

Updating During Reading Comprehension: Why Causality Matters

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The present set of 7 experiments systematically examined the effectiveness of adding causal explanations to simple refutations in reducing or eliminating the impact of outdated information on subsequent comprehension. The addition of a single causal-explanation sentence to a refutation was sufficient to eliminate any measurable disruption in comprehension caused by the outdated information (Experiment 1) but was not sufficient to eliminate its reactivation (Experiment 2). However, a 3 sentence causal-explanation addition to a refutation eliminated both any measurable disruption in comprehension (Experiment 3) and the reactivation of the outdated information (Experiment 4). A direct comparison between the 1 and 3 causal-explanation conditions provided converging evidence for these findings (Experiment 5). Furthermore, a comparison of the 3 sentence causal-explanation condition with a 3 sentence qualified-elaboration condition demonstrated that even though both conditions were sufficient to eliminate any measurable disruption in comprehension (Experiment 6), only the causal-explanation condition was sufficient to eliminate the reactivation of the outdated information (Experiment 7). These results establish a boundary condition under which outdated information will influence comprehension; they also have broader implications for both the updating process and knowledge revision in general.

Keywords: updating, refutation texts, causality

Successful reading comprehension requires the continual integration of incoming information into the evolving discourse representation in readers' memory. Integrating new information during reading results in the updating of the emerging discourse representation. Indeed, that readers continually update their discourse representation is an uncontroversial component of most models of reading comprehension (e.g., Gerrig & McKoon, 1998; Gerrig & O'Brien, 2005; Graesser, Singer, & Trabasso, 1994; Kintsch & van Dijk, 1978; Magliano, Trabasso, & Graesser, 1999; McNamara & Magliano, 2009; O'Brien & Myers, 1999; van den Broek, Young, Tzeng, & Linderholm, 1999; Zwaan, Magliano, & Graesser, 1995). Often, however, updating not only involves the incorporation of new information, but it also involves the discounting, changing, or outdating of previously read information (Johnson & Seifert, 1994, 1998, 1999; Kendeou & van den Broek, 2007; Rapp & Kendeou, 2007, 2009).

Because updating and outdating are overlapping processes, the terms are often used interchangeably; however, it is important to note that there is a distinction between updating processes and the outdating of information. *Updating* is the process whereby new information is encoded and integrated into the evolving discourse representation; as information is integrated, the representation is updated to reflect the newly encoded information. *Outdating* occurs whenever the integration of newly encoded information produces a conflict with information encoded earlier. Typically out-

dating occurs whenever new information is introduced that indicates a change in the state of affairs of a character, an object, or a scenario that requires the "negation" of earlier information. The information that has been outdated decays, dropping from the active portion of the discourse model, while the updated information remains active and is carried forward. 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 readers may infer that "Albert is sloppy" because he is described as living in a messy apartment, but then subsequently read that his apartment is messy only because he just moved (e.g., Rapp & Kendeou, 2007, 2009). In each of these cases, updating would involve incorporating this new information into the active portion of the discourse representation; this updating process would also lead to the outdating of the initially encoded information because it is no longer correct and/or relevant. The information that has been outdated remains a part of the long-term memory representation; however, as a function of having been outdated, it would lose activation and become less accessible (Zwaan & Radvansky, 1998).

Even though outdated information is not maintained in the active portion of the discourse representation, there is considerable evidence indicating that outdated information can continue to be reactivated and disrupt comprehension (e.g., Guéraud, Harmon, & Peracchi, 2005; Hakala & O'Brien, 1995; Johnson & Seifert, 1994, 1998, 1999; Kendeou & van den Broek, 2007; O'Brien, Cook, & Guéraud, 2010; O'Brien, et al., 1998; Rapp & Kendeou, 2007, 2009). For example, O'Brien et al. (1998) demonstrated that readers were influenced by their initial models of story characters despite subsequent information refuting those models. In their studies, participants read an initial description of a character (e.g., "Mary, a health nut, had been a strict vegetarian for ten years") followed by information that served to outdate that information

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(e.g., “Nevertheless, Mary never stuck to her diet when she dined out with friends”). Even though the initial character information had been outdated, readers continued to experience comprehension difficulty when the character engaged in an action that was inconsistent with the initial character information (e.g., “Mary ordered a cheeseburger and fries”). Similarly, O’Brien et al. (2010) demonstrated that outdated information continued to be reactivated and disrupt comprehension, even when the updating process involved creating an irreversible change in state of a primary object in a narrative (e.g., a once-standing tree was cut down and no longer present) that made the outdated information impossible.

Although outdated information can disrupt comprehension, the conditions under which this will occur must be limited; otherwise, readers/learners would never be able to fully revise what they know without continual interference from earlier acquired, but incorrect, information. In order for the outdated information to disrupt comprehension, it must first be reactivated; that is, it must be reintroduced into the active portion of the discourse model, thereby becoming an active component of the ongoing integration process. For that to occur, the reader must encode information that is related to the outdated information. There is considerable evidence that as the reader encodes new information, that newly encoded information, in combination with the current contents of working memory, serves as a signal to all of long-term memory, including both earlier portions of the discourse representation as well as general world knowledge (e.g., Cook & Guéraud, 2005; Garrod & Terras, 2000; Gerrig & McKoon, 1998; Gerrig & O’Brien, 2005; McKoon & Ratcliff, 1998; O’Brien & Albrecht, 1991; O’Brien & Myers, 1999; Rizzella & O’Brien, 2002). Related information from inactive portions of memory resonates (i.e., increases in activation) in response to this signal; information that rises above a particular activation threshold is returned to active portion of the discourse model. This passive activation process is derived from more global models of memory (e.g., Gillund & Shiffrin, 1984; Ratcliff & McKoon, 1988) and is consistent with the basic passive memory activation components of several models relevant to reading comprehension (e.g., Kintsch, 1988; Myers & O’Brien, 1998; O’Brien & Myers, 1999; Sanford & Garrod, 1981, 1998, 2005; van den Broek, Rapp, & Kendeou, 2005) as well as the accessibility hypothesis within the metacomprehension literature (e.g., Dunlosky, Rawson, & Middleton, 2005; Koriati, 1993, 1995). Because this initial activation process is unrestricted, any information related to the signal that is sufficiently activated is returned to working memory, independent of its relevance to the active portion of the discourse representation. At this stage, outdated information is no different from any other inactive information; if a reader encodes information that is related to the outdated information, the outdated information has the potential to be reintroduced into the comprehension process; and once it is reintroduced into the comprehension process, it has the potential to disrupt comprehension.

However, it is important to note that simply reactivating outdated information does not necessarily mean that the comprehension process will be disrupted. Whether reactivated outdated information disrupts comprehension depends on the complete pattern of activated information in working memory, and the pattern of outdated information that is activated and becomes a part of working memory will depend largely on how the outdated information was initially outdated. For example, Guéraud et al.

(2005) found that increasing the amount of updating information eliminated the disrupting impact of outdated information on the comprehension process, even though the outdated information continued to be reactivated (for similar findings of reactivation without an impact on comprehension, see Cook, Halleran, & O’Brien, 1998; Long & Chong, 2001). Similarly, Rapp and Kendeou (2007, 2009) found that when information was outdated with a simple refutation, the outdated information continued to disrupt comprehension of subsequent information; however, when information was outdated using a refutation that included an explanation, the impact of outdated information was eliminated.

The results of Rapp and Kendeou (2007, 2009) suggest that eliminating or reducing the impact of outdated information is not simply a function of the amount of updating information but also of the quality of that information. Rapp and Kendeou showed that a simple refutation that included an explanation was just as effective in eliminating the impact of outdated information as Guéraud et al. (2005) found when using multiple sentences that simply amplified a refutation. One factor particularly relevant to this finding is that the explanations used in the Rapp and Kendeou set of experiments contained implicit causal information. 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). The inclusion of implicit causal information in combination with a simple refutation may have served to create a rich network of information that would have competed with the outdated information by drawing activation to itself. This, in turn, would have decreased the amount of activation reaching the outdated information, reducing the impact of the outdated information.

The goal of the present set of experiments was to systematically examine the effectiveness of causal explanations in eliminating the impact of outdated information. On the basis of previous work, providing the reader with a simple refutation should not be sufficient to eliminate the impact of outdated information on comprehension of subsequent text (e.g., O’Brien et al., 1998, 2010). However, adding increasing amounts of causal-explanation information to the refutations should reduce the impact of outdated information in very systematic ways. As the amount of causal information is increased, the richness of the network should increase, thereby drawing increasing amounts of activation to itself and away from the outdated information. Reducing the amount of activation reaching the outdated information should first eliminate the disrupting impact of outdated information and eventually eliminate any measurable reactivation of the outdated information. In Experiments 1 and 2 the addition of a single sentence that included a refutation with a causal explanation was sufficient to eliminate any measurable disruption in comprehension caused by the outdated information but was not sufficient to eliminate its reactivation. In Experiments 3 and 4, the strengthening of the causal explanation with the inclusion of two additional causal-explanation sentences eliminated both the disruption in comprehension and the reactivation of the outdated information. Experiment 5 contained a direct comparison of activation measures employed in Experiments 2 and 4 to eliminate cross-experiment comparisons. In Experiments 6 and 7, the three sentence causal-explanation condition was compared to the three sentence qualified-elaboration condition used in Guéraud et al. (2005). Even though both the three sentence causal-explanation condition and

the three sentence qualified-elaboration conditions were sufficient to eliminate any measurable disruption in comprehension, only the causal-explanation condition was sufficient to eliminate the reactivation of the outdated information.

Experiment 1

The goal of Experiment 1 was to determine if adding a causal explanation to a simple refutation would prove sufficient to eliminate the impact of outdated information on the comprehension of subsequent text. The materials were adapted from O'Brien et al. (1998). Each passage appeared in each of three elaboration conditions: consistent elaboration, inconsistent elaboration, and causal explanation. The consistent- and inconsistent-elaboration conditions were taken directly from O'Brien et al. The causal-explanation condition was created by adding a one sentence causal explanation to the inconsistent elaboration that served to justify why the elaborated characteristic was no longer operative. Consider the example in the Appendix. In the one sentence causal-explanation condition the elaboration states that Mary is a vegetarian; this information is then refuted with a causal explanation for why she is no longer a vegetarian (i.e., "She wasn't getting enough vitamins because of her diet so her doctor said she had to start eating meat") Following several sentences that served to provide background for this information, readers were presented with the target sentence, "Mary ordered a cheeseburger and fries." If the addition of a one sentence causal explanation to the inconsistent elaboration is sufficient to eliminate any disruption in reading caused by the inconsistent information, then reading times on the target sentence following the causal explanation should not differ from reading times on the target sentence following the consistent elaboration. Also, reading times on the target sentence should be faster following both the consistent and causal-explanation elaborations than following the inconsistent elaboration.

Method

Participants. Participants were 30 undergraduate students from the University of New Hampshire who received partial course credit for their involvement in the experiment.

Materials. The materials consisted of 18 passages adapted from the materials used in O'Brien et al. (1998). An example is presented in the Appendix. Each passage was divided into five sections: introduction, elaboration section, background section, two critical sentences, and closing section. Each passage began with two to three introductory sentences that served to establish the story line of the passage. This was followed by one of the three elaboration conditions: consistent, inconsistent, and causal explanation. The consistent-elaboration section described characteristics of the protagonist that would later support the action mentioned in the critical sentence. The inconsistent-elaboration section contained character traits that conflicted with the execution of this action. The causal-explanation section was created by using the inconsistent elaboration and adding one causal-explanation sentence that outdated the inconsistent characteristic by providing a causal explanation for why the inconsistent characteristic was no longer true. The elaboration sections had mean lengths of 44.33, 44.77, and 63.10 words for the consistent, inconsistent, causal-

explanation conditions, respectively. The causal-explanation sentence ranged from 17 to 19 words with a mean length of 18.33 words. Following the elaboration section, there were six sentences of background information (range: 62–69 words) that continued the story line developed in the introduction. The background section was immediately followed by the two critical sentences. The second critical sentence did not contain information that was inconsistent with previously stated information in the text and was included to detect possible spillover effects from the first critical sentence. The mean lengths of the first and second critical sentences were 38.67 and 38.50 characters, respectively (range: 37–40 words for both critical sentences). Two to three sentences concluded the passage (range: 27–33 words). In addition to the 18 experimental passages, there were nine filler passages that were similar to the consistent elaboration versions of the experimental passages. These passages were included to ensure that there were at least as many consistent passages as potentially inconsistent passages. Each passage ended with a comprehension question that did not address information concerning the protagonist profile. They were presented to ensure that participants were carefully reading each passage and required an equal number of "yes" or "no" answers.

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

Procedure. Participants were randomly assigned to one of the three material sets. All participants were run individually in a session that lasted approximately 45 min. All materials were presented on a video monitor controlled by a 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 center 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 of text and presented the next line of text. Comprehension time was measured as the time between key presses. Participants were instructed to read at a normal and comfortable reading rate. Following the last line of each passage, the cue "QUESTIONS" appeared in the center of the screen for 2,000 ms. This was followed by the comprehension question to which participants responded by either pressing the "yes" or "no" key. On the trials where participants made an error, 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 familiarized with and understood the procedure.

Results and Discussion

In this experiment, and in all subsequent experiments, reading times or verification times that were greater than 2.5 *SDs* from the mean were discarded. Across all experiments, this resulted in the loss of less than 3% of data. Also, in all experiments reported, F_1 refers to tests against an error term based on participant variability and F_2 refers to tests against an error term based on item variability. All analyses reported are significant at the .05 alpha level unless otherwise indicated.

The reading times for both critical sentences were recorded. The mean reading times of the first and second critical sentences in Experiment 1 are presented in Table 1. Separate analyses of variance were conducted on the first and second target sentences. Reading times for the first critical sentence revealed a main effect of elaboration condition, $F_1(2, 54) = 11.46, MSE = 50,305; F_2(2, 30) = 6.52, MSE = 48,282$. Planned comparisons confirmed that the critical sentence was read more slowly when it followed the inconsistent elaboration than when it followed either the consistent elaboration, $F_1(1, 27) = 13.53, MSE = 118,320; F_2(1, 15) = 10.18, MSE = 95,992$, or the one sentence causal-explanation elaboration, $F_1(1, 27) = 17.67, MSE = 104,573; F_2(1, 15) = 9.14, MSE = 99,588$. The small difference in reading times for the first critical sentence in the consistent-elaboration condition and the one sentence causal-explanation condition was not reliable ($ps > .70$).

Reading times on the second critical sentence also showed a main effect of elaboration condition but only when tested based on participant variability, $F_1(2, 54) = 3.52, MSE = 71,458; F_2(2, 30) = 2.75, p = .08$. Although the pattern of reading times for the second critical sentence was the same as for the first critical sentence, planned comparisons revealed that only one difference approached significance. Reading times for the second critical sentence were longer in the inconsistent-elaboration condition than in the one sentence causal-explanation condition, $F_1(1, 27) = 7.09, MSE = 138,412; F_2(1, 15) = 4.83, MSE = 173,791$. No other differences approached significance ($ps > .16$).

The reading time results indicated that the addition of one causal-explanation sentence to the inconsistent elaboration was sufficient to eliminate any measurable disruption in reading caused by the outdated inconsistent information. However, it remains unclear whether the causal explanation was sufficient to also eliminate the reactivation of the outdated information. Experiment 2 was designed to test this possibility.

Experiment 2

Experiment 2 was designed to examine whether one causal-explanation sentence was sufficient to not only eliminate the disruption in comprehension caused by the outdated information but also eliminate its reactivation. The materials consisted of the one sentence causal-explanation elaboration passages used in Experiment 1. For each passage, a verification statement was written that captured the information in the outdated characteristic but was also true for the updated state of affairs (e.g., “Mary used to not eat meat at all”). The verification statement was presented either immediately after the background section or immediately after the first target sentence.

Table 1
Mean Reading Times (in Milliseconds) for Target Sentences as a Function of Elaboration Condition in Experiment 1

Target sentence	Elaboration condition		
	Consistent	Inconsistent	Causal explanation
First target sentence	1,990 (532)	2,221 (523)	1,973 (421)
Second target sentence	1,947 (476)	2,128 (498)	2,013 (459)

Note. Standard deviations are included in parentheses.

If one causal-explanation sentence served to eliminate the reactivation of the outdated information then time to respond to the verification statement should not differ when presented either after the background section or after the target sentence. Alternatively, if the target sentence continued to reactivate the inconsistent outdated information, then time to respond to the verification statement should be faster after the target sentence than after the background section.

Method

Participants. Participants were 30 University of New Hampshire undergraduates who received partial course credit for their participation in the experiment.

Materials. The materials consisted of the same 18 passages used in Experiment 1. However, each passage appeared in only the one sentence causal-explanation elaboration condition. For each passage, a verification statement was written that captured the information in the outdated characteristic. The mean length of the verification statements was 34.11 characters (range: 33–35 characters). The verification statement was presented either immediately after the background section or immediately after the first target sentence. Thus, each causal-explanation passage appeared in one of two conditions. An additional 18 filler passages were included. For each filler passage, the correct response to the verification statements was “no” to ensure that each participant responded to an equal number of “yes” and “no” verification statements. Two material sets were constructed. Each set contained nine passages in each of the two experimental conditions and 18 filler passages. Across the two sets, each experimental passage occurred once in each of the two conditions.

Procedure. Participants were randomly assigned to one of two material sets. Each participant was run individually in a session that lasted approximately 45 min. All materials were presented on a monitor controlled by a Dell 386 microcomputer.

The procedure for reading the passages was the same as described in Experiment 1. Either immediately after reading the last line of the background section or immediately after reading the first target sentences, the cue “XXX” appeared on the screen for 500 ms. The cue was then replaced by the verification statement. Participants were instructed to read the statement and respond as quickly, but also as accurately, as possible by pressing either the “yes” key or the “no” key indicating whether the statement was true given the passage they had just read. On those trials in which participants made an error, the word “ERROR” appeared in the middle of the screen for 750 ms. Before beginning the experimental passages, participants read three practice passages with the experimenter present to ensure that they were familiarized with and understood the procedure.

Results and Discussion

The time to respond to the verification statements was recorded. In this experiment, and in all subsequent verification experiments (Experiments 4, 5, and 7), all analyses included only verification times from correct “yes” responses. Across all verification experiments there was never more than one error per condition, and errors were evenly distributed across conditions. Mean verification times are presented in Table 2. The time to respond to a verification statement was faster when it followed the target sentence than

Table 2
Mean Verification Times (in Milliseconds) for Probe Statements as a Function of Probe Position in Experiments 2 and 4

Experiment	Probe position	
	After background section	After target sentence
Experiment 2	2,482 (649)	2,290 (533)
Experiment 4	2,272 (460)	2,324 (562)

Note. Standard deviations are included in parentheses.

when it followed the background region, $F_1(1, 28) = 16.21$, $MSE = 33,841$; $F_2(1, 16) = 5.56$, $MSE = 52,042$. The pattern of verification times, in combination with the reading times from Experiment 1, suggests that even though a single causal-explanation sentence was sufficient to eliminate disruption in comprehension caused by the outdated information, it was not sufficient to eliminate the reactivation of the outdated information. Indeed, the inconsistent outdated information continued to be reactivated. Presumably, if the amount of causal information was increased still further, both the disruption in comprehension and of the reactivation of the outdated information would be diminished or eliminated. Experiments 3 and 4 were designed to test this possibility.

Experiment 3

The goal of Experiment 3 was to establish that strengthening the causal explanation by adding two additional causal-explanation sentences was also sufficient to eliminate the disruption in comprehension caused by outdated information. Once it has been established that strengthening the causal explanation eliminated any disruption in comprehension, the goal of Experiment 4 will be to assess whether strengthening the causal explanation is also sufficient to eliminate any measurable activation of the outdated information. The materials consisted of the same passages used in Experiment 1 with one modification: Two additional sentences were added to the causal-explanation sentence to strengthen the causal explanation (e.g., "Mary recently had blood work done. Her lack of iron was causing her to become anemic"). The two additional causal-explanation sentences strengthened and supported the original causal explanation. The sentences were written so that they were connected both to each other and to the original causal explanation, providing a rich, recursive, and interconnected network of information that should draw even greater activation than the single causal explanation. If strengthening the causal explanation is sufficient to eliminate any disruption in reading caused by the outdated information, then reading times on the target sentence following the three sentence causal-explanation elaboration should not differ from reading times on the target sentence following the consistent elaboration. If correct, then reading times on the target sentence should be faster following both the consistent and three sentence causal-explanation elaborations than following the inconsistent elaboration.

Method

Participants. Participants were 30 University of New Hampshire undergraduates who received partial course credit for their participation in the experiment.

Materials. The materials consisted of the same 18 passages used in Experiment 1 with one modification: Two additional sentences were added to the causal-explanation elaboration condition. The additional sentences expanded upon and elaborated on the causal explanation. With the addition of these two sentences, the elaboration section in the causal-explanation condition ranged between from 35 to 49 words with a mean length of 44.33 words. The consistent-elaboration condition and the inconsistent-elaboration condition remained the same as in Experiment 1.

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

Results and Discussion

The mean reading times of the first and second critical sentences are presented in Table 3. Separate analyses of variance were conducted on the first and second target sentences. Reading times for the first critical sentence revealed a main effect of elaboration condition, $F_1(2, 54) = 30.27$, $MSE = 37,870$; $F_2(2, 30) = 29.16$, $MSE = 25,503$. Consistent with Experiment 1, planned comparisons confirmed that the critical sentence was read more slowly when it followed the inconsistent elaboration than when it followed either the consistent elaboration, $F_1(1, 27) = 33.07$, $MSE = 103,007$; $F_2(1, 15) = 41.16$, $MSE = 58,474$, or the three sentence causal-explanation elaboration, $F_1(1, 27) = 67.49$, $MSE = 51,434$; $F_2(1, 15) = 32.33$, $MSE = 63,130$. Reading times for the first critical sentence in the consistent-elaboration condition and the three sentence causal-explanation condition did not differ reliably ($ps > .49$). Although the pattern of reading times for the second critical sentence was the same as for the first critical sentence, no differences approached significance ($ps > .08$).

These findings established that strengthening the causal explanation by adding two additional sentences was sufficient to eliminate any measurable disruption on comprehension caused by outdated information. Experiment 4 was designed to assess whether this condition was sufficient to also eliminate the reactivation of the outdated inconsistent information.

Experiment 4

The materials in Experiment 4 consisted of the three sentence causal-explanation elaboration passages used in Experiment 3. For each passage, a verification statement that captured the information in the outdated characteristic was presented either immediately after the background section or immediately after the first target sentence. The verification statements were the same as those used in Experiment 2.

Table 3
Mean Reading Times (in Milliseconds) for Target Sentences as a Function of Elaboration Condition in Experiment 3

Target sentence	Elaboration condition		
	Consistent	Inconsistent	Causal explanation
First target sentence	1,797 (437)	2,134 (451)	1,794 (417)
Second target sentence	1,892 (434)	1,996 (582)	1,873 (447)

Note. Standard deviations are included in parentheses.

If strengthening the causal explanation served to eliminate the reactivation of the outdated information then time to respond to the verification statement should not differ when presented either after the background section or after the target sentence. Alternatively, if the target sentence continued to reactivate the outdated information, then time to respond to the verification statement should be faster after the target sentence than after the background section.

Method

Participants. Participants were 30 University of New Hampshire undergraduates who received partial course credit for their participation in the experiment.

Materials. The materials consisted of the same 18 passages used in Experiment 3. Each passage appeared in only the three sentence causal-explanation elaboration condition. The verification statements were the same as used in Experiment 2. The same 18 filler passages used in Experiment 3 were also included to ensure an equal number of “yes” and “no” responses.

Procedure. The procedure was identical to that used in Experiment 2.

Results and Discussion

Mean verification times are presented in Table 2. There was no reliable difference in the time to respond to the verification statement as a function of whether it was presented after the background section or after the first target sentence, $F_1(1, 28) = 0.58$, $MSE = 71,630$; $F_2(1, 16) = 0.36$, $MSE = 49,238$.

This pattern of verification times, in combination with those from Experiment 2, suggests that strengthening the causal explanation by adding two sentences was sufficient to eliminate the reactivation of the outdated information. However, a closer look at the findings from these two experiments shows that verification times before the target sentence in Experiment 4 were comparable to verification times after the target sentence in Experiment 2. This pattern may simply reflect random variability often present in a between-experiment comparison. Alternatively, it may have occurred because the additional causal elaboration served to maintain the target outdated inconsistent information in an active state. Experiment 5 was designed to test this latter possibility by directly comparing verification times when the causal-explanation condition contained only one causal sentence and when the causal-explanation condition contained three causal sentences.

Experiment 5

The materials in Experiment 5 consisted of the one sentence causal-explanation elaboration passages used in Experiment 2 and the three sentence causal-explanation elaboration passages used in Experiment 4. If the three sentence causal-explanation condition is sufficient to eliminate the reactivation of the outdated information, then the following pattern should occur. In the three sentence causal-explanation condition, time to respond to the verification statement as a function of whether it is presented after the background section or after the first target sentence should not differ reliably (consistent with Experiment 4). In the one sentence causal-explanation condition, time to respond to the verification statement

following the target sentence should be faster than time to respond to the verification statement following the background section (consistent with Experiment 2). More important, verification times in the three sentence causal-explanation condition both following the background section and the target sentence should not differ reliably from verification times following the background section in the one sentence causal-explanation condition.

Method

Participants. Participants were 40 University of New Hampshire undergraduates who received partial course credit for their participation in the experiment.

Materials. The materials consisted of 16 of the 18 passages used in Experiments 2 and 4. Each passage appeared in either the one sentence causal-explanation elaboration condition (Experiment 2) or the three sentence causal-explanation elaboration condition (Experiment 4). As in Experiments 2 and 4, the verification statement was presented either immediately after the background section or immediately after the first target sentence for both causal-explanation conditions. Thus, each causal-explanation passage appeared in one of four conditions. Sixteen filler passages were included to ensure that each participant responded to an equal number of “yes” and “no” verification statements. Four material sets were constructed. Each set contained four passages in each of the four experimental conditions and 16 filler passages. Across the four sets, each experimental passage occurred once in each of the four conditions.

Procedure. The procedure was identical to that used in Experiments 2 and 4.

Results and Discussion

Mean verification times are presented in Table 4. Overall, verification times in the one sentence causal-explanation condition and the three sentence causal-explanation condition did not differ reliably, $F_1(1, 36) = 2.06$, $MSE = 174,601$, $p = .16$; $F_2(1, 12) = 2.30$, $MSE = 82,537$, $p = .155$. Verification times tended to be faster when they followed the target sentence than when they followed the background section, $F_1(1, 36) = 3.75$, $MSE = 72,740$, $p = .061$; $F_2(1, 12) = 3.82$, $MSE = 62,183$, $p = .074$; however, this difference was true only for verification response times in the one sentence causal-explanation condition, $F_1(1, 36) = 7.16$, $MSE = 80,431$, $p = .01$; $F_2(1, 12) = 5.56$, $MSE = 48,996$, $p = .03$.

Planned comparisons confirmed that consistent with Experiment 2, when the explanation section contained only one causal sen-

Table 4
Mean Verification Times (in Milliseconds) for Probe Statements as a Function of Probe Position in Experiment 5

Probe position	Causal-explanation condition	
	One sentence	Three sentences
After background section	2,315 (497)	2,290 (545)
After target sentence	2,113 (455)	2,328 (574)

Note. Standard deviations are included in parentheses.

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tence, the time to respond to the verification statement was faster when it followed the target sentence than when it followed the background section, $F_1(1, 36) = 18.69$, $MSE = 87,813$; $F_2(1, 12) = 5.91$, $MSE = 172,385$. And, consistent with Experiment 4, when the explanation section contained three causal sentences, time to respond to the verification statement as a function of whether it was presented after the background section or after the first target sentence did not differ reliably, $F_1(1, 36) = 0.26$, $MSE = 218,528$; $F_2(1, 12) = 0.02$, $MSE = 49,973$.

Furthermore, verification times in the one sentence causal-explanation condition following the background section did not differ reliably from verification times in the three sentence causal-explanation condition following either the background section, $F_1(1, 36) = 0.10$, $MSE = 247,837$; $F_2(1, 12) = 0.03$, $MSE = 216,109$, or following the target sentence, $F_1(1, 36) = 0.02$, $MSE = 295,602$; $F_2(1, 12) = 0.02$, $MSE = 170,152$. In contrast, verification times in the one sentence causal-explanation condition following the target sentence were reliably faster than verification times in the three sentence causal-explanation condition following either the background section, $F_1(1, 36) = 6.32$, $MSE = 199,080$; $F_2(1, 12) = 7.14$, $MSE = 119,288$, or the target sentence, $F_1(1, 36) = 7.03$, $MSE = 262,225$; $F_2(1, 12) = 19.53$, $MSE = 46,956$.

This set of findings provides converging evidence for the findings obtained in Experiments 2 and 4 and rule out the possibility that the outdated information simply remained active in the three sentence causal-explanation condition. Specifically, when directly compared in a single experiment, a one sentence causal explanation is not sufficient to eliminate the reactivation of the outdated information, whereas a three sentence causal explanation is sufficient.

These findings raise an interesting question: Was it the sheer amount of additional information that eliminated the reactivation of the outdated information or was it the nature of the additional information (i.e., sentences that were connected both to each other and to the original causal explanation, providing a rich, recursive, interconnect network of information)? There is precedent in the literature regarding the effects of the sheer amount of additional information. Specifically, Guéraud et al. (2005) added three sentences that simply extended and elaborated on a refutation. The three additional sentences were sufficient to eliminate the disruption in comprehension caused by the outdated information but they were not sufficient to eliminate its reactivation. In contrast, when in the present study three causal sentences were used (Experiments 3 and 4)—the same number of sentences used by Guéraud et al.—both disruption in comprehension and reactivation were eliminated. Thus, an examination of the pattern of results obtained by Guéraud et al. and the current Experiments 3 and 4 suggests that it was the nature of the additional information that was critical to eliminating the reactivation of the outdated information, not the sheer amount of information. Experiments 6 and 7 were designed to directly test this hypothesis.

Experiment 6

Experiment 6 was designed to examine and establish that both the three sentence causal-explanation condition and the three sentence qualified-elaboration condition (Guéraud et al., 2005) were sufficient to eliminate the disruption of outdated information in comprehension. The materials consisted of the same passages used

in Experiment 3 with one modification: An additional qualified-elaboration condition adapted from Guéraud et al. was included (e.g., “Recently Mary had stopped worrying about eating nutritious foods and began to eat more meat and fast food. In fact, she ate at McDonald’s at least three times a week. This was Mary’s favorite restaurant because it had fantastic junk food, and she loved the hamburgers”).

If both the three sentence causal-explanation condition and the three sentence qualified-elaboration condition are sufficient to eliminate the disruption of outdated information in comprehension, then reading times on the target sentence following either the qualified-elaboration or the causal-elaboration conditions should not differ, and both of these conditions should not differ from the consistent-elaboration condition. Furthermore, reading times in these three conditions should all be faster than reading times in the inconsistent-elaboration condition.

Method

Participants. Participants were 40 University of New Hampshire undergraduates who received partial course credit for their participation in the experiment.

Materials. The materials consisted of 16 of the 18 passages used in Experiments 3 and 4 with one modification: An additional qualified-elaboration condition adapted from Guéraud et al. (2005) was added. The qualified-elaboration condition consisted of the inconsistent condition followed by three sentences that outdated the inconsistent characteristic by stating that the inconsistent characteristic was no longer true; it did not contain any causal explanation. The qualified elaboration ranged between 42 and 48 words with a mean length of 44.39 words. As noted earlier, the three sentence causal elaboration ranged between 35 and 49 words with a mean length of 44.33 words. Four material sets were constructed. Each set contained four passages in each of the four experimental conditions: consistent elaboration, inconsistent elaboration, causal explanation, and qualified elaboration. Across the four sets, each experimental passage occurred once in each of the four conditions.

Procedure. The procedure was identical to that used in Experiments 1 and 3.

Results and Discussion

The mean reading times of the first and second critical sentences are presented in Table 5. Separate analyses of variance were conducted on the first and second target sentences. Reading times for the first critical sentence revealed a main effect of elaboration condition, $F_1(3, 108) = 9.83$, $MSE = 85,030$; $F_2(3, 36) = 6.57$, $MSE = 39,474$. Planned comparisons confirmed that the critical sentence was read more slowly when it followed the inconsistent elaboration than when it followed either the consistent elaboration, $F_1(1, 36) = 23.56$, $MSE = 161,687$; $F_2(1, 12) = 15.58$, $MSE = 69,321$; the three sentence causal-explanation elaboration, $F_1(1, 36) = 23.90$, $MSE = 137,443$; $F_2(1, 12) = 9.75$, $MSE = 70,577$; or the qualified elaboration, $F_1(1, 36) = 12.54$, $MSE = 225,530$; $F_2(1, 12) = 15.71$, $MSE = 77,540$. The small difference in reading times for the first critical sentence in the consistent-elaboration condition, the three sentence causal-explanation condition, and the qualified-elaboration condition was not reliable ($ps > .56$).

Reading times on the second critical sentence also showed a main effect of elaboration condition but only when tested based on

Table 5
Mean Reading Times (in Milliseconds) for Target Sentences as a Function of Elaboration Condition in Experiment 6

Target sentence	Elaboration condition			
	Consistent	Inconsistent	Qualified	Causal explanation
First target sentence	1,851 (505)	2,159 (595)	1,893 (558)	1,873 (517)
Second target sentence	1,881 (467)	2,032 (531)	1,966 (566)	2,078 (651)

Note. Standard deviations are included in parentheses.

participant variability, $F_1(3, 108) = 2.87, MSE = 101,963; F_2(3, 36) = 2.55, p = .07$. Although the pattern of reading times for the second critical sentence was the same as for the first critical sentence, planned comparisons revealed only one difference: Reading times were longer in the inconsistent-elaboration condition than in the consistent-elaboration condition; however, this difference was reliable only when tested against participant variability, $F_1(1, 36) = 5.12, MSE = 177,755; F_2(1, 12) = 3.97, MSE = 153,789, p = .07$. No other differences approached significance ($ps > .11$).

The pattern of reading times confirmed that both the three sentence causal-explanation and the qualified-elaboration conditions were sufficient to eliminate the disruption in comprehension caused by the outdated information. However, the critical test is to determine whether the causal-explanation elaboration is more effective than the qualified elaboration at also eliminating the activation of the outdated information. Experiment 7 was designed to directly test this possibility.

Experiment 7

The materials consisted of the three sentence causal-explanation elaboration and qualified-elaboration passages used in Experiment 6. The same verification statements used in Experiments 2, 4, and 5 were presented either immediately after the background section or immediately after the first target sentence.

If the sheer amount of information is sufficient to eliminate the reactivation of the outdated information, then time to respond to the verification statement should not differ when presented either after the background section or after the target sentence, and this should be true for both the qualified-elaboration condition and the causal-elaboration condition. In contrast, if only the causal elaboration is effective at eliminating the reactivation of the outdated information, then a finding of no difference in verification times following the background sentence and the target sentence should occur only in the causal-elaboration condition. In the qualified-elaboration condition, response times following the target sentence should be faster following the target sentence than following the background section.

Method

Participants. Participants were 40 University of New Hampshire undergraduates who received partial course credit for their participation in the experiment.

Materials. The materials consisted of the 16 passages used in Experiment 5. Each passage appeared in either the qualified-

elaboration condition (Experiment 6) or the three sentence causal-explanation elaboration condition (Experiments 3, 4, and 5). The verification statements were the same as used in all prior experiments. The verification statements were presented either immediately after the background section or immediately after the first target sentence for both elaboration conditions. The same 16 filler passages used in Experiment 5 were also included to ensure that each participant responded to an equal number of “yes” and “no” verification statements. Four material sets were constructed. Each set contained four passages in each of the four experimental conditions and 16 filler passages. Across the four sets, each experimental passage occurred once in each of the four conditions.

Procedure. The procedure was identical to that used in Experiments 2, 4, and 5.

Results and Discussion

Mean verification times are presented in Table 6. Overall, verification times were faster in the qualified-elaboration condition than in the causal-explanation condition, $F_1(1, 36) = 3.94, MSE = 79,123; F_2(1, 12) = 6.90, MSE = 31,141$. Also, verification times were faster following the target sentence than following the background section, $F_1(1, 36) = 10.98, MSE = 73,130; F_2(1, 12) = 15.67, MSE = 29,445$; however, this was true only for verification times in the qualified-elaboration condition. This interaction was reliable when tested against participant variability and marginal when tested against item variability, $F_1(1, 36) = 8.01, MSE = 85,712; F_2(1, 12) = 3.37, MSE = 183,557, p = .09$.

Planned comparisons confirmed that in the causal-explanation elaboration condition there were no reliable differences in verification times when they were presented either after the background section or after the target sentence, $F_1(1, 36) = 0.021, MSE = 212,338; F_2(1, 12) = 0.04, MSE = 266,145$. In contrast, in the qualified-elaboration condition, verification times were faster

Table 6
Mean Verification Times (in Milliseconds) for Probe Statements as a Function of Probe Position in Experiment 7

Probe position	Elaboration condition	
	Qualified	Causal explanation
After background section	2,356 (584)	2,313 (632)
After target sentence	2,083 (441)	2,303 (631)

Note. Standard deviations are included in parentheses.

when they followed the target sentence than when they followed the background section, $F_1(1, 36) = 28.22$, $MSE = 105,346$; $F_2(1, 12) = 13.43$, $MSE = 159,859$.

Furthermore, verification times in the qualified-elaboration condition following the background section did not differ reliably from verification times in the causal-explanation elaboration condition following either the background section, $F_1(1, 36) = 0.40$, $MSE = 182,603$; $F_2(1, 12) = 0.32$, $MSE = 326,926$, or the target sentence, $F_1(1, 36) = 0.60$, $MSE = 189,734$; $F_2(1, 12) = 0.77$, $MSE = 60,130$. In contrast, verification times in the qualified-elaboration condition following the target sentence were reliably faster than verification times in the causal-explanation elaboration condition following either the background section, $F_1(1, 36) = 18.43$, $MSE = 114,773$; $F_2(1, 12) = 21.40$, $MSE = 61,043$, or the target sentence, $F_1(1, 36) = 13.08$, $MSE = 147,068$; $F_2(1, 12) = 15.24$, $MSE = 102,470$.

These verification times confirmed that the three sentence causal-explanation elaboration was sufficient to eliminate the reactivation of the outdated information but the qualified elaboration was not. Thus one critical factor in completely eliminating the impact of outdated information is the quality—as opposed to quantity—of the updating information.

General Discussion

Previous research has shown that outdated information can continue to be reactivated during reading and disrupt comprehension (e.g., Guéraud et al., 2005; Hakala & O'Brien, 1995; Johnson & Seifert, 1994, 1998, 1999; Kendeou & van den Broek, 2007; O'Brien et al., 1998, 2010; Rapp & Kendeou, 2007, 2009). However, the conditions under which this will occur must be limited; otherwise, readers would never be able to fully revise what they know without continual interference from earlier acquired, but incorrect or refuted, information. The goal of the present set of experiments was to systematically examine the effectiveness of adding causal explanations to simple refutations in reducing or eliminating the impact of outdated information on subsequent comprehension. In Experiments 1 and 2, a single sentence that included a refutation with a causal explanation was sufficient to eliminate any measurable disruption in comprehension caused by the outdated information but was not sufficient to eliminate its reactivation. In Experiments 3 and 4, strengthening the causal explanation by adding two additional sentences eliminated both the disruption in comprehension and the reactivation of the outdated information. In Experiment 5, a direct comparison of Experiments 2 and 4 in a single study provided converging evidence for the power of the three sentence causal explanation in eliminating the reactivation of the outdated information. In Experiments 6 and 7, the three sentence causal-explanation condition was compared to the three sentence qualified-elaboration condition of Guéraud et al. (2005). Even though both conditions were sufficient to eliminate any measurable disruption in comprehension, only the three sentence causal-explanation condition was sufficient to eliminate the reactivation of the outdated information.

That the systematic addition of causal information leads to a systematic reduction in the impact of outdated information makes good sense. As noted earlier, there is considerable evi-

dence that when targeted information has been outdated with a simple refutation, subsequent references in the text to that outdated information lead to its reactivation. Once the information is reactivated, the reader must “recompute” that the outdated information is no longer relevant, and this causes a disruption in comprehension (e.g., Johnson & Seifert, 1994, 1998, 1999; Kendeou & van den Broek, 2007; O'Brien et al., 1998, 2010; Rapp & Kendeou, 2007, 2009). However, consider what happens when a causal explanation is added to the refutation that explains why the outdated information is no longer relevant. When subsequent text makes reference to the outdated information, the outdated information continues to be reactivated; but along with the outdated information, the refutation information as well as the causal explanation for why the outdated information was no longer relevant will also be reactivated. The refutation in combination with the causal explanation draws sufficient activation so that the outdated information reaches insufficient activation to cause a disruption in comprehension. Indeed, the results of the first two experiments taken together confirm that the outdated information continued to be reactivated, but any impact on comprehension was eliminated (see Cook et al., 1998; Long & Chong, 2001, for similar findings regarding activation without impact on comprehension).

When the causal explanation was strengthened by adding three causal sentences to the refutation, not only was the disruption in comprehension caused by the outdated information eliminated (Experiment 3), but the reactivation of the outdated information was also eliminated (Experiment 4). It is important to note that is not merely the sheer amount of additional information that eliminated the reactivation of the outdated information. In Experiment 7 where we included the qualification-elaboration condition of Guéraud et al. (2005), the outdated information continued to be reactivated. The qualification-elaboration condition consisted of three sentences that elaborated on a refutation. Even though the three qualification sentences were sufficient to eliminate the disruption in comprehension caused by the outdated information, they were not sufficient to eliminate its reactivation. However, three causal sentences—the same number of sentences used by Guéraud et al.—were sufficient to eliminate both disruption in comprehension and reactivation. Thus, the current set of findings extends the growing body of literature on updating by highlighting that both the quality and the quantity of the updating information can influence the degree to which outdated information will interfere with comprehension.

The measure used to assess the reactivation of outdated information was probe verification—the time to verify a statement that captured the information presented in the elaboration region. There are potential issues that can arise when using this measure. Whenever a measure of (re)activation is used that requires a dichotomous response, there is the potential that a facilitation in response times is the result of either a backward integration process (ease with which the probe integrates with the immediately preceding text) or semantic overlap between the probe and the immediately preceding text. However, in each of the experiments in which probe verification times were measured, the background region, the target sentence, and the verification statements were always identical. Any facilitation in verification times due to backward integration or semantic overlap should have occurred equally

across all conditions in all experiments. That facilitation in verification times was observed in some conditions (the one sentence causal-explanation condition and the qualified-elaboration condition) and not in other conditions (the three sentence causal-explanation condition) cannot be attributed to either backward integration or differences in semantic overlap. Also, because verification probes require an explicit decision that involves both the activating and assessing of targeted information, they are not a pure measure of activation. Nevertheless, because the verification probes were presented at two different points within each passage (i.e., following the background region and following the target sentence), any facilitation following the target sentence would have occurred because the target sentence activated the necessary information.

Perhaps the most interesting question is why the three causal-explanation sentences were sufficient to eliminate even the activation of the outdated information, whereas three qualified-elaboration sentences were not. Causal information inherently provides a rich elaborated network of information, as well as additional connections to readers' background knowledge (O'Brien & Myers, 1987; Trabasso & Suh, 1993; Trabasso & van den Broek, 1985). In the current study, the three causal sentences were purposefully written so that they were connected both to each other and to the original causal explanation. This highly interconnected network of information competed with the outdated information for reactivation when the reader encoded information related to the outdated information. The structural richness of the causal network (i.e., multiple connections, multiple retrieval routes) increased the amount of activation it drew, thereby ensuring that it was returned to active memory. Equally important, at the same time that it drew increased activation to itself, it also drew activation away from the outdated information, enough to eliminate any measurable activation.

In contrast, the three qualified sentences were written in a manner that served to strengthen the refutation by elaborating on the refutation in much more linear fashion (i.e., repeating and extending the information already contained in the refutation sentence). Thus, the three qualified sentences lacked the interconnectedness and recursiveness present in the three sentence causal explanation. The lack of interconnectedness reduced the amount of activation the qualified elaboration drew, allowing enough activation to reach the outdated information for that activation to be detected with a simple verification procedure.

However, it is important to note that the critical difference between the three causal sentences and the three qualified sentences was not causality per se. The critical difference was the richer, more interconnected, network of information provided by the three causal sentences relative to the network provided by the three qualified sentences. Presumably, it ought to be possible to create a set of qualified sentences that would provide a sufficiently rich network to successfully compete with the outdated information for activation. At the same time, a set of causal sentences that each provided an independent causal explanation would not provide a rich, interconnected network and would be less likely to eliminate activation of the outdated information. The advantage of causality is that, by definition, it requires the connection of one piece of information to another through a causal link, allowing for the easy, efficient, and effective development of integrated net-

works (O'Brien & Myers, 1987; Trabasso & Suh, 1993; Trabasso & van den Broek, 1985).

Consider how the present set of results fits within the passive memory activation process that is central to the memory-based processing view (e.g., Gerrig & McKoon, 1998; Gerrig & O'Brien, 2005; McKoon & Ratcliff, 1998; O'Brien & Myers, 1999; O'Brien et al., 1998, 2010). One test of this passive activation process has been the demonstration that information that is related, but no longer relevant, to the comprehension process (i.e., outdated information) can still be reactivated and disrupt comprehension (e.g., O'Brien et al., 1998, 2010; Rapp & Kendeou, 2007, 2009). However, consistent with more global models of memory on which the memory-based view has been developed (e.g., Gillund & Shiffrin, 1984; Hintzman, 1986; Ratcliff, 1978; Ratcliff & McKoon, 1988), not all related information is equal, and only a subset of related information will resonate sufficiently to return to active memory. Information that is more highly related or more richly interconnected will draw more activation. This, in turn, will reduce activation of other related information (i.e., interfere with the activation of other related information). In the present set of experiments, we have demonstrated just that: As the amount updating information was systematically increased by providing causal explanations that created rich, interconnected networks of competing information, the impact and activation of outdated information was systematically reduced.

In conclusion, the present set of results adds to a growing body of literature demonstrating the impact that outdated information can have on comprehension (e.g., Ecker, Lewandowsky, & Tang, 2010; Johnson & Seifert, 1994, 1998, 1999; O'Brien et al., 1998, 2010; Rapp & Kendeou, 2007, 2009). Although the current work was done in the context of reading narratives, the findings have broad implications for updating or knowledge revision in general. For example, in the context of reading science texts readers often have to deal with the activation of inaccurate prior knowledge, incorrect beliefs, or misconceptions that disrupt comprehension. Unless these incorrect beliefs are revised (i.e., updated) they can interfere with the acquisition of new knowledge (see the work by Kendeou and colleagues on the coactivation hypothesis in the context of refutation texts; Kendeou, Muis, & Fulton, 2011; Kendeou & van den Broek, 2005, 2007; van den Broek & Kendeou, 2008). The present set of results demonstrates that providing the reader/learner with causal explanations supporting the updating or knowledge-revision process can serve to eliminate the interference produced by the reactivation of previously acquired, but no longer correct, information.

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Appendix

Sample Passage for Experiments 1-7

Introduction (All Experiments)

Today, Mary was meeting a friend for lunch. She arrived early at the restaurant and decided to get a table. After she sat down, she started looking at the menu.

Consistent Elaboration (Experiments 1, 3, and 6)

This was Mary’s favorite restaurant because it had fantastic junk food. Mary enjoyed eating anything that was quick and easy to fix. In fact, she ate at McDonald’s at least three times a week. Mary never worried about her diet and saw no reason to eat nutritious foods.

Inconsistent Elaboration (Experiments 1, 3, and 6)

This was Mary’s favorite restaurant because it had fantastic health food. Mary, a health nut, has been a strict vegetarian for ten years. Her favorite food was cauliflower. Mary was so serious about her diet that she refused to eat anything which was fried or cooked in grease.

One Sentence Causal Explanation (Experiments 1, 2, and 5)

This was Mary’s favorite restaurant because it had fantastic health food. Mary, a health nut, has been a strict vegetarian for ten years. Her favorite food was cauliflower. Mary was so serious about her diet that she refused to eat anything which was fried or cooked in grease. *She wasn’t getting enough vitamins because of her diet so her doctor said she had to start eating meat.*

Three Sentence Causal Explanation (Experiments 3, 4, 5, 6, and 7)

This was Mary’s favorite restaurant because it had fantastic health food. Mary, a health nut, has been a strict vegetarian for ten years. Her favorite food was cauliflower. Mary was so serious about her diet that she refused to eat anything which was fried or cooked in grease. *She wasn’t getting enough vitamins because of her diet so her doctor said she had to start eating meat. Mary recently had blood work done. Her lack of iron was causing her to become anemic.*

Three Sentence Qualified Elaboration (Experiments 6 and 7)

This was Mary’s favorite restaurant because it had fantastic health food. Mary, a health nut, has been a strict vegetarian for ten years. Her favorite food was cauliflower. Mary was so serious about her diet that she refused to eat anything which was fried or cooked in grease. *Recently Mary had stopped worrying about eating nutritious foods and began to eat more meat and fast food. In fact, she ate at McDonald’s at least three times a week. This was Mary’s favorite restaurant because it had fantastic junk food, and she loved the hamburgers.*

Filler (All Experiments)

After about ten minutes, Mary’s friend arrived. It had been a few months since they had seen each other. Because of this they had a lot to talk about and chatted for over a half hour. Finally, Mary signaled the waiter to come take their orders. Mary checked the menu one more time. She had a hard time deciding what to have for lunch.

Target Sentences (All Experiments)

Mary ordered a cheeseburger and fries.
She handed the menu back to the waiter.

Closing (All Experiments)

Her friend didn’t have as much trouble deciding what she wanted. She ordered and they began to chat again. They didn’t realize there was so much for them to catch up on.

Comprehension Question (All Experiments)

Was Mary meeting her husband for lunch?

Probe Verification (Experiments 2, 4, 5, and 7)

Mary used to not eat meat at all.

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