norms may be out of date or may not apply to undergraduates in this region.

Although the preceding explanation seems the strongest case to explain the low *different* performance, other elements of the experiment may have exacerbated this effect. The assumption that the *different* condition prevented reminders may be mistaken. Although homographs in this condition never shared a background image with their biasing cue words, they sometimes shared a background image with a previously seen word from another critical pair. In these cases, a

homograph's interpretation might have been biased by these earlier words, even though they were not specifically chosen for their relevance to the homograph. While the influence of such unintended reminders seems unlikely, it is nonetheless a confound addressed in Experiment 2.

Word Recognition

The effects of background-elicited reminding should also be evident in the word recognition phase. Reminding can potentially increase memory of a critical pair by simply acting to rehearse each item of the pair again. The benefit may be even greater if subjects notice a meaningful connection between the two words, such as their semantic relation.

Background-elicited reminders should be equally likely in the *same* and *reverse* conditions. Both conditions used the same background image for the two words of a critical pair – the only difference was whether the cue or the homograph appeared first. Participants might also experience word-elicited reminders, in which a word's meaning brings to mind an earlier, related word (most likely the other member of its critical pair). The relative likelihood of word-elicited reminders between cue-first (*same* and *different*) or homograph-first (*reverse*) pairs is difficult to guess because the free-association norms were unidirectional, only showing how often a homograph elicits associates of a particular meaning. Thus, we expect that word recognition is roughly equal in the *same* and *reverse* conditions, reflecting background-elicited reminding between members of a critical pair, and that both show higher hit rates than the *different* condition, in which there is no such reminding.

Word recognition performance did, in fact, show evidence of differential reminding between conditions. Recognition performance for words from the *same* and *reverse* conditions was roughly equal ($M = .849$ and $M = .855$, respectively). Both also showed greater

performance than *different* words ($M = .817$), though this difference was only reliable for the *reverse* condition. This pattern of results, though ambiguous, is consistent with my prediction that background-elicited reminders should strengthen memory for both items in a critical pair. It is true, however, that the *same* condition alone fails to reach statistical significance when compared with *different*, which seems counter to this interpretation. A potential explanation is that word-elicited reminders are more likely from a cue to an earlier homograph than vice versa, and that the combined influence of both kinds of reminding lent an advantage for *reverse* words that was not present for *same* words. To evaluate this possibility, I needed a measure of the associative strength both from cue to homograph and from homograph to cue. As a stand-in for associative strength I measured how often recalling a homograph led to recalling its associated cue, and vice versa. For example, to determine homograph-to-cue associative strength in the free recall data, first I tallied the number of times a homograph appeared as the first member of a critical pair, regardless of what words were or were not recalled later. For convenience, I'll call this count "first-recalls." Then I tallied the proportion of first-recalls for which the related cue word in that critical pair was later recalled. If cue to homograph reminding is more likely, then cue recalls should be followed by homograph recalls more often than homograph recalls are followed by cue recalls. This turned out not to be the case: cue-to-homograph associative strength ($M = 0.372$) was not significantly different from homograph-to-cue associative strength ($M = 0.438$), $t(60) = 1.443$, $p = .154$.

An alternative explanation is that reminders did not strengthen memory for any of the words, regardless of condition. On this view, the lower word recognition performance for *different* condition words is not real, but may be an artifact brought about by some of the factors responsible for the similarly puzzling homograph interpretation results. Reminders may not

have helped if the task was easy enough that performance had little room for improvement – a possibility consistent with the extremely good performance displayed (see Figs. 4 and 5).

A finer-grained prediction for the word recognition phase is suggested by Appleton-Knapp, Bjork, and Wickens (2007). As they point out, when reminding occurs between two related items, the order in which the items are presented may lead to differential encoding, resulting in different later memory performance. Specifically, if viewing the second of a pair of items brings to mind the first item, then this reminding acts to encode the first item a second time while detracting mental resources from the second item's encoding process. This view predicts that the first-presented item in a pair should be better remembered later. This was not the case in the present experiment: presentation order for items in a critical pair did not significantly predict later recognition performance. If reminding does affect recognition performance on the whole, this non-effect may indicate that both items are strengthened evenly by the reminding process. This makes intuitive sense if some of the memory benefit from reminding arises from the learner comparing both items and noticing their semantic relation. The latter possibility would agree with much memory research in showing that meaningful information is better remembered. Future work may test whether any such explicit comparison between reminded items occur, perhaps by testing for schema induction or false memory effects (i.e., will eliciting a reminding between the words “punch” and “bowl” increase the rate at which “drink” is later incorrectly remembered?)

EXPERIMENT 2

Experiment 2 had two main goals. The first goal was to confirm that reminders elicited by repeated background images do bias ambiguous homograph interpretation. The second goal was to discover if the anomalous *different* condition performance was a true effect or a consequence of methodological issues.

Experiment 2 addresses several methodological issues, some of which may have contributed to the low *different* performance, and some that are improvements more generally. First, to ensure that interpretation bias reflected reminding condition rather than item differences, groups of homographs were equated based on empirical base rates from Experiment 1 – the average rate, for each homograph, of nondominant interpretation across conditions. To ensure a higher completion rate, I reduced the number of critical word pairs per condition from fourteen to eight, replaced the word recognition test with a shorter free recall test, and removed the primacy and recency buffers, which were no longer needed. Finally, every background in the *different* condition now appears only once, hopefully preventing accidental background-elicited reminders

Method

Subjects

61 University of Illinois undergraduates participated for course credit. However, three subjects' data were discarded for failure to follow instructions. All experimental sessions lasted 50 minutes or less.

Design

A within-subjects design was used, with each subject exposed to eight critical (cue-homograph) pairs for each condition. The method by which experimental conditions were counterbalanced was the same as in the first experiment.

Experiment 2 used the same task as the first experiment during word list presentation. Therefore the main dependent measure of interest, and its relevant predictions, applies here. The main dependent variable was the proportion of homographs that were interpreted as their normatively less dominant meaning. The *same* condition was expected to show the highest proportion of non-dominant interpretation, due to semantic (cue) and contextual (background) reminding. The *different* condition, where only semantic reminding was possible, was expected to show a lower proportion. The *reverse* condition provides a baseline rate at which the non-dominant interpretation is provided. A dependent variable of secondary interest is the proportion of non-dominant homograph interpretations contingent on background recognition response in the word list phase.

Experiment 2 used a free recall test, rather than recognition, to assess memory for cues and homographs. Two dependent variables of interest here were the proportion of words (both cues and homographs) recalled from each condition, and the proportion of complete pairs recalled from each condition.

Materials

Twenty-four homographs were chosen out of the original set of forty-two used in the first experiment. These twenty-four were selected because they showed the highest rates of non-dominant interpretation in the first experiment. This selection criteria was an attempt to prevent

floor effects, where some interpretations would be so uncommon that they would never occur at all. Additionally, the empirically obtained interpretation rates were roughly equal between the groups of homographs used for each condition. Each homograph was paired with the same cue word as in Experiment 1. Twenty-four critical cue-homograph word pairs were thus obtained (see Appendix).

Word-list presentation. Background images were a subset of those used in the first experiment. As before, they included nature scenes, animals, buildings, food, statues, and musical instruments. Even when multiple pictures depicted the same categorical content (i.e., two nature pictures), they differed in color, composition, and so on.

Each subject received one of three list orders. For each list order, the same 65 words were presented: 24 critical pairs and 17 filler words. To control for order effects, all 24 homographs remained in the same list position for all three list orders. However, depending on condition, a homograph's semantically related cue word might be three list positions before (*same* or *different*) or three list positions after (*reverse*). Filler words were inserted into the list in order to better disguise the semantic relationships among the critical stimuli.

For every subject, each word was randomly assigned a background image, with the following constraints: 1) the members of each critical pair in the *same* and *reverse* conditions shared the same background image, 2) critical pairs in the *different* condition had different background images, and 3) each background image used in the *different* condition or for filler words appeared only once. Each subject saw the same forty-nine backgrounds, though presented in a different order.

Free recall test. An untimed free recall test followed the word-list presentation. Subjects were asked to recall as many of the just-presented words as possible.

Results

Homograph Interpretation Results. The homograph interpretation data are summarized in Figure 5. There was a significant main effect for reminding condition, showing that homograph word interpretation was biased by the presence of visual or semantic cues, $F(2, 110) = 9.89, p < .001$. Follow-up tests were performed comparing the means of the three experimental conditions. The difference between *same* and *different* conditions was significant, $t(57) = 2.84, p = .006$. The difference between the *same* and *reverse* conditions was also significant, $t(57) = 4.15, p < .001$. The difference between the *different* and *reverse* conditions was not significant, $t(57) = .979, p = .332$. In all three cases, Type I error was controlled using the Bonferroni correction. No main effect for the counterbalancing variable of list order was found, $F(2, 55) = .225, p = .799$. Additionally, no interaction between reminding condition and list order was found, $F(2, 55) = 2.52, p = .09$.

Homograph interpretation rates contingent on background recognition response were also tabulated (see Table 4). The prediction that correct “yes” responses in the ‘same’ condition should lead to higher rates of nondominant interpretations is not borne out here. However, because many subjects did not contribute a score to some of the cells in this comparison, no inferential statistics were performed. The *same* condition bias is a result of background-elicited reminders. Thus, within the *same* condition, we should expect bias only when the participant correctly recognizes a background as having been seen before. For backgrounds incorrectly classified as new, on the other hand, homograph interpretation should mirror the *different* condition results. In this case, performance was too close to ceiling to test this prediction – future experiments with less powerful retrieval cues or more difficult memory tasks may allow us to test this prediction.

Free Recall Results. Free recall performance on the final test is shown in Figure 6. There was a significant main effect for condition, $F(2, 59) = 15.809, p < .001$. Pairwise comparisons were made with all three possible pairs of conditions. Type I error was controlled using the Bonferroni correction, resulting in an adjusted alpha level of 0.0167 for each test. There was no difference in word recall between the *same* and *reverse* conditions, $t(60) = 2.301, p = .075$. However, the *same* condition showed higher recall than *different*, $t(60) = 5.579, p < .001$, as did *reverse*, $t(60) = 3.225, p = .006$.

Discussion

The second experiment again supported my primary prediction – that repeating a distinctive background image would cause subjects to “look back” to its first occurrence, and information activated by this reminding would bias homograph interpretation. Furthermore, the puzzling effect from Experiment 1, that the rate of nondominant interpretation was unusually low in the *different* condition, disappeared when several confounds (unequal n between conditions and other methodological issues) were eliminated for Experiment 2. Interestingly, this resulted in *different* performance that was no different than baseline. That is, homograph interpretation was not biased by a semantically relevant cue word preceding it when lacking a repeated background image to activate the earlier word. While contrary to my initial predictions, this result has no bearing on the importance of reminders in the experiment – it only shows that semantic priming alone did not influence homograph interpretation. On the whole, the results support the idea that the relevant information activated by reminders has a much deeper and more basic influence than previously thought.

GENERAL DISCUSSION

The purpose of these experiments was to determine whether the potentially useful information activated by reminders can influence the basic understanding of new information. I evaluated whether reminding can influence even the fast, non-deliberative determination of word meaning. Specifically, I tested whether exposure to semantic or visual cues prior to semantically ambiguous homographs could influence their interpretation.

Whether such reminders can influence the resolution of lexical ambiguity was an open question. In the ordinary course of language comprehension, we are frequently unaware of a word's multiple possible meanings (e.g., Yates, 1978; Dixon and Twilley, 1999). Our fluency in writing and speaking is partly a result of quick, seemingly automatic resolution of lexical ambiguity (allowing phenomena such as garden path sentences to arise). This resolution acts quickly enough to preclude our conscious awareness of it. Because reminders had not yet been shown to influence such early, seemingly automatic processes, our predictions were based on experimenter intuition that this was possible.

This discussion will focus on three main points. First, these findings are likely to generalize to a broad range of psychological contexts and experimental paradigms, though special attention is given to how reminding might influence resolution of perceptual ambiguity (i.e., visual, auditory). Second, implications of the present experiments on more naturalistic or contextually rich situations are considered. Finally, I address implications for category learning, as well as potential limitations of these experiments.

Resolving perceptual ambiguity

Given memory's associative nature and the intuitive prevalence of reminders, it would be interesting to explore their effects in the many other cases of ambiguity that we regularly experience. Take auditory ambiguity, for example – information directly from the speech stream is often ambiguous. Phonemes are pronounced differently by different speakers or in different situations, or noisy conditions (say, on a cell phone call with poor reception) obscure information. Your understanding of what a word means (or even what word it was in the first place) might change as a result of reminding. Maybe you'd think a man with a deep, booming voice who talks about "training" and "practice" is more likely discussing pedagogy than sports training, if he sounds like a favorite professor. On a more serious note, you may be more likely to take umbrage at a rude comment by a passerby if that person superficially resembles someone you dislike. Presumably, any distinctive characteristic of a speaker, regardless of sensory modality, could trigger reminders that color your interpretation of their words.

There are also interesting implications for eyewitness testimony and police work, areas where the resolution of perceptual ambiguity is critically important. A witness may see a crime in progress in conditions of less than perfect visibility – would being reminded of similar earlier instances affect what he sees? The criminal might have a mane of red hair that brings to mind an aggressive classmate the witness once knew. He may now be more likely to call the criminal's actions aggressive, or see the ambiguous object the criminal carries as a gun rather than a flashlight. Police officers assessing a potential threat may be likewise influenced. Of course, it is likely that, most of the time, when these reminders influence understanding they are useful and correct. But, as the present experiments demonstrate, particularly unusual and salient memory cues may disproportionately and inappropriately influence how a given ambiguity is resolved.

Generalizing to Richer Contexts: Multiple Reminders

One potentially unrealistic constraint of the present experiments is that only a single earlier experience (i.e., the semantically related cue word) was brought to mind. In less artificial environments, a single retrieval cue might elicit several past experiences, or several retrieval cues might each be available to trigger reminding. We can examine the same process used here, that of lexical ambiguity resolution, and how it might be affected by multiple reminders.

First, I make a simplifying assumption that biasing words influence ambiguous homograph interpretation in a manner consistent with semantic networks, in particular those based on spreading activation (e.g., Collins and Loftus, 1975; Neely, 1977). Reminding back to a semantic cue word activates that word or concept, and activation spreads to related words. The cue word's activation makes one particular meaning of a homograph more available, and a given word is more likely to be recognized in terms of that meaning.

Note that this view assumes that word interpretation is biased implicitly. Although a conscious experience (i.e., a recollection of seeing the earlier related word) may accompany this activation, only the former's influence is considered here. This focus on implicit aspects of reminding is based on the idea that lexical ambiguity resolution is itself relatively automatic and nonconscious; a focus on the explicit aspects of reminding might be more relevant when dealing with processes that are themselves relatively deliberative and explicit (e.g., solving a puzzling problem by reference to an earlier one).

One possibility is that, when paired with more than one salient retrieval cue, multiple reminders become active at once to jointly influence ambiguity resolution. Suppose that in addition to background images, I introduce distinctive fonts and font colors. At the time of homograph presentation, I can display unique values on all three cues, potentially eliciting

reminding for three previously seen related words. Multiple remindings, in terms of spreading activation, would entail activation converging from each reminded item onto the homograph meaning I choose to cue. For example, bringing both ‘travel’ and ‘vacation’ to mind (with cursive font and bright blue text) will make ‘lobby’ seem more like a hotel lobby than ‘travel’ alone.

If word interpretation in the preceding scenario is truly biased by multiple remindings, the effect should also be apparent in a later memory test. The prediction is that if multiple conceptually related items are brought to mind sometime after their initial presentation, false alarms to conceptually related words are more likely. For example, if I use salient contextual cues to remind participants of the words ‘bed’, ‘dream’, and ‘pillow’ after their initial presentations, they should more often falsely recall ‘sleep’ than if they only saw those words once but without later reminding. This is essentially the reminding homolog of the DRM false memory effect, which shows that presenting many related words in a single list can cause false alarms to a highly associated concept (e.g., Roediger and McDermott, 1995.)

On the other hand, memory capacity limits may reduce the influence of multiple concurrent remindings. Remindings may be limited in the number of previous episodes, the amount of information from each episode, or both. Such limits are implemented in spreading activation models by limiting the total amount of concurrent activation. Therefore, as the number of potential remindings increase, their effects on quick processes like lexical ambiguity resolution will fail to scale linearly. In other words, four potential remindings are not necessarily twice as influential as two potential remindings.

Finally, the early influence of remindings on homograph interpretation enlarges the scope of what can be considered context when resolving ambiguity. Context is not limited to the

environment and mental states co-occurring with the stimulus. It also includes knowledge that is episodically linked. The principles of memory which govern successful retrieval – distinctiveness, recency, and so on – presumably guide the availability of this information. This suggests a line of research aimed at discovering when this fact proves useful and when it proves harmful.

Implications for Category Learning

Like word meaning, the features we predicate about objects are potentially ambiguous, though we may resolve this ambiguity quickly and below awareness. Features are potentially ambiguous at an abstract level – for instance, suppose a teenager named Roger always helps his neighbors carry groceries. There are several abstract features that Roger’s actions are consistent with: “helpful,” “attention-seeking,” “responsible,” etc. Featural ambiguity might also exist at a more basic level – for instance, the tray that slides out of my computer tower might be a DVD drive or a cupholder. More generally, the point is that category features are not necessarily given, but may be determined by the learner (Spalding and Ross, 2000). Most models of category learning, however, concentrate on learning regularities about the features without addressing how the features are determined.

Consistent with the theme of the present experiments, I now concentrate on how featural ambiguity on the level of basic understanding or even perception is resolved. Top-down influences in the form of intuitive theories or schemas seem to play an important role in this process (Brewer and Lambert, 1993). Medin and Wisniewski (1994), for example, showed that activating category expectations can lead people to interpret the same physical stimulus as a different physical feature. One group of participants was shown drawings made by either “farm

or city kids,” and another group was shown the same drawings made by either “creative or uncreative kids.” A participant might interpret a vertical line of dots as buttons if he expected detail (a drawing by a creative child) or as a tie if he expected sophistication (a drawing by a city child).

Being reminded of earlier similar items or events may be one mechanism for such top-down influences in category learning. This idea could be tested with a simple modification of Medin and Wisniewski’s materials. Before seeing an ambiguous picture, participants could read a passage that activates particular category expectations – for instance, a story about a creative young painter who lives in a loft in New York City. The passage would include some salient but incidental characteristics – it could be written in an unusual cursive font, or make mention of watermelons. Repeating the unusual font or watermelons along with the ambiguous picture should increase the likelihood of perceiving “creative” physical features. Such salient cues would play the same role as the repeated background images in the present homograph experiments -- they would bring to mind specific recent items and the expectations with which they are associated.

The influence on basic understanding of specific earlier events, rather than general category or schema information, might be particularly useful when little to no general information is available. This might be the case when first learning novel categories, or when encountering an object which is difficult to classify by virtue of difficult to interpret features. This may explain some ordering effects in category learning – initial examples may derive some of their extra influence by biasing what features are predicated for later items.

Problems and Limitations

One might argue that the task in the present experiments did not truly measure automatic or very fast processes. While lexical ambiguity resolution is one such process, we have only a surrogate measure of it – the sentences participants wrote with each word shortly after its presentation. We have no assurances here that only participants' initial understanding of the word was influenced. It is possible, on the contrary, that reminding to an earlier related word merely biases how the current word will be used in a sentence, but not its initial understanding. Participants might have noticed an ambiguity and consciously chosen a meaning to write about, and reminders might have affected this later revision process rather than the initial determination of word meaning. These criticisms can be addressed in future experiments by using implicit measures to more directly assess whether it is the initial, quick determination of meaning, rather than some conscious choice, that is biased by co-occurring reminding. For instance, we could replace the sentence generation task used here with a semantic verification task, in which we record the time taken to verify some fact (e.g., "A shot can leave a mark on your arm.") The fact should take longer to verify if it uses a word you have already seen and that you initially interpreted with a different meaning (e.g., a shot of whiskey.)

CONCLUSION

These experiments concentrated on the influence of reminding on understanding of very specific, isolated stimuli – singly presented words, without the usual rich semantic context a reader encounters in normal text. But reminders likely also influence understanding in a more naturalistic, contextually rich environment. Additionally, their potential implications in category learning, as well as some limitations of the present research, have been outlined here.

But that is only a start – though we may not realize it, many of the problems our mind solves daily are grossly underconstrained by information in the environment. We bring to bear a surprising amount of background knowledge to deal with these potential ambiguities (e.g., Nagy & Gentner, 1990; Markman, 1984; Biederman, 1987). Much work has elaborated on our use of general information (e.g., schemas, heuristics) to make sense of the world. Reminding theory complements these other approaches by predicting the influence of *specific*, similar earlier instances (e.g., the word I learned yesterday which means “to investigate”, the weird striped fish I saw in the lake) rather than just *general* information (e.g., category knowledge or schemas about verbs or fish). Further research will determine if reminders are as fundamental to our efficient understanding of the world.

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TABLES AND FIGURES

Table 1

Proportion of non-dominant homograph interpretations contingent on background recognition response

Condition	Background Recognition Response			
	Correct Yes	Incorrect No	Correct No	Incorrect Yes
Same	0.358 (324)	0.067 (15)	X	X
Different	0.128 (164)	0.182 (11)	0.205 (151)	0.091 (11)
Reverse	X	X	0.244 (324)	0.25 (24)

Note. An *X* denotes a response that is not possible in that condition (i.e., in the *same* condition, a “no” is never correct, since all homographs are paired with a background’s second presentation).

The number of observations for each cell is shown in parentheses.

Table 2

Homograph interpretation by condition in Experiment 1, broken down by the counterbalancing variable list order. The proportion of homographs that were interpreted using the non-dominant (cued) meaning is shown in the same, different, and reverse conditions, respectively.

List order	Proportion of nondominant meaning interpretation		
	<i>Same</i>	<i>Different</i>	<i>Reverse</i>
List 1 (n = 11)	0.357	0.088	0.246
List 2 (n = 7)	0.297	0.208	0.305
List 3 (n = 8)	0.365	0.218	0.183

Table 3

Homograph interpretation by condition in Experiment 1, either weighted or unweighted. The unweighted means reduce the strange different condition effect by reducing the influence of the list order for which the effect most strongly occurred.

	Proportion of nondominant meaning interpretation		
	<i>Same</i>	<i>Different</i>	<i>Reverse</i>
Weighted (each subject equally)	0.343	0.160	0.243
Unweighted (each list equally)	0.340	0.171	0.245

Table 4

Proportion of non-dominant homograph interpretations contingent on background recognition response in Experiment 2.

Condition	Background Recognition Response			
	Correct Yes	Incorrect No	Correct No	Incorrect Yes
Same	0.401 (409)	0.429 (35)	X	X
Different	X	X	0.310 (403)	0.364 (33)
Reverse	X	X	0.281 (399)	0.270 (37)

Note. An *X* denotes a response that is not possible in that condition (i.e., in the *same* condition, a “no” is never correct, since all homographs are paired with a background’s second presentation). The number of observations for each cell is shown in parentheses.



Figure 1. A screenshot from the word list presentation phase of the experiment, showing a word superimposed on a background image.

Homograph Interpretation

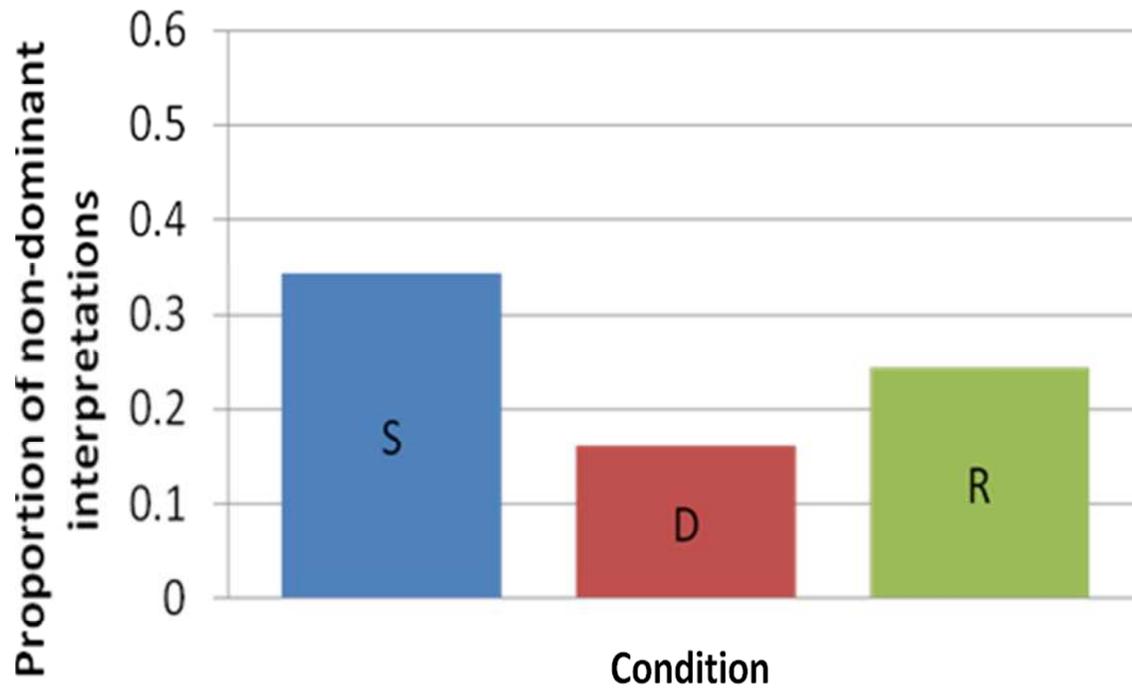


Figure 2. Homograph interpretation by condition in Experiment 1. The proportion of homographs that were interpreted using the non-dominant (cued) meaning is shown in the *same*, *different*, and *reverse* conditions, respectively.

Word Recognition Performance

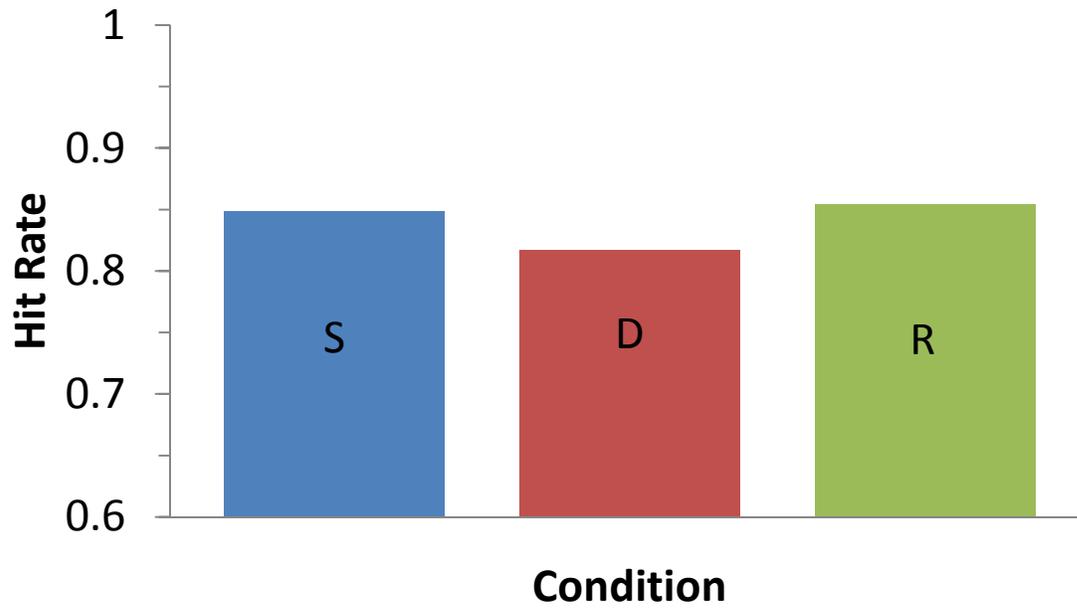


Figure 3. Experiment 1. Proportion of previously seen words from each condition that were correctly recognized in the word recognition test. In other words, the hit rate for *same*, *different*, and *reverse*.

Word Recognition Performance

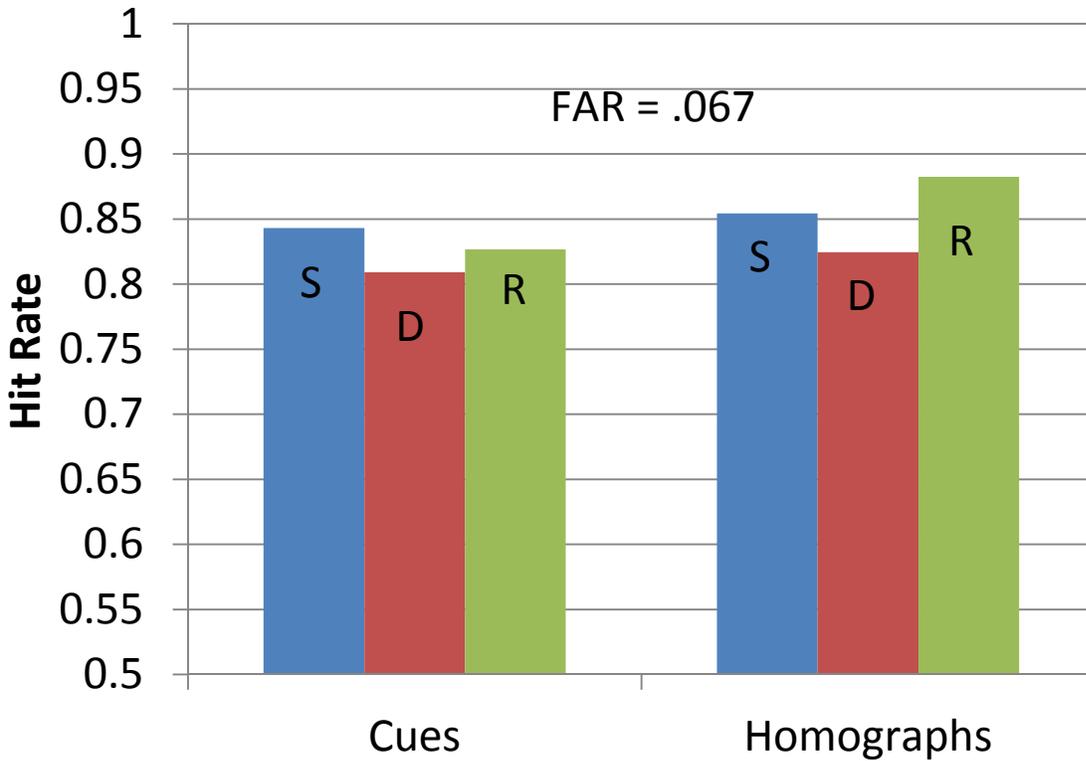


Figure 4. Word recognition performance on the final recognition test in Experiment 1. The hit rate (proportion of correct “yes” responses) is shown separately for cues and homographs in the *same*, *different*, and *reverse* conditions. The false alarm rate (proportion of incorrect “yes” responses) is shown at the top.

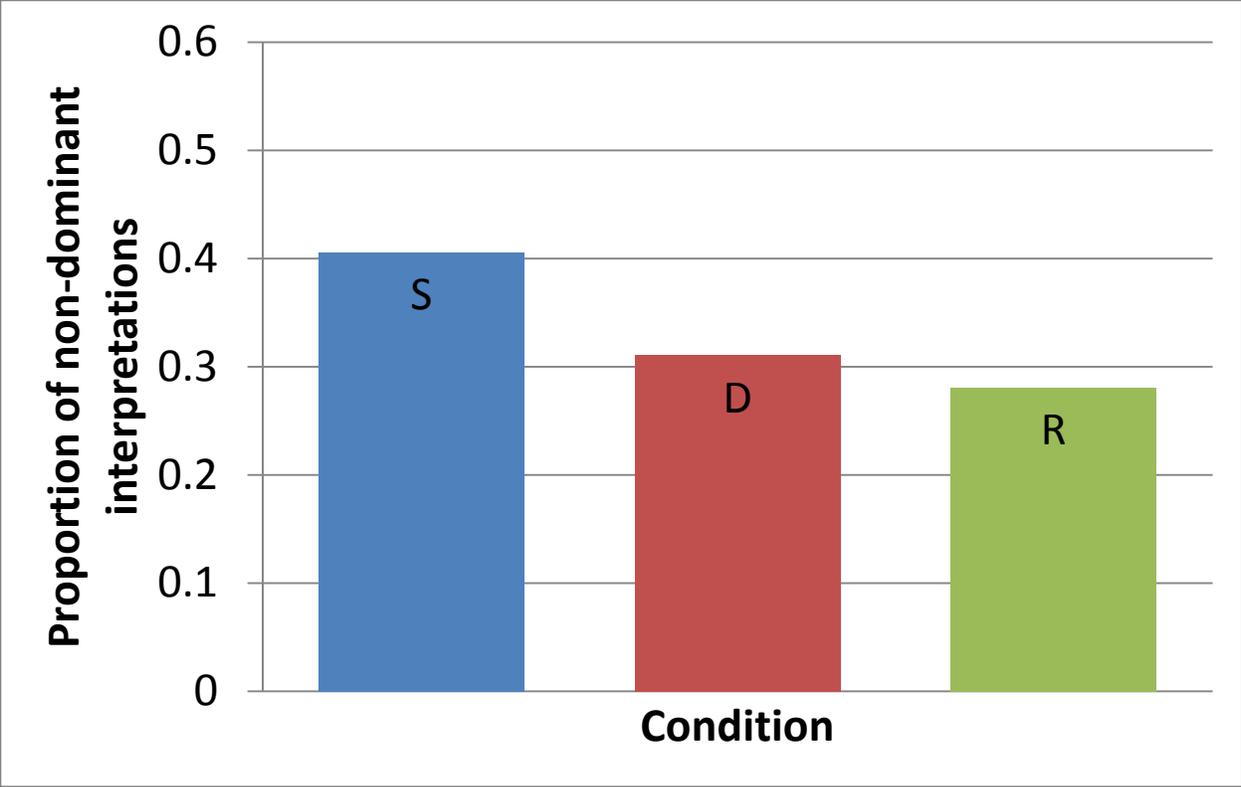


Figure 5. Homograph interpretation by condition in Experiment 2. The proportion of homographs that were interpreted using the non-dominant (cued) meaning is shown in the *same*, *different*, and *reverse* conditions, respectively.



Figure 6. Critical words (cues or homographs) recalled by condition in Experiment 2. The proportion of critical words generated in the final recall test in the *same*, *different*, and *reverse* conditions, respectively.

APPENDIX A

Cue-Homograph pairs used in Experiment 1

Table 1A

Word Type		Word Type	
Cue	Homograph	Cue	Homograph
whiskey	shot	wise	sage
sick	well	skyscraper	story
bowl	punch	money	dough
radio	speaker	look	peer
race	lap	tree	palm
influence	lobby	fish	perch
tennis	court	committee	board
hair	comb	smell	rank
watched	saw	glide	coast
fireplace	poker	drink	straw
heavy	light	joke	gag
healthy	fit	river	bank
ball	marble	airplane	land
dispose	shed	hunter	game
cards	spade	interrogate	grill
eye	pupil	crazy	nut
sick	cold	hit	ram
famous	star	bird	swallow
glance	watch	dismiss	fire
title	deed	fig	date
field	plain	eat	fast
		.	.

APPENDIX B

Cue-Homograph pairs used in Experiment 2

Table 2A

Word Type		Word Type	
Cue	Homograph	Cue	Homograph
sick	well	wise	sage
bowl	punch	money	dough
radio	speaker	look	peer
race	lap	tree	palm
tennis	court	fish	perch
watched	saw	glide	coast
healthy	fit	drink	straw
ball	marble	joke	gag
dispose	shed	hit	ram
cards	spade	title	deed
sick	cold	fig	date
famous	star	eye	pupil