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Reminders influence the interpretation of ambiguous stimuli

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Abstract

Reminders—stimulus-guided retrievals of prior events—may help us interpret ambiguous events by linking the current situation to relevant prior experiences. Evidence suggests that reminders play an important role in interpreting complex ambiguous stimuli (Ross & Bradshaw, 1994); here we evaluate whether reminders influence word interpretation and memory in a new paradigm. Learners studied words on distinct visual backgrounds and generated a sentence for each word. Homographs were either preceded by a biasing cue on the same background three items earlier, preceded by a biasing cue on a different background three items earlier, or followed by a biasing cue on the same background three items later. When biasing cues preceded the homographs on the same backgrounds as the homographs, the meanings of the homographs in learner-generated sentences were consistent with the biasing cues more often than the other two conditions. These results show that reminders can influence word interpretation. In addition, later memory for the homographs and cues was greater when the meaning of the homograph in the sentence was consistent with the earlier biasing cue, suggesting that reminders enhanced mnemonic performance. Reminders play an important role in how we interpret ambiguous stimuli and enhance memory for the involved material.

Keywords

reminding; interpretation; ambiguity; memory; study-phase retrieval

Reminders serve a critical role in navigating novel situations because they direct us to relevant prior knowledge. In doing so, reminders reduce the separation of events distributed in time and space and enable distant events to influence each other (Benjamin & Ross, 2010). Prior research shows that reminders can influence categorization (Ross, Perkins, & Tenpenny, 1990), analogical reasoning (Gentner, Ratterman, & Forbus, 1993), and problem solving (Reeves & Weisberg, 1994). In the current experiment, we evaluate if reminders play a role in interpreting ambiguous stimuli and if reminders influence subsequent mnemonic performance for those stimuli, as seen in prior literature (Benjamin & Tullis, 2010). More specifically, we investigate whether reminders can influence our understanding of homographs and whether reminders affect free recall of those homographs.

Considerable research in categorization and problem solving has examined the importance of reminders. Exemplar-based views of categorization suggest that learners rely upon earlier, similar examples as a means of determining category membership (Murphy, 2002; Ross & Makin, 1999). Reminders of non-critical features can affect how items are categorized, sometimes deleteriously (Ross et al., 1990; Brooks, Norman, & Allen, 1991), and can affect what is learned about a category (Medin & Schaffer, 1978; Spalding & Ross,

1994). Reminders in problem solving influence which prior examples are used to solve current problems and what generalization might be induced (e.g. Reeves & Weisberg, 1994; Ross & Kennedy, 1990). Reminders are influenced by the surface similarity of problems, context, learners' expertise, and problem difficulty (Gentner et al., 1993; Gick & Holyoak, 1983; Ross, 1984). Reminders play a significant role in categorization and problem solving; however, their role in encoding and interpreting stimuli remains less well explored.

One study suggests that reminders impact how stimuli are initially encoded and bias how ambiguous stimuli are interpreted. In Ross and Bradshaw (1994), learners read several stories, some which had two possible interpretations. An unimportant, superficial detail cued the learners to earlier stories that could bias the interpretation of the current ambiguous story. Learners' interpretation of the ambiguous story depended upon which cue they received, and hence, which prior story they were reminded of. This prior episodic, and unrelated, information of which learners were reminded biased learners' interpretation of complex ambiguous events. Here we investigate whether reminders influence interpretation of different, simpler stimuli in a novel paradigm.

While research in higher cognition shows how earlier episodes proactively affect later processing, reminding theory suggests that later episodes retroactively influence memory for earlier items as well. Recent mnemonic theories of reminding suggest that later presentations of associated stimuli encourage retrieval of earlier episodes, and the act of retrieval modifies the memory trace of the earlier item (Benjamin & Tullis, 2010). Through the reminding process, memory is enhanced for the items in an associated pair (Tullis, Benjamin, & Ross, under review), for the order of the associated items (Tzeng & Cotton, 1980; Winograd & Soloway, 1985), and for the spacing between associated items (Hintzman, Summers, & Block, 1975). Reminders may also determine the shape of the lag function seen in spacing functions (Tullis, Benjamin, & Ross, in preparation). Across most of the memory literature, reminders are assumed to occur because final mnemonic performance is greater for items that encourage reminders than for other items. For example, reminders are thought to happen because memory performance for the individual members of an associated pair (i.e., king-queen) is greater than members of unassociated pairs (i.e., radish-queen; Tullis et al., under review; see also Bruce & Weaver, 1973). The mnemonic benefits of reminders have also been assessed by asking learners whether a reminding has occurred (Wahlheim & Jacoby, 2013). Self-report procedures rely upon learners' awareness of reminders; further, procedures involving self-reports of reminders encourage learners to strategically look back during study for prior related items, which may obscure the stimulus-driven nature of more natural reminding processes. Unlike prior reminding studies that use self-reports or final mnemonic performance as an indicator of reminders, the current paradigm provides an independent metric of whether a reminding has likely occurred.

In the current study, we investigate whether reminders influence our interpretation of ambiguous stimuli (homographs) using a novel paradigm. Subjects studied a list of single words, including homographs and cues that bias the interpretation of those homographs, presented on distinct backgrounds. Reminders were encouraged by presenting cues and homographs on the same backgrounds. Subjects were asked to write a sentence using each word during the study trial, and we use their sentences to evaluate how learners interpreted the ambiguous words. Finally, subjects took a free recall test on all of the studied items. If reminders influence word interpretation, the meaning of the homographs in the sentences will be consistent with the meaning of the prior biasing cue more when reminding is likely (i.e., when the backgrounds are repeated) than when it is less likely. In addition, if reminders influence memory, mnemonic performance should be enhanced for items of which learners were reminded.

Method

Subjects

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

Materials

Twenty-four homographs, each with a dominant meaning (one that occurred at least 50% of the time according to the University of South Florida Free Association Norms (Nelson, McElvoy, & Schreiber, 1988)), were collected. A cue word was selected from the Free Association Norms so as to bias the meaning of each homograph towards its nondominant meaning. Cue words were almost always synonyms of the homograph (e.g., hit and ram), but were sometimes antonyms (e.g., sick and well) or disambiguating associates of the homograph (e.g., tennis and court). Additionally, seventeen words that were not related to any of the homographs or cue words were collected to be used as fillers throughout the lists. To counterbalance the ordering of the within-subjects conditions, three different list structures of 65 slots each were created. Across the three list structures, the homographs appeared in the same list positions while the context cues and filler items shifted positions. For the backgrounds, forty-nine distinct high-resolution photographs were collected from various internet sources. Their content included landscapes, art, furniture, animals, architecture, and technology. Examples of study screens are displayed in Figure 1.

Design

The experiment included 3 within-subjects conditions: same, different, and reverse. In the same condition, the biasing context cue appeared 3 items before its homograph on the *same* background as the homograph. In the different condition, the biasing context cue appeared 3 items before its homograph on a *different* background than the homograph. Finally, in the reverse condition, which served as a baseline condition, the biasing context cue appeared 3 items *after* its homograph on the same background as the homograph. The reverse condition includes the same words and backgrounds as the same condition, but the homograph and cue are presented in the reverse order from the same condition.

While the positions of the homographs remained constant across the three list structures, the order of conditions assigned to each homograph was counterbalanced across subjects in order to mitigate against item and order effects. For each list structure, the homographs were assigned alternatively to the three different conditions (ie, the first homograph was assigned to the same condition, the second to the different, the third to the reverse, the fourth to the same, and so on). Subjects were alternatively assigned to each of the three different list structures. Background images were randomly paired with words, with the constraint that they repeated between context cue and homograph when demanded by the conditions in the list structure.

Procedure

Subjects were tested individually on computers programmed with PsyScope. They were instructed that they would see a list of words presented on a variety of background images and that they would be asked questions about the backgrounds. Subjects were also informed that their memory for the words would be tested and, to improve their memory for the words, they were instructed to type a sentence including the word after studying each word. After reading through the instructions, subjects viewed the sequence of 65 presentations of backgrounds and words.

During each trial, a background image was displayed across the full screen for 4 seconds. Then the question “Have you seen this background before?” was superimposed over the picture in 12 pt black font. We asked this question because reminders, and subsequent memory effects, are enhanced by explicitly asking subjects to look back through their memory for related items (Jacoby, 1974). However, a difference between this study and that past work is that learners were never asked about prior words, only prior backgrounds. Subjects responded “yes” or “no” by pressing the “y” or “n” key. Once a subject responded to that question, a target word was superimposed on the background in 48 pt black font in a white box placed in the center of the screen. The word was displayed for 2.5 secs before a blank white screen appeared and the subject was asked to type in a sentence using the word they just studied. After studying the list of presented words, subjects were immediately given a free recall test on paper where they were asked to write down any words they remember studying. No time limits during the test phase were enforced, and subjects usually completed the experiment within 50 minutes.

Results

All statistics reported here are significant at an $\alpha < .05$ level unless otherwise noted. Performance on the background recognition question was very high and consistent across the three conditions (mean = 0.95). Because we want to avoid item selection effects and because the patterns of data for correctly recognized backgrounds did not differ from misremembered backgrounds, we will analyze all data without regard to the accuracy of this response.

Homograph interpretation

The sentences generated by the subjects were coded for the meaning of the homograph by two researchers blind to the items’ condition. The authors initially agreed on 93% of classifications, and resolved disagreements through discussion. For 6% of the sentences, the meaning of the homograph could not be classified and these trials were discarded. The nondominant meaning is expected more often when people use the cue to interpret the homograph. The proportion of sentences using the nondominant meaning of the homograph by condition is displayed in Figure 2. A 3 (condition: same, different, or reverse) repeated measures ANOVA on the percentage of nondominant meanings used revealed that condition significantly affected the use of nondominant meanings ($F(2,118) = 16.04$, $\eta^2 = 0.21$). Follow-up t-tests reveal that the nondominant meaning was produced in the same condition ($u_{\text{same}} = 0.40$) more frequently than in the different ($u_{\text{different}} = 0.27$; $t(59) = 3.63$; Cohen’s $d = 0.49$) and reverse conditions ($u_{\text{reverse}} = 0.25$; $t(59) = 4.70$; $d = 0.73$). The proportion of sentences using the nondominant meaning of the homograph in the different and reverse conditions did not significantly differ from each other ($t(59) = 0.53$, $p = 0.50$; $d = 0.15$).

The frequency with which subjects included the associated context cue in the sentence with the homograph was also calculated. Subjects were not instructed to include the related context cue in the sentence with the associated homograph, but it often appeared in the learner-generated sentence for the homograph. Counting the frequency of this provides an interpretation-free measure of homograph meaning and is more conservative than the interpretation measure reported above. Condition significantly affected the proportion of sentences using the context cue ($F(2,118) = 17.19$, $\eta^2 = 0.23$), as shown in Figure 3. Subsequent t-tests show that related context cues were used in the homographs’ sentences more frequently in the same condition ($u_{\text{same}} = 0.21$) than in the different ($u_{\text{different}} = 0.09$; $t(59) = 3.73$; $d = 0.49$) or reverse conditions ($u_{\text{reverse}} = 0.05$, $t(59) = 4.79$; $d = 0.62$). Additionally, the different condition included more context cues than the reverse condition ($t(59) = 2.30$; $d = 0.30$), because, in the reverse condition, the cue had not been presented in the list yet.

Free Recall

In addition to the interpretation of ambiguous stimuli, we also assessed the influence of reminding on memory. We assessed learners' recall of the homographs and biasing cues, and the output order of these items. On the final recall test, learners recalled 32% of the homographs from the study list. Reminding is expected whenever two associated stimuli are presented on the same backgrounds, so enhancements in recall should be apparent in the *same* and *reverse* conditions, but not in the *different* condition. As shown in Figure 4, condition did affect homograph recall ($F(2,118) = 9.76$, $\eta^2 = 0.13$). Learners recalled more homographs in the *same* ($u_{\text{same}} = 0.38$) and *reverse* ($u_{\text{reverse}} = 0.34$) conditions than in the *different* condition ($u_{\text{different}} = 0.25$; $t(59) = 4.09$, $d = 0.54$; $t(59) = 2.93$, $d = 0.34$, respectively), but the number recalled in the *same* and *reverse* conditions did not differ ($t(59) = 1.36$, $p = 0.15$; $d = 0.23$). Condition also affected how many cues were recalled ($F(2,118) = 11.03$, $\eta^2 = 0.17$), as also shown in Figure 4. Learners recalled more cues in the *same* ($u_{\text{same}} = 0.38$) and *reverse* ($u_{\text{reverse}} = 0.34$) conditions than in the *different* condition ($u_{\text{different}} = 0.24$; $t(59) = 4.37$, $d = 0.62$; $t(59) = 3.51$, $d = 0.39$, respectively), but the number of cues recalled in the *same* and *reverse* conditions did not differ ($t(59) = 1.19$, $p = 0.20$, $d = 0.24$). The percentage of trials on which both the cue and homograph were recalled followed the same pattern as homograph and cue recall; it was greater in the *same* ($u_{\text{same}} = 0.24$) and *reverse* ($u_{\text{reverse}} = 0.23$) conditions than in the *different* condition ($u_{\text{different}} = 0.10$; $t(59) = 4.51$, $d = 0.60$; $t(59) = 4.07$, $d = 0.48$ respectively), but these two conditions did not differ from one another ($t(59) = 0.41$, $p = 0.69$, $d = 0.11$). When both the cue and homograph were recalled, there was some evidence that the lag between production of those items was shorter in the *same* ($u = 2.24$) and *reverse* ($u = 3.08$) conditions than in the *different* ($u = 6.35$) condition, but this trend reached only marginal significance ($F[2,46] = 2.35$; $p = 0.11$; $\eta^2 = 0.09$). This analysis has lower power than the others reported here because only 23 subjects contributed data to all conditions.

In order to determine if reminders caused a boost in recall, we additionally compare memory performance for homographs for which there is evidence of reminding during study to memory performance for ones for which that evidence is absent. We use homograph interpretation as an index of reminding. In the *same* condition, reminders caused some proportion of the nondominant interpretations of homograph; therefore, a mnemonic benefit may be apparent for homographs for which nondominant interpretations were accorded during learning. In the *different* and *reverse* conditions, however, nondominant interpretations of homographs are unlikely to have been caused by reminders and we predict no mnemonic differences between homographs accorded a nondominant and homographs accorded a dominant meaning. To test this, we performed a 2 (meaning: dominant vs. nondominant) $\times$ 2 (condition: *same* vs. *reverse* and *different*) repeated measures ANOVA on the proportion of homographs recalled. The data are shown in Figure 5, and the ANOVA revealed a significant interaction between meaning and condition ($F(1, 55) = 16.93$, $\eta^2 = 0.23$). Memory for homographs interpreted in the nondominant manner was significantly greater than memory for ones given a dominant interpretation, but only in the *same* condition ($t(59) = 4.40$, $d = 0.51$). This pattern was numerically in the opposite direction for the *different* and *reverse* conditions and did not reach significance ($t(59) = 0.23$, $p = 0.82$, $d = 0.05$). The power to detect an effect the same size as in the *same* condition is large (power = 0.97). This pattern of results suggests that the process of reminding enhances free recall (see also Tullis et al., under review).

Discussion

Reminders influence the interpretation of ambiguous stimuli. The meanings of the sentences generated for homographs were more consistent with the biasing cues when the

cue was presented first and was presented on the same background than when it was presented on a different background or after the ambiguous stimulus. Reminders also influenced mnemonic performance, such that cues and homographs in conditions that promoted reminders (the same and reverse conditions) were better remembered than those in the different condition.

That reminders can influence the interpretation of homographs provides a new perspective of the influence of reminding because, in the ordinary course of language comprehension, we are frequently unaware of a word's multiple possible meanings (Dixon & Twilley, 1999; Yates, 1978). Resolving the lexical ambiguity of homographs may happen very quickly, and yet, reminders play a part in resolving the ambiguity of the homographs studied. This suggests that reminders may very quickly influence how we interpret the world.

Reminders enhance free recall performance for both P1 and P2, in addition to influencing how we interpret the world. Memory for homographs and cues is enhanced when they are presented on the same background compared to when they are presented on different backgrounds. In the reverse condition, presenting the biasing cue on the same background after the homograph cannot influence the interpretation of the prior homograph, but it enhances memory for the homograph nonetheless. The results from conditionalizing memory performance upon the initial interpretation of the homograph provides more evidence that reminders enhance memory: when a nondominant interpretation of the homograph is likely due to a reminding (in the same condition), memory for homographs interpreted in the nondominant manner was significantly greater than for the homographs interpreted in a dominant manner. The memory effect is not caused just by interpreting the homograph in a nondominant manner, as recall performance for dominant and nondominant items does not differ in the other two conditions. Reminding, then, must underlie this difference.

According to Benjamin and Tullis (2010), reminders enhance memory performance because the retrieval of reminded information enhances memory for the earlier presented information. Whether and why memory for P2 is enhanced is debated. Memory for P2 may be enhanced because the context for P1 has been incorporated into the memory trace for P2 and thus made it more variable and elaborate (Hintzman, 2010). Other research suggests that the enhancements in free recall performance for P2 results from strategic control that learners exercise during output (Tullis & Benjamin, in prep). Increased recall of P1 may lead learners to output P2 more often, and memory enhancements for P2 may only reflect reminding during retrieval rather than during encoding. For a more thorough discussion of how reminders affect memory for individual presentations in a reminded pair, see Tullis and Benjamin (in prep).

The current study also reveals that the mnemonic benefits of reminding are not caused exclusively by semantic priming effects. In other studies (e.g., Tullis et al., under review), reminders are encouraged by presenting related items in a list. Memory is then compared between a condition where an associate was presented (ie., king – queen) and a condition where no associate was presented (ie, radish – queen). In these cases, the earlier associated item may semantically prime learners to better remember the later associated item. However, in the current study, the same biasing cue is presented in both the same and different conditions, yet mnemonic benefits are only apparent in the same condition. Only when the biasing cue is presented on the same background as the later homograph do large mnemonic benefits appear, which suggests that more than semantic priming play a role in the benefits of reminding.

In this study, as in previous studies (Jacoby, 1974; Jacoby & Wahlheim, 2013), instructions encouraged learners to “look back” through the prior studied episodes during encoding. Such instructions may remove some of the spontaneous, stimulus-driven qualities of real-world reminding. However, similar effects of reminders can be found in more spontaneous, stimulus-driven situations. For example, in recent work, learners studied a list of words in which some words were highly associated to others (Tullis & Benjamin, in prep). Memory performance was enhanced for the related items compared to the same unrelated items, even though learners were not instructed to look back through the list. Stimulus-driven reminders may be more spontaneous than the conditions analyzed here and may better reflect how reminders spontaneously happen in the real world. However, the enhancement in free recall for both P1 and P2 is consistent across instruction-driven and stimulus-driven reminding experiments.

Reminders reduce the temporal distance between items and enable distant events to influence each other. Whether through superficial relationships (like the consistent background pictures used here) or through semantic relationships, reminders connect events distant in time and subsequently influence both their interpretation and how well they are remembered. Connecting distant events in time, reminders may prompt learners to compare segregated items, generalize across distinct events, form schemas, and make predictions about new situations.

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Figure 1.
Examples of possible stimuli.

Figure 2.

The proportion of homographs interpreted using their nondominant meaning based upon condition. Error bars show the within subject 95% confidence intervals (CIs) (see Benjamin, 2003; Loftus & Masson, 1994).

Figure 3.

The proportion of sentences for homographs including the biasing cue based upon condition. Error bars show the within subject 95% confidence intervals (CIs) across conditions (see Benjamin, 2003; Loftus & Masson, 1994).

Figure 4. The proportion of homographs (left side) and cues (right side) recalled on the final free recall test per each condition. Error bars show the within subject 95% confidence intervals (CIs) across the homograph analysis and the cue analysis (see Benjamin, 2003; Loftus & Masson, 1994).

Figure 5.

The proportion of homographs recalled on the free recall test conditionalized upon their condition and their interpretation during study. Error bars and values show the width of within subject 95% confidence intervals of the difference between dominant and nondominant interpretations. Error bars are not placed on the means themselves because they show the within-subject variability of the differences between interpretations.