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Accessibility of Outdated Information

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In 2 previous studies (O'Brien, Rizzella, Albrecht, & Halleran, 1998; Zwaan & Madden, 2004), researchers have provided conflicting accounts about whether outdated information continues to influence the comprehension of subsequent text. The current set of experiments was designed to explore further the impact of outdated information on comprehension. First, we examined factors that may have contributed to Zwaan and Madden's (2004) finding that outdated information did not influence comprehension. Experiments 1a and 1b demonstrated that when Zwaan and Madden's target sentences were rewritten to move the targeted anaphor away from the end of the sentence, the impact of outdated information emerged with their materials. With a new set of materials, Experiment 2 demonstrated that outdated information continued to disrupt comprehension, even when the updating information created an irreversible change-in-state of a primary object in the story. The results of all 3 experiments are consistent with a passive reactivation process in which outdated information can influence comprehension processes.

Keywords: accessibility of text information, updating, memory-based processes

During reading, successful comprehension requires a continual integration of incoming information into the evolving discourse representation in memory; whenever new information is encountered that information must be incorporated, thereby updating the representation. That readers continually update their discourse representation is an uncontroversial component of most theories of discourse comprehension (e.g., Gerrig & McKoon, 1998; Gerrig & O'Brien, 2005; Graesser, Singer, & Trabasso, 1994; Magliano, Trabasso, & Graesser, 1999; Magliano, Zwaan, & Graesser, 1998; O'Brien & Myers, 1999; Zwaan & Radvansky, 1998). Often, however, updating not only involves the incorporation of new information, but it also involves the discounting or outdating of previously read information (Johnson & Seifert, 1994, 1998, 1999; Kendeou & van den Broek, 2007; Rapp & Kendeou, 2007, 2009). For example, a reader may initially learn that *Mary is a vegetarian* but then subsequently read that this is no longer correct (e.g., O'Brien, Rizzella, Albrecht, & Halleran, 1998). Or a reader may first learn that *Bobby lost his hammer* and later read that he found it (e.g., Zwaan & Madden, 2004). In each of these cases, updating would involve incorporating this new information into the active portion of the discourse representation; at the same time the outdated information would lose activation and become less accessible (Zwaan & Radvansky, 1998).

Because outdated information remains a part of the representation, it has the potential to influence comprehension of subsequent text. There are two contrasting views concerning the extent to which outdated information from inactive portions of the discourse representation will influence the comprehension process: the here-and-now view and the memory-based view. The critical assumption that separates these two views is whether low-level, bottom-up activation processes (e.g., resonance) can be shut off. That is, does information in the active portion of the discourse model passively activate related but outdated information, even if that information is incorrect, contradicts, or is inconsistent with the active portion of the discourse model? According to the here-and-now view (e.g., Morrow, Greenspan, & Bower, 1987; Zwaan & Madden, 2004), readers maintain a fully updated representation of the situation described by the text within the here-and-now portion of the discourse representation—the active portion of the representation. As new information is encoded, it is checked against the fully updated here-and-now and is integrated. Because outdated information is not part of the here-and-now, it should not have an effect on the integration of new information, even if the new information conflicts with the outdated information. As Zwaan and Madden (2004) noted, "new information that is inconsistent with the prior situation but consistent with the current situation can be integrated as easily as information that was never inconsistent" (p. 286).

In contrast, according to the memory-based view (e.g., Gerrig & McKoon, 1998; Gerrig & O'Brien, 2005; McKoon & Ratcliff, 1998; O'Brien & Myers, 1999), newly encoded information—in

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combination with the current contents of working memory—serves as a signal to all of long-term memory, including both the inactive portion of the discourse representation as well as general world knowledge (e.g., Cook, 2000; Cook & Guéraud, 2005; Cook & Myers, 2004; Garrod & Terras, 2000; O'Brien & Albrecht, 1991; Rizzella & O'Brien, 2002). Inactive concepts resonate in response to this signal, and those concepts that resonate the most are returned to working memory. Concepts resonate primarily as a function of the preexisting associations in semantic memory (see O'Brien & Myers, 1999, for a review of moderating factors). The resonance process is derived from more global models of memory (e.g., Gillund & Shiffrin, 1984; Ratcliff, 1978; Ratcliff & McKoon, 1988) that assume memory access is fast, direct, unrestricted, and passive. Because the resonance process is unrestricted, information that resonates sufficiently is returned to working memory, independent of its relevance to the active portion of the discourse representation. Outdated information is no different than any other backgrounded information; if a reader encodes a target sentence that is related to the outdated information, the target sentence can serve to reactivate that information, even if it causes integration difficulty.

There is considerable evidence for this basic assumption of the memory-based view of updating, namely that related backgrounded information is routinely reactivated (e.g., Albrecht & O'Brien, 1993; Cook, Halleran, & O'Brien, 1998; Guéraud, Harmon, & Peracchi, 2005; Hakala & O'Brien, 1995; Lea, Mulligan, & Walton, 2005). For example, Albrecht and O'Brien (1993) had participants read passages that described a particular characteristic of a protagonist (e.g., *Mary was a strict vegetarian*). Following several sentences that served to background the characteristic, a target sentence was read in which the protagonist engaged in an action that was locally coherent but was either consistent, inconsistent, or neutral with respect to the earlier described characteristic (e.g., *Mary ordered a cheeseburger and fries*). Although the elaborated characteristic was not active in memory immediately prior to the target sentence (Myers, O'Brien, Albrecht, & Mason, 1994), and the target sentence was locally coherent, reading times on the target sentence were significantly longer when it was inconsistent with the earlier described characteristics than when it was either consistent or neutral relative to the earlier described characteristics; this slowdown in reading indicated that the backgrounded characteristics were reactivated.

Building on the results of Albrecht and O'Brien (1993), O'Brien et al. (1998) provided a direct test of the here-and-now view and memory-based view of updating. They included a qualified elaboration condition in which the inconsistent elaboration was revised to indicate to the reader that the critical characteristic of the protagonist was outdated; that is, additional information was included to make clear that Mary was no longer a vegetarian, or as in one experiment (Experiment 5), that Mary had never been a vegetarian. According to the here-and-now view of updating, when readers encounter the qualification (e.g., *Mary is no longer a vegetarian*), the here-and-now portion of the discourse model should be updated to accommodate this information; that Mary was a vegetarian should be outdated and therefore dropped from the here-and-now. When readers encounter the subsequent target sentence (e.g., *Mary ordered a cheeseburger and fries*), it needs only to be checked against the here-and-now. Because there is nothing in the here-and-now to conflict with the target sentence, readers should not experience integration difficulty.

In contrast, according to the memory-based view of updating, even though the information about Mary being a vegetarian has been outdated or disconfirmed (and in one experiment, never true), it should still resonate and potentially become active simply because it is related to information in the target sentence. Consistent with this view, O'Brien et al. (1998) found that reading times on the target sentence continued to be slow in the qualified condition relative to the consistent condition (reading times on the target sentence were always slowest in the inconsistent condition). Thus, even though the reader learned that the target characteristic was outdated (i.e., no longer true, or had never been true), information about the target characteristic continued to be reactivated and affected integration of the information in the target sentence.

Zwaan and Madden (2004) argued that the results of O'Brien et al. (1998) could not be interpreted as providing support for the memory-based view for two primary reasons. First, using latent semantic analysis (LSA; Landauer, Foltz, & Laham, 1998) as a measure of semantic overlap, Zwaan and Madden reported some evidence that the target sentences contained "less semantic overlap" with the preceding text when they appeared in the qualified condition than when they appeared in the consistent condition. This could make the target sentences more difficult to integrate in the qualified condition. Second, they found that the target sentences in O'Brien et al. (1998; e.g., *Mary ordered a cheeseburger and fries*) were rated as less plausible in the qualified condition than in the consistent condition; this could also make the target sentences more difficult to integrate in the qualified condition. Thus, according to Zwaan and Madden, either (or both) of these factors could potentially explain the slowdown in reading times on the target sentence in the qualified conditions without appealing to a memory-based process.

Consider first the issue of semantic overlap. Using LSA, Zwaan and Madden (2004) measured the degree of semantic overlap between the target sentence and the one sentence from the elaboration region that produced the highest cosine (maximum cosine) using the materials from two of the five experiments reported in O'Brien et al. (1998; Experiments 1 and 5). The findings were inconsistent: The materials from Experiment 1 yielded no reliable differences in cosines between the consistent and qualified conditions; for the materials used in Experiment 5, the maximum cosine was lower for the qualified condition than for the consistent condition. O'Brien, Cook, and Perrachi (2004) extended these analyses by computing cosines for all five experiments in O'Brien et al. (1998) using three different computational methods, including maximum cosine (Zwaan & Madden's 2004, method). With 15 different measures of semantic overlap (cosines), they found no relation between cosines and reading time on the target sentences in the consistent and qualified conditions.[1] These findings by both Zwaan and Madden and O'Brien et al. (2004) are not surprising for several reasons: LSA does not work well with short texts; LSA

[1] See O'Brien et al. (2004) for a complete description of how LSA cosines were computed. All three cosine measures for all passages in all five experiments, all computed contrasts between cosines, and the complete set of materials used in O'Brien et al. (1998) can be found at http://pubpages.unh.edu/~eob

does not understand negation (a critical component in both Zwaan and Madden's, 2004, and O'Brien et al.'s, 1998, studies); and LSA is a representational model, not a process model, and therefore cannot accurately predict comprehension difficulty as measured by reading time (see Foltz, Kintsch, & Landauer, 1998; Kintsch, McNamara, Dennis, & Landauer, 2007; Rehder et al., 1998).

The second issue raised by Zwaan and Madden (2004) concerned the plausibility of the consistent, inconsistent, and qualified elaborations relative to the target sentence in the O'Brien et al. (1998) materials. They collected plausibility ratings for each of these three conditions using the materials from Experiments 1 and 5 from O'Brien et al. (1998). Participants read each passage up to just prior to the target sentence, the passage was removed, and they then rated the probability of the action contained in the target sentence on a scale of 1–7 (e.g., "How likely is it that Mary will order a cheeseburger?") For the materials in both experiments, Zwaan and Madden found that the inconsistent conditions were rated as less plausible than either the consistent or qualified conditions. More important, they found that the qualified conditions were rated as less plausible than the consistent condition. Thus, the pattern of plausibility ratings paralleled the reading times in each of the three conditions in the O'Brien et al. study (1998).

Zwaan and Madden (2004) argued that equal plausibility across conditions was "pivotal" (p. 284) for contrasting different predictions from the here-and-now view and the memory-based view. However, this measure of plausibility is an offline measure, completed only after the participant has finished reading each passage. At this point there is no longer a here-and-now portion of the representation; there is only the representation of the entire passage up to the target sentence. When participants rate the action contained in the target sentence, it is checked against this entire representation, which includes both updated and outdated information; plausibility ratings should be influenced by the outdated information contained in the qualified condition, resulting in reduced plausibility ratings in this condition. This is similar to the process assumed by the memory-based view to occur during normal reading, where both updated and outdated information influences the comprehension process. Therefore, it is expected that the pattern of plausibility ratings of the target sentences would parallel reading times for the target sentences—and they do.

Zwaan and Madden (2004) created a new set of materials that included conditions similar to those used by O'Brien et al. (1998) but that focused on instrument availability instead of protagonist characteristics. For example, in one passage, an instrument (e.g., *hammer*) was described as either available to the protagonist (enablement condition; e.g., *Bobby took out a hammer, but then remembered that he lost his saw*), unavailable to the protagonist (disablement condition; e.g., *Bobby took out a saw, but then remembered that he lost his hammer*), or previously unavailable but now available (reenablement condition; e.g., *Bobby took out a saw, but then remembered that he lost his hammer. After some searching, he found it in his father's tool shed*). The description of the instrument was then backgrounded by several sentences of text. This was followed by a target sentence that included a direct reference to the instrument, indicating that it was available (e.g., *Bobby began pounding the boards together with the hammer*.) Zwaan and Madden found no reliable difference in reading times between the enablement and the reenablement conditions (the equivalent of O'Brien et al.'s, 1998, consistent and qualified conditions). Given the lack of a measurable slowdown in reading times in the reenablement condition relative to the enablement condition, Zwaan and Madden concluded that readers had updated their discourse representations and that the outdated information (i.e., the hammer had been lost) did not influence comprehension. They interpreted this finding as supportive of the here-and-now view of updating.

The findings obtained by O'Brien et al. (1998) and Zwaan and Madden (2004) stand in stark contrast to each other. In O'Brien et al.'s (1998) five experiments, outdated information continually disrupted the comprehension of subsequent information, whereas in Zwaan and Madden's experiment, outdated information had no measurable influence. In 35 of 36 passages used by Zwaan and Madden, the target instrument was a direct anaphor to a previously established antecedent (e.g., hammer). One potential problem that may have contributed to Zwaan and Madden's null result was that in half the passages, the anaphor was the last word in the target sentence. Eye movement data have clearly established that readers continue to process anaphors after the eye has passed them (e.g., Duffy & Rayner, 1990; Ehrlich & Rayner, 1983) and comprehension difficulties may only become evident downstream or after initial bonding (e.g., Garrod, 1994; Garrod & Sanford, 1994; Garrod & Terras, 2000; Sturt, 2003). It is possible that a disruption in reading in the reenablement condition occurred after the end of the target sentence. The goal of Experiments 1a and 1b was to test this possibility. In Experiment 1a, the target sentences from Zwaan and Madden's materials were rewritten to move the target anaphor away from the end of the target sentence. In Experiment 1b, the original target sentences were used.

Experiment 1a

Two primary modifications were made to Zwaan and Madden's (2004) materials. An example is presented in Appendix B. First, the target sentences were rewritten to move the target instrument away from the end of the sentence. Moving the target instrument away from the end of the sentence reduced the likelihood that any slowdown in reading times was confounded with sentence wrap-up or occurred past the point of the end of the sentence. Second, a spill-over sentence (hereafter referred to as the *second target sentence*) was added in an attempt to measure any processing difficulty that continued after the reader had moved past the first target sentence in the text. With full-sentence reading times, delayed effects can sometimes be detected on a subsequent sentence; often, however, these effects are reduced or lost in the time between key presses from one sentence to the next. The second target sentence was equivalent in length to the first target sentence and immediately followed the first target sentence in the text. Other minor changes were made to the materials to ensure that the passages read smoothly. These changes did not alter the materials substantively and are described in detail in the materials section. Slower reading times in the reenablement condition relative to the enablement condition would be consistent with the memory-based view. Equivalence in reading times in these two conditions (the result originally obtained by Zwaan and Madden) would be consistent with the here-and-now view.

In addition, three norming studies were conducted to rule out other factors in the materials that may have contributed to Zwaan and Madden's (2004) failure to detect a difference between their

enablement and reenablement conditions. The first norming study was designed to replicate the plausibility in the original materials from Zwaan and Madden (an example is presented in Appendix A). Zwaan and Madden failed to detect a difference in plausibility between their enablement and reenablement conditions. This null finding was interpreted as supportive of the here-and-now view. However, as O'Brien et al. (2004) noted, the difference in their plausibility ratings converted into a medium effect size ($d = 0.52$), and the low number of participants (18) resulted in low power (52%) with which to test this difference. In the replication, the sample size was increased to 45. The second norming study measured plausibility for the materials used in Experiment 1a. This ensured that the changes to the materials did not alter the overall level of plausibility across conditions. Finally, although both O'Brien et al. (1998) and Zwaan and Madden (2004) were exploring the fate of outdated information, in neither case was there a check to ensure that readers had actually outdated the targeted information. The third norming study was designed to ensure that the information assumed to be outdated in the reenablement condition was actually outdated. Details and results of all three norming studies are presented within the Materials section.

Method

Participants. Participants were 30 University of New Hampshire undergraduates enrolled in introductory psychology courses. Participants received partial course credit for their involvement in the experiment.

Materials. The materials used were the 36 narrative passages used in Zwaan and Madden (2004), modified by altering the target sentence to move the target antecedent away from the end of the sentence. This shortened the length of the target sentence but did not change the content. A second target sentence was included to capture any spillover in processing the target sentence. Also, the number of mentions of the target instrument was equated across conditions. An example is presented in Appendix B. Each passage was divided into five sections: introduction, description of the instrument, background section, two target sentences, and conclusion. The introduction comprised two to four sentences that served to introduce the story line. This was followed by the description of the target instrument in either the enablement, disablement, or reenablement condition. The reenablement condition was created by adding one sentence to the disablement condition that served to reenable the target instrument. The description of the instrument had mean lengths of 44.97, 44.67, and 55.33 words for the enablement, disablement, and reenablement conditions, respectively. In the enablement and disablement conditions, the target instrument was mentioned twice explicitly and twice implicitly. The final sentence in the reenablement condition contained one additional mention of the target instrument. The background section ranged from four to eight sentences, with a mean of 5.86 sentences (a range of 62–69 words, with a mean of 64.83 words). After the background section, the two target sentences were presented. The first target sentence ranged from 38–43 characters, with a mean of 40.64 characters; the second target sentence ranged from 37–42 characters, with a mean of 39.72 characters. Two to three sentences concluded the passage. A comprehension question then followed to ensure that participants were carefully reading each passage for comprehension. The questions did not address information concerning the instrument, and there were an equal number of yes and no questions.

Three material sets were constructed; each set contained 12 passages in each of the three conditions. Across the three sets, each passage occurred once in each of the three conditions.

Norming Study—Plausibility. Plausibility ratings were collected for both Zwaan and Madden's (2004) original materials, as well as the altered materials used in Experiment 1a. For each set of materials, 45 participants were randomly assigned to one of three stimulus sets, with the restriction that each set was read by an equal number of participants. Each participant was run individually in a session that lasted approximately 1 hr. Each participant was given a booklet containing 36 passages, one per page. Each passage was terminated just prior to the first target sentence of each passage. Participants were instructed to read each passage carefully and then turn the page. On the next page, participants were presented with a question asking them to rate, on a 7-point scale ranging from 1 (*highly implausible*) to 7 (*highly plausible*), the likelihood that the action in the target sentence could occur (e.g., *How likely is it that Bobby began pounding the boards with the hammer?*). Three sets of booklets were generated; each booklet contained 12 passages in each of the three conditions: enablement, disablement, and reenablement. Across booklets, each passage appeared once in each of the three conditions.

The mean plausibility ratings in each of the three conditions for both Zwaan and Maddens's (2004) original materials and the materials used in Experiment 1a are presented in Table 1. For purposes of comparison, the plausibility ratings obtained by Zwaan and Madden are also presented in Table 1. In all experiments reported, F_1 and t_1 refer to tests against an error-term based on participant variability, and F_2 and t_2 refer to tests against an error-term based on item variability. All analyses reported are significant at the .05 alpha level unless otherwise indicated.

For Zwaan and Madden's (2004) original materials, there was an overall effect of condition, $F_1(2, 84) = 262.75$, $MSE = 0.655$; $F_2(2, 66) = 367.95$, $MSE = 0.373$. Planned comparisons confirmed that plausibility ratings were significantly lower in the disablement condition than in either the enablement condition, $F_1(1, 42) = 294.09$, $MSE = 1.96$; $F_2(1, 33) = 491.07$, $MSE = .935$, or the reenablement condition, $F_1(1, 42) = 259.80$, $MSE = 1.73$; $F_2(1, 33) = 382.60$, $MSE = .938$. More important, plausibility ratings were reliably lower in the reenablement condition than in the enablement condition, $F_1(1, 42) = 31.68$, $MSE = 0.243$; $F_2(1, 33) = 16.86$, $MSE = 0.367$.

Table 1
Mean Plausibility Ratings as a Function of Passage Condition: Zwaan and Madden (2004), Replication With Zwaan and Madden's (2004) Materials, and Experiment 1a

	Passage condition		
Experiment	Enablement	Reenablement	Disablement
Zwaan and Madden (2004)	5.92	5.53	1.94
Zwaan and Madden replication	5.82 (0.11)	5.40 (0.12)	2.24 (0.11)
Experiment 1a	5.87 (0.08)	5.22 (0.10)	2.45 (0.13)

Note. Standard errors are in parentheses.

The pattern of plausibility ratings was the same for the materials used in Experiment 1a. There was an overall effect of condition, $F_1(2, 84) = 316.78$, $MSE = 0.442$; $F_2(2, 66) = 235.94$, $MSE = 0.502$. Again, planned comparisons confirmed that plausibility ratings were significantly lower in the disablement condition than in either the enablement condition, $F_1(1, 42) = 503.36$, $MSE = 1.05$; $F_2(1, 33) = 360.37$, $MSE = 1.167$, or the reenablement condition, $F_1(1, 42) = 270.34$, $MSE = 1.27$; $F_2(1, 33) = 191.35$, $MSE = 1.44$. Plausibility ratings remained reliably lower in the reenablement condition than in the enablement condition, $F_1(1, 42) = 39.28$, $MSE = 0.49$; $F_2(1, 33) = 37.61$, $MSE = 0.409$.

Norming Study—Outdating. To ensure that the reenabling sentence made clear that the target instrument that was initially unavailable to the protagonist had become available, we conducted a norming study. Eighteen students from the University of Utah participated for partial course credit. Each participant was given a booklet containing 36 passages, one per page. Each passage was terminated just prior to the first target sentence. Participants were instructed to read each passage carefully and then turn the page. On the next page, participants were presented with a question asking them whether the target instrument was available to the protagonist (e.g., *Did Bobby find his hammer?*). If participants understood the passages correctly, they should have been more likely to respond "yes" in the reenablement condition than in the disablement condition, and more likely to respond "no" in the disablement condition than in the reenablement condition. The enablement condition was not included because the hammer was never lost and the question would not have made sense to participants. Two sets of booklets were generated; in each set, half of the passages contained the disablement elaboration, and the remaining half contained the reenablement elaboration. Across both sets, each passage appeared in each condition an equal number of times. Participants were randomly assigned to one of two booklet sets with the restriction that each set was read by an equal number of participants. Participants clearly understood the passages correctly. They were significantly more likely to respond "no" (94%) than "yes" (6%) in the disablement condition, $t_1(17) = 31.29$, $t_2(35) = 28.72$. In contrast, participants were significantly more likely to respond "yes" (89%) than "no" (11%) in the reenablement condition, $t_1(17) = 19.36$, $t_2(35) = 18.82$.

Procedure. Participants were randomly assigned to one of the three materials sets. Each participant was run individually in a session that lasted approximately 1 hr. All materials were presented on a monitor controlled by a Zenith Z100 or Dell 386 microcomputer.

Participants were instructed to rest their right thumbs on a line-advance key, their right index fingers on a *yes* key, and their left index fingers on a *no* key. Each trial began with the word *READY* in the middle of the screen. When participants were ready to read a passage, they pressed the line-advance key. Each press of the key erased the current line and presented the next line. Comprehension time was measured as the time between key presses. Each participant was instructed to read at a comfortable, normal reading pace. After the last line of the passage disappeared from the screen, the cue *QUESTIONS* appeared in the middle of the screen for 2,000 ms, followed by the comprehension question. Participants were instructed to respond to the comprehension question by pressing either the *yes* or the *no* key. Participants were also instructed that answering the comprehension questions was the most important part of the experiment, and that they should respond as quickly as possible without sacrificing accuracy. On the trials in which participants made errors, the word *ERROR* appeared in the middle of the screen for 750 ms. Before beginning the experimental passages, participants read three practice passages to ensure that they were thoroughly familiarized with and understood the procedure.

Results and Discussion

Overall, participants answered 97% of the comprehension questions correctly, and no individual participant answered less than 92% of the comprehension questions correctly. No participants were eliminated. The reading times for both target sentences were recorded. Reading times that were greater than 2.5 standard deviations from the mean were discarded. This cutoff procedure was used in this experiment and all subsequent experiments that reported measures of reading times. Across all experiments, this resulted in a loss of less than 5% of the data.

The reading times for the target sentences are presented in Table 2. In all experiments reported, separate analyses of variance were conducted on the first and second target sentences. There was a significant main effect of conditions for the first target sentence, $F_1(2, 54) = 14.88$, $MSE = 36{,}210$; $F_2(2, 66) = 16.17$, $MSE = 54{,}984$. Planned comparisons confirmed that reading times were significantly slower in the disablement condition than in either the enablement condition, $F_1(1, 27) = 24.03$, $MSE = 88{,}937$; $F_2(1, 33) = 30.04$, $MSE = 113{,}957$, or the reenablement condition, $F_1(1, 27) = 8.35$, $MSE = 85{,}989$; $F_2(1, 33) = 10.59$, $MSE = 145{,}659$. Reading times were also slower in the reenablement condition than in the enablement condition, $F_1(1, 27) = 8.93$, $MSE = 42{,}336$; $F_2(1, 33) = 5.27$, $MSE = 70{,}288$.

The main effect for conditions was also significant for the second target sentence, $F_1(2, 54) = 4.62$, $MSE = 20{,}151$; $F_2(2, 66) = 4.53$, $MSE = 34{,}661$. Planned comparisons showed that reading times remained significantly slower in the disablement condition than in the enablement condition, $F_1(1, 27) = 13.91$, $MSE = 25{,}735$; $F_2(1, 33) = 8.47$, $MSE = 66{,}551$. Reading times also tended to be longer in the disablement condition than in the reenablement condition; however, this difference was only reliable when tested against item variability, $F_1(1, 27) = 0.77$, $MSE = 48{,}975$; $F_2(1, 33) = 4.78$, $MSE = 73{,}866$. Reading times tended to be slower in the reenablement condition than in the enablement condition; however, this difference did not reach significance when tested against participant variability, $F_1(1, 27) = 3.52$,

Table 2
Mean Reading Times (in Milliseconds) for the Target Sentences With Anaphors Occurring Midsentence as a Function of Passage Condition: Experiment 1a

	Passage condition		
Target sentence	Enablement	Reenablement	Disablement
First target sentence	1,838 (70.0)	1,950 (82.5)	2,105 (95.6)
Second target sentence	1,934 (70.6)	2,007 (80.4)	2,043 (78.7)

Note. Standard errors are in parentheses.

$MSE = 46{,}199$, $p = .07$, or when tested against item variability, $F_2(1, 33) = 0.36$, $MSE = 67{,}546$, $p > .50$.

The pattern of reading times in Experiment 1a was consistent with O'Brien et al.'s (1998) results; reading times in the reenablement condition were significantly slower than in the enablement condition. This occurred even though the results of the outdating norming study made clear that readers were able to correctly understand that the instrument had been reenabled in the reenablement condition. The plausibility ratings were also consistent with O'Brien et al. (1998); plausibility ratings paralleled reading times.

The substantive change made to the materials from Zwaan and Madden's (2004) materials was to rewrite the target sentence to move the target instrument away from the end of the sentence. To ensure that the obtained slowdown in reading times in the reenablement condition was the result of this change, we conducted Experiment 1b using the same materials as Experiment 1a except the first target sentences were replaced with Zwaan and Madden's original target sentences. Further discussion will be postponed until after presenting those results.

Experiment 1b

Experiment 1b was a replication of Experiment 1a with one change to the materials. The target sentences used in Experiment 1b were replaced with the original target sentences from Zwaan and Madden (2004). If moving the target anaphor away from the end of the target sentence was the primary reason why Zwaan and Madden failed to detect a difference between the enablement condition and the reenablement condition, then we expected the results of Experiment 1b should replicate the findings by Zwaan and Madden: The difference between the enablement and reenablement conditions found in Experiment 1a should not be present.

Method

Participants. Participants were 30 University of New Hampshire undergraduates enrolled in introductory psychology courses. Participants received partial course credit for their involvement in the experiment.

Materials. The materials used were the same 36 narrative passages used in Experiment 1a with one modification. The first target sentences were removed and replaced with the target sentences from the original Zwaan and Madden (2004) materials. An example is presented in Appendix B.

Procedure. The procedure was identical to that in Experiment 1a.

Results and Discussion

Overall, participants answered 96% of the comprehension questions correctly, and no individual participant answered less than 92% of the comprehension questions correctly. No participants were eliminated. The reading times for both target sentences were recorded. The first target sentences were Zwaan and Madden's (2004) original target sentences; the second target sentences were the same as those used in Experiment 1a.

The reading times for the target sentences are presented in Table 3. There was a significant main effect of conditions for the first target sentence, $F_1(2, 54) = 14.29$, $MSE = 95{,}232$; $F_2(2, 66) = 5.40$, $MSE = 116{,}080$. As in Experiment 1a, planned comparisons confirmed that reading times were significantly slower in the disablement condition than in either the enablement condition, $F_1(1, 27) = 24.48$, $MSE = 186{,}793$; $F_2(1, 33) = 9.40$, $MSE = 250{,}456$, or the reenablement condition, $F_1(1, 27) = 12.84$, $MSE = 274{,}721$; $F_2(1, 33) = 5.25$, $MSE = 231{,}724$. More important, reading times between the reenablement condition and the enablement condition did not differ reliably, $F_1(1, 27) = .62$, $MSE = 109{,}877$; $F_2(1, 33) = 0.87$, $MSE = 214{,}299$. There were no reliable differences on the second target sentence.

Table 3
Mean Reading Times (in Milliseconds) for the Target Sentences With Anaphors Occurring Both Midsentence and End-of-Sentence as a Function of Passage Condition: Experiment 1b

	Passage condition		
Target sentence	Enablement	Reenablement	Disablement
First target sentence	2,435 (132.7)	2,482 (114.0)	2,825 (171.2)
Second target sentence	2,000 (106.0)	1,985 (90.1)	2,080 (74.2)

Note. Standard errors are in parentheses.

The combined results of Experiments 1a and 1b confirmed that the primary reason Zwaan and Madden (2004) failed to detect a difference between their enablement and reenablement conditions was because the target anaphor appeared at the end of the sentence. When the target sentences were rewritten to move the target anaphor away from the end of the target sentence (Experiment 1a), reading times in the reenablement condition were significantly slower than in the enablement condition. In contrast, when Zwaan and Madden's original target sentences were used (Experiment 1b), reading times in the reenablement and enablement conditions did not differ reliably. In fact, the pattern of reading times obtained in Experiment 1b closely matched those reported by Zwaan and Madden. Most important, the slowdown in reading time in the reenablement condition compared to the enablement condition found in Experiment 1a replicates the findings of O'Brien et al. (1998) with a different set of materials, indicating that the effect generalizes to different text scenarios.

Experiment 2

Experiment 2 was designed to provide an additional test of the memory-based and here-and-now views by creating a new set of materials. The reenablement condition in Experiments 1a and 1b always referred to the recovery of an instrument that had previously been unavailable to the protagonist. The change in the availability of the instrument (reenabling) was a relatively minor event in the story, and outdated information (that the instrument was unavailable) continued to influence comprehension. The goal of Experiment 2 was to determine if creating an irreversible change in the status of an important character or object (e.g., a tree is cut down) would eliminate the impact of outdated information.

Consider the sample passage presented in Appendix C. Similar to O'Brien et al. (1998), the passage contains information that is either consistent, inconsistent, or qualified with respect to information in a target sentence (e.g., *All that remained of the tree was a stump*). In the consistent condition, the tree is described and the

reader learns that it had been cut down. In the inconsistent condition, the tree is described and a decision is made that it will not be cut down. In the qualified condition, the tree is described, a decision is made that it will not be cut down, but then the tree was struck by lightning and had to be cut down. Both the memory-based and here-and-now views would predict fast reading times on the target sentence in the consistent condition and slow reading times in the inconsistent condition. The critical contrast between the memory-based view and the here-and-now view is in the qualified condition. In this condition, a major object has undergone an irreversible change-in-state (i.e., the tree has been cut down) that updates the status of the object.

According to the here-and-now view, this updated information is carried forward and used to comprehend later textual input; outdated information (i.e., that the tree would not be cut down) should not be reactivated and readers should have no trouble comprehending the target sentence (i.e., *All that remained of the tree was the stump*). Reading times for the target sentences in the qualified condition should not differ from those in the consistent condition. In contrast, within the memory-based view, any information that is related to the contents of the target sentence has the potential to be reactivated; that the change-in-state was irreversible should not matter. Information about the tree not being cut down should conflict with the contents of the target sentence and slow comprehension times in the qualified condition relative to the consistent condition.

Method

Participants. Participants were 36 University of Utah undergraduates enrolled in introductory educational psychology courses. Participants received partial course credit for their involvement in the experiment.

Materials. The materials used were 24 narrative passages. The materials were structured similarly to those passages used in the first two experiments. Each passage began with a one-sentence introductory section, and this was followed by a description of an object or entity that was either consistent, inconsistent, or qualified with respect to a later event in the passage. The mean lengths of the consistent, inconsistent, and qualified conditions were 80.06, 80.06, and 92.67 words, respectively. An irreversible change-in-state only occurred in the main events of the story in the consistent and qualified conditions; however, it was also mentioned in the inconsistent condition—in a slightly different context—in order to control the number of times this concept appeared across conditions. In the consistent and inconsistent conditions, the change in state (e.g., cut down, taken down, removed) was always mentioned four times, and the target object (e.g., tree) was mentioned four times: twice explicitly and twice implicitly. The qualified condition was created by adding one sentence to the inconsistent condition to create the change-in-state. This sentence contained one additional mention of the target object and the change-of-state of the object. The backgrounding information consisted of three to six sentences with a mean of 4.39 sentences (a range of 57–60 words, with a mean of 58.33 words). The first target sentence ranged from 38 to 42 characters, with a mean of 40.22 characters; the second target sentence ranged from 38 to 42 characters, with a mean of 39.39 characters. A one-sentence closing sentence concluded the passage. A comprehension question followed each passage to ensure that participants were reading carefully. There were equal numbers of "yes" and "no" comprehension questions.

Three material sets were constructed; each set contained eight passages in each of the three conditions. Across the three sets, each passage occurred once in each of the three conditions.

Norming Study—Plausibility. To ensure that the new materials maintained the same pattern of plausibility across conditions, we repeated the plausibility study conducted in Experiment 1a with the new materials. Forty-five University of New Hampshire students participated for partial course credit. The design and procedure were the same as in Experiment 1a. The mean plausibility ratings in each of the three conditions are presented in Table 4. As can be seen, the pattern of plausibility ratings remained the same. There was an overall effect of condition, $F_1(2, 84) = 169.12$, $MSE = 0.767$; $F_2(2, 30) = 87.54$, $MSE = 0.593$. Planned comparisons showed that plausibility ratings were significantly lower in the inconsistent condition than in either the consistent condition, $F_1(1, 42) = 234.87$, $MSE = 1.84$; $F_2(1, 15) = 95.59$, $MSE = 1.805$, or the qualified condition, $F_1(1, 42) = 178.7$, $MSE = 1.912$; $F_2(1, 15) = 97.45$, $MSE = 1.40$. Also, plausibility ratings were reliably lower in the qualified condition than in the consistent condition, $F_1(1, 42) = 6.12$, $MSE = 0.853$; $F_2(1, 33) = 6.0$, $MSE = 0.349$.

Norming Study—Outdating. As in Experiments 1a and 1b, we conducted a norming study for the materials used in Experiment 2 to ensure that the qualification sentence made clear to readers that the critical change-in-state had occurred. Thirty students from the University of Utah participated in exchange for partial course credit. The predictions, design, and procedure were the same as for the outdating norming study in Experiment 1a.

Table 4
Mean Plausibility Ratings and Reading Times (in Milliseconds) for the Target Sentences as a Function of Passage Condition: Experiment 2

	Passage condition		
Measure	Consistent	Qualified	Inconsistent
Plausibility ratings	5.69 (0.14)	5.34 (0.15)	2.59 (0.11)
Reading times			
First target sentence	1,909 (106.7)	2,038 (110.8)	2,377 (160.2)
Second target sentence	1,887 (110.7)	1,873 (96.2)	1,991 (101.6)

Note. Standard errors are in parentheses.

Participants were asked about the state of the target object (e.g., *Was the tree cut down?*). Participants clearly understood the meaning of the qualifying sentence. They were significantly more likely to respond "no" (90%) than "yes" (10%) in the inconsistent condition, $t_1(29) = 14.36$, $t_2(17) = 13.96$. In contrast, participants were significantly more likely to respond "yes" (92%) than "no" (8%) in the qualified condition, $t_1(29) = 20.32$, $t_2(17) = 17.75$.

Procedure. The procedure for Experiment 2 was the same as in Experiments 1a and 1b.

Results and Discussion

Overall, participants answered 96% of the comprehension questions correctly, and no individual participant answered less than 92% of the comprehension questions correctly. No participants were eliminated.

The mean reading times for the target sentences in Experiment 2 are presented in Table 4. There was a significant main effect of consistency for the first target sentence, $F_1(2, 66) = 16.20$, $MSE = 129{,}890$; $F_2(2, 30) = 13.41$, $MSE = 115{,}798$. Planned comparisons confirmed that reading times were significantly slower in the inconsistent condition than in either the consistent condition, $F_1(1, 33) = 21.50$, $MSE = 366{,}880$; $F_2(1, 15) = 22.34$, $MSE = 276{,}225$, or the qualified condition, $F_1(1, 33) = 11.84$, $MSE = 349{,}644$; $F_2(1, 21) = 5.55$, $MSE = 361{,}009$. Reading times were also significantly slower in the qualified condition than in the consistent condition, $F_1(1, 33) = 9.53$, $MSE = 62{,}814$; $F_2(1, 15) = 19.86$, $MSE = 57{,}555$.

The overall effect of consistency was not as strong for the second target sentence. The main effect was marginal when tested against participant variability, $F_1(2, 66) = 3.05$, $MSE = 49{,}379$, $p = .054$, and reliable when tested against item variability, $F_2(2, 30) = 6.075$, $MSE = 38{,}673$. Planned comparisons showed that reading times were significantly slower in the inconsistent condition than in either the consistent condition $F_1(1, 33) = 5.96$, $MSE = 65{,}231$; $F_2(1, 15) = 9.58$, $MSE = 85{,}437$, or the qualified condition, $F_1(1, 33) = 3.96$, $MSE = 127{,}888$; $F_2(1, 15) = 7.29$, $MSE = 77{,}965$. However, reading times in the qualified condition did not differ reliably from reading times in the consistent condition ($ps > .40$).

The results of the plausibility study again confirmed that the outdated information was still part of the overall representation of each passage; however, the outdating norming study also confirmed that readers understood that the information was outdated and no longer correct. The pattern of reading times in Experiment 2 remained the same as in Experiment 1a. Even though the qualification used in this experiment introduced an irreversible change-in-state to a central object, the outdated information continued to affect integration of the target sentence; reading times in the qualified condition were significantly slower than in the consistent condition. Thus, introducing an irreversible change-in-state of a primary object certainly leads a reader to update their understanding of the passage, and to outdate information about that object prior to the change-in-state. Nevertheless, the outdated information about that object continues to disrupt comprehension of subsequent text that conflicts with that outdated information.

General Discussion

The present set of experiments was designed to explore factors that may have contributed to conflicting results regarding the impact of outdated information on comprehension. Over a series of five experiments, O'Brien et al. (1998) found that outdated information continually disrupted the comprehension of subsequent information, a result consistent with the memory-based view. In contrast, in one experiment Zwaan and Madden (2004) found that outdated information had no measurable influence, a result interpreted as support for the here-and-now view. As noted earlier, for half of the passages used in Zwaan and Madden's experiment, a target anaphor was the last word in their target sentences. Because readers often continue to process anaphors after they have been initially encoded, comprehension difficulties may only become evident downstream (e.g., Garrod, 1994; Garrod & Sanford, 1994; Garrod & Terras, 2000; Sturt, 2003). It is possible that a disruption in reading in Zwaan and Madden's reenablement condition did not occur until after the end of the target sentence. The combined results of Experiments 1a and 1b confirmed this possibility. In Experiment 1a, when the target anaphor was moved away from the end of the target sentence, reading times were significantly slower in the reenablement condition than in the enablement condition. In contrast, in Experiment 1b when Zwaan and Madden's original target sentences were used, this difference was no longer evident.

Experiment 2 provided an additional test of the memory-based and here-and-now views by creating a new set of materials different from both those used by O'Brien et al. (1998) or Zwaan and Madden (2004). Passages were constructed so that the qualifying sentence produced an irreversible change-in-state of a primary object in the story. Each change-in-state created a situation in which the updating information and the outdated information were completely incompatible. For example, if updating information indicated that a tree had been cut down, the outdated information (e.g., that the tree remained standing) could not remain valid. Comprehension of the qualifying information would, by definition, require that the prior state be outdated. As Zwaan and Radvansky (1998) have noted, readers are most likely to keep track of primary characters and/or objects, and are therefore most likely to continually update information regarding these aspects of the narrative. Nevertheless, even when a primary object was updated by creating an irreversible change-in-state, outdated information continued to disrupt comprehension.

An alternative explanation for the results of Experiments 1a and 2 is that readers never updated their representation of a passage. The outdating norming studies were designed to directly address this concern. Participants were asked direct questions about the updating information to ensure that they understood that the outdated information was indeed outdated. For the materials used in both Experiments 1a and 1b, as well as Experiment 2, the results of norming studies confirmed that readers were able to update their understanding of the passages, outdate the appropriate information, and maintain the updated information as the correct information. These results confirm that the slowdowns in reading times in the reenablement condition (Experiment 1a) and the qualified condition (Experiment 2) were the result of the reactivation of information that had been successfully outdated.

It could be argued that the 11% error rate in the reenablement condition of the outdating norming study that was conducted to

inform both Experiments 1a and 1b (e.g., participants responded "no" to "Did Bobby find his hammer?") was responsible for the slower reading times that occurred in the reenablement condition only in Experiment 1a. That is, the error rates in the offline norming study might reflect the fact that participants in the online reading time studies were not attending to the reenablement. However, the materials used in Experiments 1a and 1b were identical up to the first target sentence: the point at which participants in the norming study were asked about the outdated information. The only difference between the materials used in Experiments 1a and 1b was in the first target sentence, which was never present in the outdating norming study. Thus, the results from the outdating norming study cannot explain the obtained slowdown in reading times in the reenablement condition in Experiment 1a while also explaining the failure to obtain this difference in the reenablement condition in Experiment 1b.

The plausibility ratings obtained for both Zwaan and Madden's (2004) original materials and the materials used in Experiment 1a matched almost perfectly the ratings obtained by Zwaan and Madden. However, with the number of participants increased from 18 to 45, the critical contrast between the enablement and reenablement conditions was reliable. This finding makes good sense. Because the task of rating the plausibility of the target action takes place after the participant has finished reading a passage, there is no longer a distinction between the here-and-now and inactive portions of the representation. The action is checked against the representation of the entire passage. In the reenablement condition, this representation contains information that would make the target action implausible, even though it was subsequently discounted—outdated from the here-and-now. Although resolvable, this outdated information would interfere with the plausibility judgments, reducing them relative to the enablement condition. A similar finding that outdated (or incorrect information) can affect memory judgments is widely reported within the metacognition literature (e.g., Dunlosky, Rawson, & Middleton, 2005; Eakin, 2005; Koriat, 1993, 1995). For example, according to the accessibility hypothesis (Koriat, 1993, 1995), individuals often make judgments based on the total amount of information accessed. If some of the information accessed is incorrect (e.g., Bobby lost his hammer) then accuracy judgments will be reduced.

The combined LSA analyses from Zwaan and Madden (2004) and O'Brien et al. (2004) make clear that LSA is an unreliable predictor or comprehension time, and that the cosine values returned are strongly dependent on how the analysis is conducted. However, there is a more fundamental problem with any attempt to predict comprehension times as a function of the semantic overlap between text that is currently being read and portions of a text that preceded it. The comprehensibility of a sentence is a function of many factors that can be loosely captured by determining its relevance or connectivity (e.g., causal, spatial, temporal, logical) to the prior context. There is an important distinction between relevance or connectivity and semantic overlap. A sentence can have high semantic overlap with the preceding context but can have low relevance and weak connectivity; in this case, the sentence would be difficult to integrate. Alternatively, a sentence can have low semantic overlap with a preceding context but still be highly relevant with strong connectivity. All possible permutations of levels of semantic overlap and levels of relevance and connectivity are possible. In none of these possible conditions would semantic overlap alone predict ease of integration or comprehension difficulty.

That measures of semantic overlap alone cannot be used to assess or predict comprehension difficulty raises important limitations of the memory-based view and the resonance model, in particular (Myers & O'Brien, 1998; O'Brien & Myers, 1999). First, within the memory-based view and the resonance model, activation is determined primarily as a function of semantic overlap (but see Lea, Rapp, Elfenbein, Mitchel, & Romine, 2008). Second, the resonance model was developed to capture only the passive activation process, which is an uncontroversial, albeit limited, component of more complete models of comprehension (e.g., Graesser et al., 1994). Any predictions regarding comprehension difficulty can only be made indirectly based on patterns of activation.

Nevertheless, considerable support for the memory-based view has been obtained using measures of comprehension difficulty with the contradiction paradigm developed by O'Brien and colleagues (Albrecht & O'Brien, 1993; Cook et al., 1998; Guéraud et al., 2005; Hakala & O'Brien, 1995; Myers et al., 1994; O'Brien & Albrecht, 1992; O'Brien et al., 1998). When there is semantic overlap between backgrounded information and currently read text, a slowdown in reading time can be taken as evidence that the backgrounded information was reactivated and interfered with the comprehension process. A finding of a slowdown in reading when there is no (or a very weak) semantic overlap between backgrounded information and currently read text would falsify a strong version of the memory-based view (Richards & Singer, 2001).

Independent of these limitations, the contradiction paradigm lends itself nicely to testing the fate of outdated information and predictions derived from the memory-based view. Assessing the fate of outdated information first requires that the targeted information be outdated. Subsequent information must then make reference to the targeted information in order to determine if only the updated information is available to the reader, or if both the updated and outdated information become available. When subsequent information makes direct reference to targeted outdated information (as in Zwaan & Madden, 2004, and the current study), there must, by definition, be a high level of semantic overlap. As the current study shows, when that occurs, there is a disruption in comprehension. It remains an interesting question whether indirect references to outdated information would produce similar results.

Recently Rapp and Kendeou (2007; see also Rapp & Kendeou, 2009) found that when information was outdated with a simple refutation, the outdated information continued to disrupt comprehension of subsequent information. However, when the outdating information contained a causal explanation, the impact of outdated information was eliminated. Causal information generally results in a rich, elaborated network of information (e.g., O'Brien & Myers, 1987; Trabasso & Suh, 1993; Trabasso & van den Broek, 1985). Thus, the causal information condition in Rapp and Kendeou (2007, 2009) would have provided the reader with proportionally more updating information than a simple refutation. This finding fits nicely with the results from Guéraud et al. (2005), who found that elaboration of the qualified information also eliminated any measurable comprehension difficulty. It is also consistent with the accessibility hypothesis within the metacognition literature (e.g., Dunlosky et al., 2005; Koriat, 1993, 1995). As the

amount of updating information is increased, it increases in accessibility and diminishes the impact of the outdated information. However, it is important to note that even though Guéraud et al. found that the outdated information did not affect comprehension, probe responses indicated that it continued to be reactivated (for similar findings of reactivation without an impact on comprehension, see Cook et al., 1998; Guéraud, 2003; Guéraud & Tapiero, 2003; Long & Chong, 2001). Presumably, if the amount of updating information was increased still further, eventually even activation of the outdated information would be diminished or eliminated.

Outdating is a process that occurs whenever new information is introduced that indicates a change in the state of affairs of a concept, character, or scenario and the reader's representation is updated to reflect that change. Although outdating frequently involves explicitly negating information presented earlier in the discourse, it should not be equated with negation. Kaup, Zwaan, and colleagues have extensively examined the impact of negation on the accessibility of concepts within text (e.g., Kaup, 2001; Kaup, Lüdkte, & Zwaan, 2006; Kaup & Zwaan, 2003). The general finding has been that, at the level of the discourse model, information presented in the negative (e.g., *The door was not open*) is equivalent in representation to information presented in the positive (e.g., *The door was closed*). In each case, the representation contains the same state of affairs that the door was closed (see Kaup, Zwaan, & Lüdkte, 2007, for an excellent review). Whether a specific concept has been introduced as absent, as in Experiment 1a (e.g., *The hammer was lost*) or as present, as in Experiment 2 (e.g., *The tree was standing*), if its initial state is subsequently outdated (i.e., negated), the impact of the outdated information on subsequent references to the concept should be the same.

Zwaan and colleagues have provided substantial evidence for the existence and role of the discourse model, as well as the types of information that a reader is likely to track and update (e.g., Zwaan, Magliano, & Graesser, 1995; Zwaan & Radvansky, 1998). However, in adopting the here-and-now view, Zwaan and Madden (2004) assumed that the processes involved in updating can override basic memory processes, allowing the reader to avoid the reactivation of related information that has been dropped from the discourse model. The current results add to a large body of evidence, in both the memory literature and text-processing literature, demonstrating that this assumption is too strong. Even under conditions in which reactivation of outdated information does not occur, it would seem more parsimonious to seek an explanation based on basic memory processes, rather than to assume some additional component that is specific to reading (i.e., that passive reactivation processes can be shut off during reading, eliminating the reactivation of outdated information). As Singer and Richards (2005) have noted, the strong test of the memory-based view is not whether passive reactivation is necessary (obligatory) but whether it is sufficient. Questions along these lines are most likely to advance researchers' understanding of the interacting role of basic memory processes and higher order, problem-solving processing in the comprehension of discourse.

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(*Appendices follow*)

Appendix A

A Bird House

Introduction. Bobby really enjoyed bird watching. He wished more birds would come to his house. He decided to build a bird house in order to attract more birds to his yard.

Disablement condition. Bobby took out a saw, but then remembered that he had lost his hammer. He hadn't used it in a while and he didn't know where to look. He checked in the basement but came up empty handed. After some searching, he still couldn't find the hammer and gave up.

Enablement condition. Bobby took out his hammer, but then remembered that he had lost his saw. He wasn't worried because he knew the saw was not important. He really needed the hammer to put the bird house together. He was glad he put it away after he used it last time.

Reenablement condition. Bobby took out a saw, but then remembered that he had lost his hammer. He hadn't used it in a while and he didn't know where to look. He checked in the basement but came up empty handed. After some searching, he found the hammer in his father's tool shed.

Filler. Bobby began gathering the rest of the materials that he would need. He had made out a list so he wouldn't forget anything. He collected the lumber and paint he had bought. He had already selected an oak tree as the site for the birdhouse. It was a giant tree that he could see from his bedroom window.

Target sentence. Bobby began pounding the boards together with the hammer.

Closing. The hammer was quite heavy for his young arm. Bobby was pleased with how well the birdhouse came out. He couldn't wait to watch all the birds that would come to his new birdhouse.

Question. Was Bobby building a doghouse?

Note. Reprinted from "Updating Situation Models," by R. A. Zwaan and C. J. Madden, 2004, *Journal of Experimental Psychology: Learning, Memory, and Cognition, 30,* p. 288. Copyright 2004 by the American Psychological Association.

Appendix B

Sample Passage for Experiments 1a and 1b

Introduction. Bobby really enjoyed bird watching. He wished more birds would come to his house. He decided to build a bird house in order to attract more birds to his yard.

Enablement condition. Bobby took out a hammer, but then remembered that he lost his tape measure. He was not worried because he knew the hammer was more important. He needed it to actually put the bird house together. He just hoped he did not hurt himself while using it.

Disablement condition. Bobby took out a tape measure, but then remembered that he lost his hammer. He hadn't used it in a while and didn't know where it could be. He searched the basement but could not find the hammer. He asked his parents but they could not help him.

Reenablement condition. Bobby took out a tape measure, but then remembered that he lost his hammer. He hadn't used it in a while and didn't know where it could be. He searched the basement but could not find the hammer. He asked his parents but they could not help him. After some searching, he found it in his father's tool shed.

Background. Bobby began gathering the rest of the materials that he would need. He had made out a list so he wouldn't forget anything. He collected the lumber and paint he had bought. He had already selected an oak tree as the site for the birdhouse. It was a giant tree that he could see from his bedroom window. He marked the boards and cut them out.

Target sentence 1 from Experiment 1a. He used the hammer to nail them together.

Target sentence 1 from Experiment 1b. Bobby began pounding the boards together with the hammer.

Target sentence 2. The hammer was heavy for his young arm.

Closing. Bobby was pleased with how well the birdhouse came out. He couldn't wait to watch all of the birds that would come to his big beautiful birdhouse.

Note. Adapted from "Updating Situation Models," by R. A. Zwaan and C. J. Madden, 2004, *Journal of Experimental Psychology: Learning, Memory, and Cognition, 30,* p. 288. Copyright 2004 by the American Psychological Association.

Appendix C

Sample Passage for Experiment 2

Introduction. Susan was writing her first novel from her study at home.

Consistent condition. Her study was on the second floor and she had a beautiful view from one of the widows facing the backyard. She loved to sit and think about what she wanted to write while looking out the window at a graceful old oak tree. When her husband wanted to cut it down she reluctantly agreed with him. They both thought it was a tragedy that such a beautiful tree had to be taken down. Still, they had it cut down and removed.

Inconsistent condition. Her study was on the second floor and she had a beautiful view from one of the widows facing the backyard. She loved to sit and think about what she wanted to write while looking out the window at a graceful old oak tree. Once her husband wanted to cut it down but she stopped him. She thought it would be a tragedy if such a beautiful tree were taken down. He agreed and decided not have it cut down and removed.

Qualified condition. Her study was on the second floor and she had a beautiful view from one of the widows facing the backyard. She loved to sit and think about what she wanted to write while looking out the window at a graceful old oak tree. Once her husband wanted to cut it down but she stopped him. She thought it would be a tragedy if such a beautiful tree were taken down. He agreed and decided not to have it cut down and removed. Soon afterwards, however, the tree was struck by lightning and had to be cut down.

Filler. Susan really wanted to focus on working on her novel. She had already outlined the plot and developed her characters. Today, though, she was suffering from a bad case of writer's block. She just could not decide what she wanted to write next. While she was thinking, she got up and went over to look out the window.

Target sentence 1. All that remained of the tree was a stump.

Target sentence 2. Susan missed seeing the tree in her yard.

Closing. She decided to plant a new tree in the same spot in the spring.

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