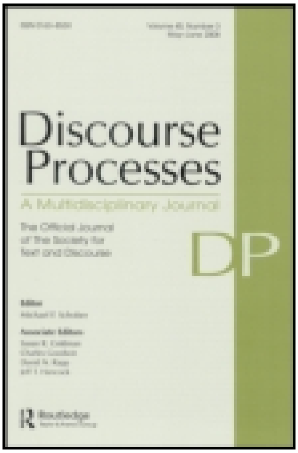


Discourse Processes
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/hdsp20

# Processing Causality in Narrative Events: Temporal Order Matters

Stephen W. Briner [a] , Sandra Virtue [b] & Christopher A. Kurby [c]
[a] Department of Psychology, University of Illinois at Chicago
[b] Department of Psychology, DePaul University
[c] Department of Psychology, Grand Valley State University

Available online: 20 Oct 2011

To cite this article: Stephen W. Briner, Sandra Virtue & Christopher A. Kurby (2011): Processing Causality in Narrative Events: Temporal Order Matters, Discourse Processes, 49:1, 61-77

To link to this article: http://dx.doi.org/10.1080/0163853X.2011.607952

*Discourse Processes*, 49:61–77, 2012

ISSN: 0163-853X print/1532-6950 online
DOI: 10.1080/0163853X.2011.607952





# Processing Causality in Narrative Events: Temporal Order Matters

Stephen W. Briner
*Department of Psychology, University of Illinois at Chicago*

Sandra Virtue
*Department of Psychology, DePaul University*

Christopher A. Kurby
*Department of Psychology, Grand Valley State University*

To successfully comprehend narrative text, readers often make inferences about different causes and effects that occur in a text. In this study, participants read texts in which events related to a cause were presented before an effect (i.e., the forward causal condition), texts in which an effect was presented before the events related to a cause (i.e., the backward causal condition), or control (i.e., the non-causal) texts. Lexical decision response times to cause-relevant words were faster in the forward causal condition than in the control condition and were faster in the backward causal condition than in the control condition. Importantly, response times were faster in the forward causal condition than in the backward causal condition. These effects were unrelated to individual differences in reading ability. These results suggest that readers process causal relations regardless of temporal order but that causal events presented in backward temporal order may be processed more slowly compared to causal events presented in forward temporal order.

When individuals read a narrative text, they often make connections between different events in a story. To make these connections, readers often need to

Correspondence concerning this article should be addressed to Stephen W. Briner, Department of Psychology, University of Illinois at Chicago, 1007 West Harrison Street, Chicago, IL 60607, USA. E-mail: sbriner@uic.edu

understand how specific events in a text cause other events in a text (i.e., they identify the text's *causal relations*). Evidence suggests that readers are able to detect and process causal relations when reading narrative text (Myers, 1990; Trabasso & van den Broek, 1985; Trabasso & Wiley, 2005; Zwaan, Langston, & Graesser, 1995). For example, when events in a text have more causal relations, readers rate those events as more important than events with fewer causal relations (Trabasso & Sperry, 1985). In addition, texts with more causal relations are read more quickly and recalled more accurately than texts with fewer causal relations (Myers, Shinjo, & Duffy, 1987; van den Broek, Lorch, & Thurlow, 1996; Wolfe, Magliano, & Larsen, 2005; Zwaan, Magliano, & Graesser, 1995). Although evidence suggests that readers can monitor the causes and effects during narrative text comprehension, it is possible that readers process causal relations differently depending on whether an event's cause is presented before or after its effect. In narrative text, information related to a text's cause (i.e., the *antecedent*) is typically presented before information related to the effect (i.e., the *consequence*; Ohtsuka & Brewer, 1992). For example, "The coach instructed the karate expert to hit the brick. The brick broke in two," contains a forward causal relation because information related to the cause is presented before information related to the effect (Singer, Halldorson, Lear, & Andrusiak, 1992). In other narrative texts, causal information is presented out of chronological order. For example, "The brick broke in two. The coach instructed the karate expert to hit the brick," contains a backward causal relation because information related to the effect is presented before information related to the cause (Singer, Halldorson, et al., 1992). Although both forward and backward causal inferences can be expressed as bridging inferences, they represent different types of causal bridges. Forward causal relations require the reader to make an inference from cause to effect (i.e., a *forward causal connection*), whereas backward causal relations requires the reader to make an inference from effect to cause (i.e., a *backward causal connection*). It is currently unclear whether more processing time is required when readers comprehend backward causal relations compared to forward causal relations during reading.

Although several theoretical frameworks account for how readers process causal information during text comprehension, those frameworks do not explicitly distinguish forward from backward causal relation processing. For example, the causal network theory predicts that readers routinely track causal relations in a text (Trabasso & Sperry, 1985); however, this theory does not specifically account for the temporal direction of causality. Similarly, the event-indexing model (Zwaan, Langston, & Graesser, 1995) predicts that readers monitor both causal and temporal information (among other types of situational information) when reading narrative text to form relations between story events, but does not make distinctions about the directionality of such relations during reading. Therefore, a more thorough understanding of the time it takes to process forward and backward causal relations would deepen our understanding of how readers construct mental representations (i.e., *situation models*) during text comprehension.

It is possible that backward causal relations are processed more slowly than forward causal relations because readers often assume that events in a text will be presented in chronological order. This tendency to expect events in narrative text to be depicted chronologically is known as the *iconicity assumption* (Fleischman, 1990; Hopper, 1979; Zwaan & Radvansky, 1998). When the iconicity assumption is supported (i.e., when events are depicted in chronological order), readers are more accurate at answering comprehension questions and process text more quickly than when events are described out of chronological order (Mandler, 1986; Ohtsuka & Brewer, 1992; Rinck & Weber, 2003). Although research shows that readers have difficulty comprehending events in a text that violate the iconicity assumption (Zwaan & Radvansky, 1998), it is currently unclear how readers process text when a sentence contains both a violation of temporal order and a backward causal relation. For example, "The cup lay in pieces. I dropped it," contains a violation of the iconicity assumption and a backward causal relation (i.e., the second sentence helps explain why the events in the first sentence occur). In contrast, "I dropped the cup. It lay in pieces," does not violate the iconicity assumption, and contains a forward causal relation (i.e., the first sentence helps explain why the events in the second occur). Thus, backward causal relations may be processed differently from forward causal relations because backward causal relations violate readers' expectations of temporality. Readers' expectations for how events in text will be presented often follow from their knowledge of how events occur in real life. For example, many readers possess the knowledge that events in the past occur before events in the future in narrative text (Graesser, Millis, & Zwaan, 1997). Readers likely expect causes to precede their effects in text partly because in real life, causes precede effects chronologically (van den Broek, 1990). Thus, backward causal relations violate readers' expected order for how narrative events are presented, and may require more time to process than forward causal relations.

Although some evidence suggests that backward causal relations should require additional processing time compared to forward causal relations, other evidence suggests that backward and forward causal relations are processed similarly. In a previous study, participants read texts with either a forward cause (e.g., "The hunter shot the deer. The deer died") or a backward cause (e.g., "The deer died. The hunter shot it."), and answered yes/no questions that focused on the background knowledge needed to understand the causal relation (e.g., "Do bullets kill animals?"; Singer, Halldorson, et al., 1992). Response times to these questions were faster when participants read the causal texts than when participants read a text with no causal relation (e.g., "The hiker examined the deer. The deer died."). Interestingly, the type of relation (i.e., the backward or forward relation) did not influence these response times. There are several possible reasons for why researchers did not find response time differences between forward and backward causal relations. First, it is possible that the sentence pairs that convey forward and backward causal relations are processed similarly if no intervening events occur between the sentence pair. For instance, the causal events examined in the previous study occurred very close in temporal order, with the information related to the cause–effect relation explicitly stated in the text. Thus, participants may not have needed to make an inference about how the two events are causally related. However, in cases in which the cause of an event is not explicitly stated, readers likely need to identify the cause of the event (i.e., readers must make a causal bridging inference; Beeman, Bowden, & Gernsbacher, 2000; Myers et al., 1987; Schmalhofer, McDaniel, & Keefe, 2002). For example, the text, "Adam had bought all the fireworks he could afford. That evening, he was rubbing ointment onto his hand," requires an inference about an event that occurred between the antecedent and the consequence. Specifically, the intervening event (e.g., Adam burning his hand with the fireworks) is enabled by the first sentence in this example. This event is also the cause of the second sentence. Second, it is possible that the response times observed by Singer, Halldorson, et al. (1992) were influenced by the type of question used to measure comprehension. For example, they tested the response times for questions related to a reader's background knowledge, but not to the specific inference in the text. As such, it is difficult to know whether readers made the causal inference or activated knowledge related to the intervening event. Therefore, in this study, we examine texts in which there is an intervening event (i.e., an event takes place between the enabling sentence and the effect) that is unstated in the text. Further, in this study, we measure response times to cause-related words to assess whether readers activate causal inferences when reading forward and backward causal relations in narrative texts.

In addition, it is possible that individual differences influence how quickly readers process forward and backward causal relations in a narrative text. Specifically, readers who have different levels of background knowledge or individuals who vary with regard to reading skill may process causal relations differently. For example, older children rate sentences with more causal connections as more important to a story than do younger children (van den Broek, 1988). Additionally, skilled and less skilled readers show similar levels of recall when a text's causal structure has been temporally aligned; however, when a text has not been temporally aligned (i.e., when it contains many backward causes), skilled readers recall more of the text than less skilled readers (Linderholm, Everson, van den Broek, Mischinski, & Samuels, 2001). Thus, skilled and less skilled readers may process forward causal relations similarly, but skilled readers may be able to process backward causal relations more easily than less skilled readers.

In this study, we investigated the speed with which readers process forward and backward causal relations, as measured by response times to cause-related target words and sentence reading times. Specifically, participants read texts that contained either a forward causal relation, a backward causal relation, or a control (i.e., a non-causal) text, and made lexical decisions to cause-related target words presented after each text. Several hypotheses were examined in this study. First, based on theories of causal processing in narrative comprehension (Langston & Trabasso, 1999; Trabasso & Sperry, 1985), we predict that participants will respond more quickly to cause-related target words for texts containing causal relations (i.e., the forward and backward relation texts) than for texts not containing causal relations (i.e., the control texts). Second, if processing forward causal relations is easier than processing backward causal relations, then participants will respond to cause-related target words more quickly and accurately after reading a text with forward causal relations than after reading a text with backward causal relations. In addition, reading times should be faster for texts that contain causal information than for texts that do not contain causal information. We also examine a prediction based on the iconicity assumption. Specifically, if violations of the iconicity assumption lead to longer processing of causal relations (Fleischman, 1990), then reading times will be faster for texts when the events are presented in a forward causal order than when the events are presented in a backward causal order. Finally, if skilled and less skilled readers process forward and backward causal relations differently during text comprehension (e.g., Linderholm et al., 2001), then skilled readers will likely show stronger evidence of processing backward causal relations than less skilled readers.

## EXPERIMENT 1

The purpose of Experiment 1 was to measure response times to cause-related target words presented after participants read texts containing forward causal relations, backward causal relations, or neutral (i.e., non-causal) texts. If response times to target words are faster when the target words are paired with forward causal texts than backward causal texts, then this finding would suggest that backward causal relations require more time to process than forward causal relations.

### Method

*Participants.* Fifty-four undergraduate students from a Midwestern university participated in this study in exchange for course credit in an introductory psychology course. Of the 54 participants, 8 were men and 46 were women. All participants were native English speakers and had normal or corrected-to-normal vision. This study was conducted in accordance with the ethical guidelines of the university's institutional review board, and all participants gave informed consent prior to their inclusion in this study.

### *Materials.*

*Experimental texts.* Sixty-four sets of two-sentence texts were created for this experiment. Each set contained four conditions: *forward causal, forward control, backward causal*, and *backward control.* For both causal and control items, the pairs of sentences were temporally related. However, the sentence pairs in the causal conditions were causally linked, whereas the sentence pairs in the control condition were not casually linked. In the forward causal and forward control conditions, the events in the first sentence occurred *before* the events described in the second sentence. In the forward causal condition, the events in first sentence *enabled* the events described in the second sentence. In forward control condition, however, there was no causal relation between the events described in the two sentences. In the backward causal and backward control conditions, the events in the first sentence occurred *after* the events described in the second sentence. In the backward causal condition, the events in the second sentence *enabled* the events described in the first sentence. However, in the backward control condition, there was no causal relation between the events described in the two sentences. Please see Table 1 for an example text in each condition. Additionally, 64 filler texts were created for the experiment.

TABLE 1
Examples of Forward Causal, Forward Control, Backward Causal, and Backward Control Texts, Filler Texts, and Targets for Experiment 1

| |
|---|
| Example 1 (target: sunburn) |
| Forward causal: John had been outside all day. Later, his skin was red and peeling. |
| Forward control: John had been outside all day. Later, he went to see his uncle. |
| Backward causal: John's skin was red and peeling. Earlier, he'd been outside all day. |
| Backward control: John went to see his uncle. Earlier, he'd been outside all day. |
| Example 2 (target: bake) |
| Forward causal: Saul placed the roast in the oven. Two hours later, his kitchen smelled good. |
| Forward control: Saul placed the roast in the oven. Two hours later, he washed his clothes. |
| Backward causal: Saul's kitchen smelled good. Two hours earlier, he'd placed a roast in the oven. |
| Backward control: Saul washed his clothes. Two hours before, he'd placed a roast in the oven. |
| Filler Example 1 (target nonword: chus) |
| Filler: Tom put out a fire in his kitchen. After that, he watched his favorite movie. |
| Filler Example 2 (target nonword: sened) |
| Filler: Matt went to the supermarket for some snacks. The next evening, he washed his clothes. |

These filler texts were constructed similarly to the experimental items such that they were temporally related, but these filler texts were paired with nonword targets.

*Targets.* Each experimental text was followed by a corresponding target word, resulting in 64 experimental targets. The target word was the same for each set of text in each experimental condition (e.g., forward causal, forward control, backward causal, and backward control). In the forward causal and backward causal conditions, the target word was related to the event that causally linked the first and second sentences. This target word was unrelated to the events in the forward control and backward control conditions. The forward and backward control conditions were used to obtain a baseline measurement of how quickly participants responded to the same target word in each causal condition. The target words were matched for average word frequency in each condition ($M = 47.45$, $SE = 8.42$; based on Francis & Kucera, 1982).

Additionally, 64 nonword targets were created for each of the corresponding 64 filler texts. Nonword targets were created by finding words with similar frequencies to the target words and then rearranging the letters to create pronounceable nonwords (e.g., "nagirab"; Francis & Kucera, 1982). When nonword targets were presented, participants needed to make a "no" response during the lexical decision task.

*Pilot study.* A pilot study was conducted to ensure that the experimental target words closely matched the intended meaning of the casual relation in each text. In the pilot study, 30 participants read 64 texts. One-half of the texts contained a sentence pair that was intended to convey a forward causal relation, and the other half of the texts contained a sentence pair that was intended to convey a backward causal relation. The texts were counterbalanced such that each participant saw only one version of each text. After reading each text, participants wrote down the main idea of the text. Each participant's response was assigned a value ranging from 0 to 3 according to how well the response matched the meaning of the intended causal relation. For example, responses (e.g., "Jon got a sunburn") that matched the target word (e.g., "sunburn") were assigned a 3, responses that included a synonym of the target word (e.g., "John was scorched") were assigned a 2, and responses that were related to the target word (e.g., "John had been out in the heat") were assigned a 1. Incorrect or irrelevant responses were assigned a 0. All of the target words used in this experiment achieved a rating of at least 1.75. Ratings for targets selected for the main experiment did not significantly differ between the forward and backward cause conditions—$t(63) = 0.94$, $p = .35$ ($d = .11$)—ensuring that the causal relation was conveyed equally well by the forward and backward causal versions of each text.

*Semantic relatedness.* To ensure that the texts in the forward causal, backward causal, and control versions of each text had similar levels of semantic relatedness to the target word, the final sentence of the causal and control versions of each text was compared to the target word using latent semantic analysis (LSA; Landauer, Foltz, & Laham, 1998). This comparison produces a cosine between the target word and the final sentences of the text versions, which provides a metric of semantic relatedness between the two. Because the content of final sentences in the backward causal condition was identical to the content of the final sentences in the backward control condition, we collapsed across these two conditions in this analysis. There were no significant differences in LSA cosines between the different versions of each text, $F(2, 89) = 2.50$, $p > .09$. Because no LSA cosine differences were observed between any of the versions of each text, this finding ensures that any differences between the conditions are not due to the semantic relatedness between the texts in each condition and the target word.

*Reading comprehension measure.* The Gates–MacGinitie Reading Test (Form S) was used to measure reading ability (Gates–MacGinitie Reading Tests, 1989; MacGinitie & MacGinitie, 1989). This test consists of 11 short passages, containing four narrative texts and seven expository texts. This test consists of 48 multiple-choice comprehension questions with four to sex questions per text, all administered on paper. The version of the test used in this study was designed for Grades 10 through 12, as this is the most difficult version of the Gates–MacGinitie test. The Gates–MacGinitie test has an internal reliability of .93 and a test–retest reliability of .88 (MacGinitie, MacGinitie, Maria, & Dreyer, 2002). It should be noted, however, that these reliability scores were derived from secondary school populations and not from college students. The texts featured in the Gates–MacGinitie test represent a typical range of texts that students likely encounter. Because the texts represent a typical range of texts, it is unlikely that participants would be influenced by the structure of the Gates–MacGinitie texts to expect a greater than usual number of backward causal relations during the experimental task.

*Procedure.* All participants first completed the Gates–MacGinitie test. As commonly administered, participants were allowed to look back at a text when answering questions pertaining to that passage. Participants had 15 min to complete this portion of the experiment.

After completing the Gates–MacGinitie test, participants then completed the experimental task. The experiment was run on a personal computer using E-Prime software (Schneider, Eschman, & Zuccolotto, 2002). Four counterbalanced lists were created so that the order in which the texts were read and the condition in which the targets appeared was represented an equal number of times across participants. Each text was presented one sentence at a time in the center of the computer screen. When participants finished reading the first sentence, they pressed a button on a response box to continue to the second sentence. After reading the second sentence, a central fixation point appeared for 750 ms. After the fixation point disappeared, a target word or nonword was presented in the center of the screen for 176 ms. Participants were instructed to decide as quickly and as accurately as possible if the target was an English word or nonword (i.e., perform a lexical decision task). One-half of the sentences presented in the study (i.e., the experimental texts) were paired with real-word targets, and one-half of the texts presented (i.e., the filler texts) were paired with pronounceable nonword targets. Both causal relatedness and temporal direction were manipulated within-subjects. Participants made their responses by pressing one of two buttons on a serial response box. To ensure that participants adequately comprehended the texts, comprehension questions were presented after a subset of texts throughout the experiment. These questions were presented in true/false format (e.g., "Had John been indoors all day?").

## Results

Response times and accuracy for the lexical decisions were analyzed. Only correct responses were included in the response time analyses. Two participants were removed from the data analyses for having <70% correct in the lexical decision task. Therefore, 52 participants (8 men and 44 women) were included in the final analyses. The top and bottom 1% of the response times for each condition were removed prior to the analyses to minimize the influence of outliers (for a description of this procedure, see Ratcliff, 1993). For all analyses, an alpha level of .05 was used to determine significance. All analyses included the between participant variables of gender and counterbalance list. Because there were no effects of gender or counterbalance list, these analyses were collapsed across these variables. All analyses were conducted for both participants ($F_1$) and items ($F_2$). Please see Table 2 for mean response times and proportion correct for the responses in the lexical decision task.

*Response Time Effects.* Lexical decision response times were analyzed in a two-way repeated-measures analysis of variance (ANOVA). The independent variables were causal relation (causal and control) and temporal direction (forward and backward). A main effect for causal relation was found: $F_1(1, 51) = 30.08$, $p = .02$ ($MSE = 1{,}951.52$; $\eta_p^2 = .37$); $F_2(1, 63) = 15.61$, $p < .01$ ($MSE = 3{,}969.84$; $\eta_p^2 = .20$). As predicted, response times were faster for target words in the causal relation condition ($M = 349$, $SE = 14$) than for target words in the control condition ($M = 383$, $SE = 17$). There was no main effect

TABLE 2
Mean Response Time (in Milliseconds), Accuracy (in Proportion Correct), and Reading Time (Milliseconds Per Syllable) for Targets in the Forward Causal, Forward Control, Backward Causal, and Backward Control Conditions

| | *Forward* | | *Backward* | |
|---|---|---|---|---|
| *Dependent Variable* | *Causal* | *Control* | *Causal* | *Control* |
| Response time | 340 (14) | 386 (17) | 358 (15) | 380 (17) |
| Accuracy | 0.94 (0.01) | 0.94 (0.01) | 0.96 (0.01) | 0.94 (0.01) |
| Reading time | 179 (7) | 175 (6) | 171 (6) | 175 (7) |

*Notes.* Reading times (per syllable) are for the final sentences of each type of sentence pair. Values in parentheses represent standard errors.

for temporal direction: $F_1(1, 51) = 1.20$, $p = .28$ ($MSE = 1{,}379.69$; $\eta_p^2 = .02$; $F_2(1, 63) = 0.11$, $p = .74$ ($MSE = 4{,}546.08$; $\eta_p^2 = .00$). Importantly, there was a significant interaction between causal relation and temporal direction: $F_1(1, 51) = 4.54$, $p = .04$ ($MSE = 1{,}601.71$; $\eta_p^2 = .08$); $F_2(1, 63) = 5.18$, $p = .03$ ($MSE = 3{,}717.25$; $\eta_p^2 = .08$). Follow-up paired-samples $t$ tests revealed that response times were faster in the forward causal condition than in the forward control condition: $t_1(51) = 5.23$, $p < .01$ ($d = .40$); $t_2(63) = 4.19$, $p < .01$ ($d = .33$). Response times in the backward causal condition were faster than response times in the backward control condition by participants: $t_1(51) = 2.78$, $p = .01$ ($d = .19$); $t_2(63) = 1.34$, $p = .19$ ($d = .21$). However, response times were faster in the forward causal condition than in the backward causal condition: $t_1(51) = 2.60$, $p = .01$ ($d = .17$); $t_2$ $(63) = 2.70$, $p = .01$ ($d = .33$). There was no significant difference in response times between the forward control and backward control conditions: $t_1(51) = 0.74$, $p = .46$ ($d = .05$); $t_2(63) = 1.09$, $p = .29$ ($d = .19$).

*Accuracy Effects.* The proportion of correct responses in the lexical decision task was collected and analyzed in a two-way repeated-measures ANOVA. The independent variables were causal relation (causal and control) and temporal direction (forward and backward). There was no significant main effect of causal relation, $F_1(1, 51) = 1.79$, $p = .19$ ($MSE = 0.00$; $\eta_p^2 = .03$) and $F_2(1, 63) = 0.36$, $p = 51$ ($MSE = 0.03$; $\eta_p^2 = .01$); or temporal direction, $F_1(1, 51) = 3.38$, $p = .07$ ($MSE = 0.00$; $\eta_p^2 = .06$) and $F_2(1, 63) = 0.53$, $p = .30$ ($MSE = 0.02$; $\eta_p^2 = .02$). The interaction between causal relation and temporal direction was marginally significant by participants and not significant by items: $F_1(1, 51) = 3.99$, $p = .05$ ($MSE = 0.03$; $\eta_p^2 = .07$); $F_2(1, 63) = 0.41$, $p = .47$ ($MSE = 0.03$; $\eta_p^2 = .01$).

*Reading Time Effects.* The participants' reading times were analyzed by dividing the reading time in the final sentence in each condition by the number of syllables in each sentence to derive a reading time proportion (i.e., reading time per syllable). These reading times were analyzed using a two-way repeated-measures ANOVA. The independent variables were causal relation (causal and control) and temporal direction (forward and backward). No significant effects were found for causal relation, temporal direction, or the interaction between causal relation and temporal direction: largest $F(1, 51) = 2.79$, $p = .10$.

*Individual Differences.* To investigate the relation between reading skill and causal relation processing in the lexical decision response times, the Gates–MacGinite reading scores were correlated with the difference scores in response time between the forward causal and forward control conditions (i.e., the *forward causal effect*), and were correlated with the difference scores in response time between the backward causal and backward control conditions (i.e., the *backward causal effect*). For both of these difference scores, larger scores indicate faster processing relative to the control condition. However, the Gates–MacGinitie scores were not significantly correlated with the forward reading effect ($r = .07$, $p = .80$) or the backward reading effect ($r = -.24$, $p = .09$).

No individual differences analyses are reported for the lexical decision accuracy or reading time data because there were no significant effects on accuracy and reading time in the main ANOVAs.

## Discussion

The results of this study suggest that readers activate causal inferences for both forward and backward causal relations when comprehending narrative texts. Specifically, response times to cause-related target words were faster for both types of causal conditions (forward and backward) than their corresponding control conditions. These findings are consistent with previous work suggesting that readers activate causal inferences during narrative comprehension (e.g., Trabasso & Sperry, 1985; Zwaan, Langston, & Graesser, 1995). Additionally, response times to target words were significantly faster in the forward causal condition than in the backward causal condition. This finding is consistent with the iconicity assumption that narrative text is more difficult for readers to process when information is presented out of chronological order (e.g., Fleischman, 1990).

Although the results of Experiment 1 suggest that forward causal relations are processed more quickly than backward causal relations, it is possible that the response time differences observed in Experiment 1 were driven by factors other than causal relation processing. Specifically, it is possible that the target words (e.g., "sunburn") may have been more semantically related to the final sentences in the forward causal condition (e.g., "Later, his skin was red and peeling") than the final sentences in the backward causal condition (e.g., "Earlier, he'd been outside all day"). The LSAs described in Experiment 1 suggest this is likely not a strong possibility because the last sentences in the forward and backward causal conditions are equally related to their target words. Another possibility is that the faster response times occurred because of backward integration processes that were facilitated by semantic similarity. To experimentally test the possibility that our results were driven by factors other than processing causal relations, we designed a follow-up study (Experiment 2) to explore the relation between the causal texts' final sentences and the related target words.

## EXPERIMENT 2

The purpose of Experiment 2 was to investigate whether the response time differences observed in Experiment 1 truly reflected participants' causal processing of the texts. In Experiment 2, participants read the final sentence from the texts used in Experiment 1's forward and backward causal conditions, and made lexical decisions to cause-related target words presented after the texts. If response times are faster in the forward condition than in the backward condition, then this result would suggest that semantic relatedness may have played a more important role than causal relation processing in Experiment 1.

### Method

*Participants.* Forty-three undergraduate students from a Midwestern university participated in this study in exchange for course credit in an introductory psychology course. Of the 43 participants, 11 were men and 32 were women. All participants were native English speakers and had normal or corrected-to-normal vision. This study was conducted in accordance with the ethical guidelines of the university's institutional review board, and all participants gave informed consent prior to their inclusion in this study.

*Materials.*

*Experimental texts.* The 64 texts used in Experiment 1 were modified for use in Experiment 2 such that only the final sentences from the forward causal and backward causal versions of each text were presented to participants in this experiment. These final sentences were edited so that participants could easily understand the sentence even without the context of the first sentence (e.g., "Later, his skin was red and peeling" was rewritten as "John's skin was red and peeling"). In addition, 64 filler texts were used for this experiment. Filler texts consisted of the first sentence of the filler texts from Experiment 1, and were

TABLE 3
Examples of Texts and Targets for Experiment 2

| | |
|---|---|
| Example 1 (target: sunburn) | |
| | Forward: John's skin was red and peeling. |
| | Backward: John had been outside all day. |
| Example 2 (target: bake) | |
| | Forward: Saul's kitchen smelled good. |
| | Backward: Saul placed a roast in the oven. |
| Filler Example 1 (target nonword: chus) | |
| | Filler: Tom put out a fire in his kitchen. |
| Filler Example 2 (target nonword: sened) | |
| | Filler: Matt went to the supermarket for some snacks. |

paired with the same target nonwords from Experiment 1. See Table 3 for an example forward causal text, backward causal text, and corresponding target word.

*Procedure.* The procedure for Experiment 2 was identical to Experiment 1, except that participants read only one sentence (i.e., the final sentence from the forward or backward causal texts, or the filler texts) instead of reading two sentences (as in Experiment 1).

## Results

Response times for the lexical decision task were analyzed; only correct responses were included in the final analysis. The top and bottom 1% of the response times for each condition were removed prior to the analyses, as in Experiment 1. For all analyses, an alpha level of .05 was used to determine significance. All analyses included the between participant variables of gender and counterbalance list. Because there were no effects of gender or counterbalance list, these analyses were collapsed across these variables. All analyses were conducted for both participants ($t_1$) and items ($t_2$).

Lexical decision response times were analyzed using a paired-samples $t$ test, with direction (forward or backward) as the independent variable. There were no significant differences between response times in the forward causal condition ($M = 375$, $SE = 15$) and the backward causal condition ($M = 379$, $SE = 14$): $t_1(42) = 0.59$, $p = .56$; $t_2(63) = 0.41$, $p = .68$. There were no effects for accuracy or reading times: largest $t(42) = 0.725$, $p = .47$.

## Discussion

If participants had responded more quickly to target words in the forward than the backward condition, then this finding would have suggested that the results of

Experiment 1 were due to priming and not causal relation processing. However, no response time differences were observed between the forward and backward conditions in Experiment 2. Thus, in Experiment 2, we found no evidence that the response time results in Experiment 1 were caused by semantic priming or backward integration.

## GENERAL DISCUSSION

These experiments explored how quickly readers process texts when a causal event is presented before its effect (i.e., a forward causal relation) and when an effect is presented before its cause (i.e., a backward causal relation). In the first experiment, participants read texts that described temporally related events. Some of the texts described causally linked events (i.e., forward causal relations and backward causal relations), and some of the texts presented events that were not causally linked (i.e., control texts). After reading each text, participants made lexical decisions to cause-related target words. Lexical decision response times, the main variable of interest, were faster for both causal conditions than for the non-causal conditions; and, critically, response times were also faster for the forward causal condition than for the backward causal condition. Although we predicted that reading times would be faster in the forward causal condition than the backward causal condition, no such reading time differences were observed. In the second experiment, we tested the possibility that Experiment 1's results were driven by semantic relatedness and not causal relation processing. However, in Experiment 2, we failed to find a difference between lexical decisions times for forward and backward relations, weakening the argument that semantic relatedness was responsible for the effects of Experiment 1. Taken together, the results of these experiments lead to two key findings regarding how readers process narrative text. First, the results suggest that readers make local coherence inferences in response to causal information in a text, regardless of whether an effect is preceded by, or precedes, its cause. Second, the results suggest that forward causal relations may require less time to process than backward causal relations.

As stated earlier, the results of this study indicate that backward causal relations are processed more slowly than forward causal relations. Interestingly, a previous study showed no processing differences between narrative texts that contain forward and backward causal relations (Singer, Halldorson, et al., 1992). This study may have found different results because coherence breaks were present in the texts in this study, whereas previous studies did not contain coherence breaks in the texts. It is possible that forward and backward causal relations may be processed differently depending on whether the reader *must* infer an event (Mason & Just, 2004; Myers et al., 1987). Further, previous researchers (Singer, Halldorson, et al., 1992) analyzed response times to questions about background knowledge activated during comprehension, whereas this study analyzed response times to cause-related targets to measure causal inferential processing. It is possible that backward and forward causes may activate relevant knowledge structures in readers with similar speed, but that causal inferencing based on that knowledge may require additional effort for backward causal relations as opposed to forward causal relations. In future studies, it would be informative to investigate both the activation of relevant domain knowledge and the integration of causal inferences during the formation of a situation model. Perhaps response times to knowledge-based questions will not vary when readers process forward and backward causal texts, but response times to inference-based target words would be slower after reading backward causal relations than after reading forward causal relations in a text. These findings would be important in suggesting that readers activate knowledge relevant to causal relations before integrating the causal relation during text comprehension.

Although we predicted that final sentence reading times would be faster in the forward causal condition than in the backward causal condition, no reading time effects were observed in this experiment. It is unclear why we did not find significant differences in reading times, but it is possible that the relatively short length of the texts may have contributed to the lack of reading time effects. Indeed, the texts described quite simple events. Further, it is possible that the inclusion of temporal markers at the beginning of the final sentence (e.g., “Later” or “Earlier”) eased temporal processing. It should be noted that we did observe iconicity effects in the main dependent variable (i.e., the lexical decision times).

Although the results of this study suggest that backward causal relations are processed more slowly than forward causal relations, it is currently unclear what processing differences underlie this response time difference. For example, backward causal relations could be more difficult to process than forward causal relations, or backward causal relations may be associated with different types of integration processes than forward causal relations. In the future, it may be useful to conduct a study using self-explanation or think-aloud paradigms to understand more details about how readers process forward and backward causal relations during narrative comprehension.

Additionally, it would be informative to investigate how backward causal relations are processed when the source of the cause is physical or psychological in nature. For example, a glass falling to the ground and breaking would represent a physical cause, whereas a man buying flowers for his mother’s birthday would represent a psychological cause. Previous research has demonstrated that events with physical causes are easier for readers to process than events with psychological causes (Shears et al., 2007). If readers do process physical causes differently than psychological causes, it seems likely that they will process forward and backward causal relations differently depending on whether the causal information is physical or psychological in texts. Specifically, it may be more difficult for readers to process backward causal relations for psychological causes than physical causes.

In sum, the results of this study demonstrate that readers process both forward and backward causal relations during narrative text comprehension, but that processing backward causal relations take more time. The results of this study have implications for theoretical frameworks describing how readers process causal relations in a text. The causal network theory (e.g., Trabasso & Sperry, 1985) and the event-indexing model (e.g., Zwaan, Magliano, & Graesser, 1995) do not currently distinguish between backward and forward causal relations when readers process causal information in a text. These results suggest that theories of causal inferencing in narrative comprehension could gain further specificity by considering how temporal order of events effect a reader's ability to process causal relations.



## REFERENCES

Beeman, M. J., Bowden, E. M., & Gernsbacher, M. A. (2000). Right and left hemisphere cooperation for drawing predictive and coherence inferences during normal story comprehension. *Brain and Language, 71*, 310–336.

Fleischman, S. (1990). *Tense and narrativity: From medieval performance to modern fiction.* Austin, TX: University of Texas Press.

Francis, W. N., & Kucera, H. (1982). *Frequency analysis of English usage: Lexicon and grammar.* Boston, MA: Houghton Mifflin.

Gates–MacGinitie Reading Tests. (1989). *Technical report for Gates–MacGinitie Reading Tests.* Chicago, IL: Riverside.

Graesser, A. C., Millis, K., & Zwaan, R. (1997). Discourse comprehension. *Annual Review of Psychology, 48*, 163–189.

Hopper, P. J. (1979). Aspect and foregrounding in discourse. In T. Givon (Ed.), *Syntax and semantics. Vol. 12: Discourse and syntax* (pp. 213–241). New York, NY: Academic.

Landauer, T., Folz, P. W., & Laham, D. (1998). An introduction to latent semantic analysis. *Discourse Processes, 25*, 259–284.

Langston, M., & Trabasso, T. (1999). Modeling causal integration and availability of information during comprehension of narrative texts: The construction of mental representations during reading. In H. van Ostendorp & S. R. Goldman (Eds.), *The construction of mental representations during reading* (pp. 29–69). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Linderholm, T., Everson, M. G., van den Broek, P., Mischinski, A. C., & Samuels, J. (2001). Effects of causal text revisions on more- and less-skilled readers' comprehension of easy and difficult texts. *Cognition and Instruction, 18*, 525–556.

MacGinitie, W. H., & MacGinitie, R. K. (1989). *Gates–MacGinitie Reading Test* (3rd ed.). Itasca, IL: Riverside.

MacGinitie, W. H., MacGinitie, R. K., Maria, R. K., & Dreyer, L. G. (2002). *Gates–MacGinite Reading Tests technical report Form S and T.* Itasca, IL: Riverside.

Mandler, J. M. (1986). On the comprehension of temporal order. *Language and Cognitive Processes, 1*, 309–320.

Mason, R. A., & Just, M. A. (2004). How the brain processes causal inferences in text. *Psychological Science, 15*, 1–7.

Myers, J. L. (1990). Causal relatedness and text comprehension. In D. A. Balota, G. B. Flores d'Arcais, & K. Rayner (Eds.), *Comprehension processes in reading* (pp. 361–375). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Myers, J. L., Shinjo, M., & Duffy, S. A. (1987). Degree of causal relatedness and memory. *Journal of Memory and Language, 26*, 453–465.

Ohtsuka, K., & Brewer, W. E. (1992). Discourse organization in the comprehension of temporal order in narrative texts. *Discourse Processes, 15*, 317–336.

Ratcliff, R. (1993). Methods for dealing with reaction time outliers. *Psychological Bulletin, 114,* 510–532.

Rinck, M., & Weber, U. (2003). Who when where: An experimental test of the event-indexing model. *Memory and Cognition, 8*, 1284–1292.

Schmalhofer, F., McDaniel, M. A., & Keefe, D. (2002). A unified model for predictive and bridging inferences. *Discourse Processes, 33*, 105–132.

Schneider, W., Eschman, A., & Zuccolotto, A. (2002). *E-Prime users guide*. Pittsburgh, PA: Psychology Software Tools.

Shears, C., Miller, V., Ball, M., Hawkins, A., Griggs, J., & Varner, A. (2007). Cognitive demand differences in causal inferences: Characters' plans are more difficult to comprehend than physical causation. *Discourse Processes, 43*, 255–278.

Singer, M., Halldorson, J., Lear, J. C., & Andrusiak, P. C. (1992). Validation of causal bridging inferences in discourse understanding. *Journal of Memory and Language, 31*, 507–524.

Trabasso, T., & Sperry, L. (1985). Causal relatedness and importance of story events. *Journal of Memory and Language, 24*, 595–611.

Trabasso, T., & Van den Broek, P. (1985). Causal thinking and the representation of narrative events. *Journal of Memory and Language, 24*, 612–630.

Trabasso, T., & Wiley, J. (2005). Goal plans of action and inferences during the comprehension of narratives. *Discourse Processes, 39*, 129–164.

Van den Broek, P. (1988). The effects of causal relations and hierarchical position on the importance of story statements. *Journal of Memory and Language, 27*, 1–22.

Van den Broek, P. (1990). The causal inference maker: Towards a process model of inference generation in text comprehension. In D. A. Balota, G. B. Flores d'Arcais, & K. Rayner (Eds.), *Comprehension processes in reading* (pp. 423–445). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Van den Broek, P., Lorch, E. P., & Thurlow, R. (1996). Children's and adult's memories for television stories: The role of causal factors, story–grammar categories, and hierarchical level. *Child Development, 67*, 3010–3028.

Wolfe, M. B. W., Magliano, J. P., & Larsen, B. (2005). Causal and semantic relatedness in discourse understanding and representation. *Discourse Processes, 39*, 165–187.

Zwaan, R. A., Langston, M. C., & Graesser, A. C. (1995). The construction of situation models in narrative comprehension. *Psychological Science*, *6*, 292–297.

Zwaan, R. A., Magliano, J. P., & Graesser, A. C. (1995). Dimensions of situation model construction in narrative comprehension. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21*, 386–397.

Zwaan, R. A., & Radvansky, G. A. (1998). Situation models in language comprehension and memory. *Psychological Bulletin, 123*, 162–185.