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Individual Differences and the Impact of Forward and Backward Causal Relations on the Online Processing of Narratives

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Abstract

This paper investigated the impact of causality on reading time by examining the contributions of forward antecedent and backward consequence connections. Undergraduate students read four narrative texts, sentence by sentence. Reading times for each sentence were regressed onto the number of antecedents connecting forward to a sentence and backward to prior sentences. Overall, forward antecedents and backward consequences explained unique variance in reading times, with increases in antecedents and consequences predicting decreases in reading time. However, causal consequences did not contribute unique variance to participants with higher literature knowledge. Further, the presence of forward antecedents significantly attenuated reading time differences in reading skill, and lower knowledge participants read sentences significantly faster than higher knowledge participants when forward antecedents were present. These results suggest that readers track both forward causal antecedents and backward causal consequences in online comprehension.

Keywords: reading comprehension; reading time; narrative; individual differences; causal relations; causal relatedness; situation model; causality.

Introduction

According to the event-indexing model, readers track at least five situational dimensions during language comprehension (i.e., *causality*, *temporality*, *spatiality*, *protagonist goals*, and *intentionality*; Zwaan, Langston, & Graesser, 1995). Based on these dimensions, readers create a mental model (i.e., situation model) of the events described in the text. As comprehension unfolds, readers track the continuity of each dimension. When a discontinuity is encountered, readers must update their situation model to account for this shift (Zwaan et al., 1995). The tracking of these dimensions contributes to maintaining a coherent situation model of the events.

Central to the maintenance of coherence is the extent to which an event or action is causally related to previous events or goals (Graesser, Singer, & Trabasso, 1994; Zwaan et al., 1995). Causal relatedness, as described by Trabasso and Sperry (1985), refers to the internal structure of a particular text's causes and effects. In a narrative text, for example, character desires may cause the character to commit certain actions. These actions may in turn result in a change in the character's motivation or reactions from

other characters. However, not every event in a text is clear-cut. Sometimes events or states in a text flesh out the background of the narrative without those states having explicit causes or effects. Or, the events in a text may have little apparent causal structure. For example, the narrative structure of William S. Burroughs' *Naked Lunch* (1959) deliberately obscures the causal relations in the story by re-arranging the sequence of events, seemingly at random.

The seminal paper by Trabasso and Sperry (1985) argued that certain items in a text should be more important to the story than others based on their causal relations within the text. They proposed that *conceptual dependencies*, or the number of concepts that rely on a particular event in the text, are a major factor in determining the importance of a given item to the text as a whole. In this framework, *Item A* in a text is conceptually dependent on *Item B* if the events in *Item B* psychologically motivates, physically causes, or otherwise enables the events in *Item A*. Trabasso and Sperry (1985) found that the number of causal connections between particular clauses accounted for a significant amount of the variance in judgments of importance. Trabasso and van den Broek (1985) found that causal connectivity also influences the memory representation for text. They found that more causal connections between particular clauses led to improved recall.

Zwaan, Graesser, and Magliano (1995) demonstrated that causal connections have an impact on reading time. In their experiment, they collected sentence-by-sentence reading times of narrative texts. The results indicated that reading times slowed when encountering a sentence on new causal chain. Thus, reading time increases (i.e., slows down) when a causal relationship is difficult to infer from the text.

Further evidence for the importance of causal relatedness on reading time comes from Wolfe, Magliano, and Larsen (2005), in which participants read two-sentence stories. The second sentence of each story was either causally related or unrelated to the first sentence. Sentences with a high degree of causal relation to each other were read more quickly than sentences with a low degree of causal relation. These results suggest that causal relatedness has an impact on ease of processing; the easier the causal relations are to infer, the more quickly a reader will process the sentences. Others, such as Myers, Shinjo, and Duffy (1987), have reported similar findings.

The above studies clearly demonstrate the impact of causal structure on reading comprehension, yet several aspects of causal relatedness have yet to be explored. Though previous studies on causal relations have examined whether or not an event lies along a causal chain, few studies have explored the potentially different impacts of direction of causality on comprehension. Notable exceptions have been studies investigating the role of causal antecedents (which explain why an event in a text happened) and causal consequences in the form of predictions (what happens next as the result of an event). It has typically been found that readers generate causal antecedent inferences (a cause for the current event) but rarely predict what will happen next as a result of a cause presented in a current sentence (e.g., Magliano, Baggett, Johnson, & Graesser, 1993; McKoon & Ratcliff, 1986). This suggests that readers more reliably make inferences that serve to establish and maintain coherence.

However, these studies have only examined causal consequences which followed an event described in the sentence. But in many cases, an event's consequence is read before the event's cause, or antecedent. Consider the following example from Trabasso and Sperry (1985):

1. A father and his son
2. were taking their donkey to town
3. to sell him

In this example, (2) is a consequence of (3); the father and son take the donkey to town *because* they want to sell him; there is a *backward consequence* from (3) to (2). Given that Trabasso and van den Broek (1985) were interested in offline memory representations of texts, they only investigated the number of connections, not the direction of those connections. However, the online construction of a situation model involves dynamically using the causal connections in order to integrate and update situation models. Given that backward consequences explain events that occurred in the previous text, they may require a reader to update his or her situation model online.

Despite these promising findings about the importance of causal relations within a text, there is some evidence that not all readers are equally influenced by these relations. Van den Broek (1988) found that while causal connections (along with goal hierarchy) were important to ratings of sentence importance, causal connections seemed to be more important to participants over the age of 11. This finding implies that some readers are more skilled at picking up on causal connections than others, as the causes may often be implicit and not particularly transparent to a less trained or less skilled reader. A study of the differences between reading ability and prior knowledge is needed to further clarify the circumstances under which certain types of causes are more or less influential. The findings of McNamara, Kintsch, Songer, and Kintsch (1996), that individual differences play a significant role in the effects

of text cohesion on comprehension, suggest the possibility that individual differences may play a key role in causal inference generation and maintenance of coherence.

The purpose of the current study was twofold; we explored the effects of forward and backward causal connections in online comprehension. Specifically, we investigated the extent to which readers are influenced by forward antecedents and backward consequences during online comprehension. Secondly, we investigated possible knowledge and reading skill differences in the influence of these causal relations during comprehension. In this study, we conducted causal network analyses of four texts consistent with the approach detailed in Trabasso and Sperry (1985). Based on these networks, we tested the variance of sentence-by-sentence reading times accounted for by forward and backward causal relations (antecedents and backward consequences).

Method

Participants

Forty-eight undergraduate students at the University of Memphis participated in exchange for course credit. The mean age of the participants was 22.21 years ($SD = 6.04$).

Materials

Stimulus Texts Four excerpts from narratives were used as the stimulus material for this experiment. These texts were selected from the Metametrics corpus, a collection of high school textbooks. The excerpts were taken from *A Christmas Memory*, by Truman Capote (30 sentences; 416 words); *The World on a Turtle's Back*, an Iroquois creation story (28 sentences; 394 words); *Seventeen Syllables*, by Hisaye Yamamoto (19 sentences; 407 words); and *A Man Called Horse*, by Dorothy M. Johnson (38 sentences; 393 words). The average number of words across passages was 402.5 ($SD = 11.03$).

Causal Networks Causal networks were derived for the four texts. Following Trabasso and Sperry (1985), a sentence was judged to have a causal relation if the events or states in a sentence cause an event or state in another sentence. In order for a sentence to be judged as causally related to another sentence, a counterfactual test was applied. Consider two sentences A and B. Sentence A is considered causally related to sentence B if the events or states in sentence B could not have occurred if not for sentence A. In order for a sentence to be considered a cause, the sentence must motivate, physically cause, or enable an effect in another sentence.

A sentence was considered to have a *causal antecedent* if a previous sentence in the text causes a subsequent sentence. As an example, consider the following excerpt from *The World on a Turtle's Back*. This passage describes a duel between the left-handed and right-handed twins.

23. On the last day of the duel, as they stood, they at last knew how the right-handed twin was to kill his brother.
24. Each selected his weapon.
25. The left-handed twin chose a mere stick that would do him no good.
26. But the right-handed twin picked out the deer antler, and with one touch he destroyed his brother.

In this example, (23) is the causal antecedent of (24); if the twins had not met for a duel, they would not have selected weapons. Likewise, (24) is the antecedent of (25); if the twins had not selected weapons, the left-handed twin would not have chosen a stick as a weapon. However, (25) cannot be said to cause (26); the choosing of the stick is not a sufficient cause for the choosing of the antler. Instead, (24) is an antecedent of (26) in the same way that (24) is an antecedent of (25).

A sentence was considered to have a backward *causal consequence* if a previous sentence in the text was caused by a subsequent sentence. Consider the following excerpt from *A Christmas Memory*, where a young man describes the present that his friend is making for him:

27. I am fairly sure that she is building me a kite—the same as last year and the year before.
28. The year before that we exchanged slingshots.
29. All of which is fine by me.
30. For we are champion kite-fliers who study the wind like sailors; my friend, more accomplished than I, can get a kite aloft when there isn't enough breeze to carry clouds.

In the above example, (30) psychologically motivates (29) and (27). If the friends had not been champion kite-flyers, then they would not have exchanged kites year after year. Likewise, if they were not champion kite-flyers, the main character, the narrator, would not likely be fine with receiving the same gift over and over.

Sentences were judged to belong to the causal chain if a sentence's effect could be linked to an *antecedent* or previous sentence in the text. Sentences were also judged to belong to the causal chain if the sentence caused a *consequence* earlier in the text. The first two authors coded two of the four texts together, then, as a check of reliability, coded the other two separately, with differences being resolved by mutual agreement. The authors agreed on whether or not a sentence belonged on the causal chain 83% of the time. All differences were resolved by discussion between the first two authors.

Individual Difference Measures To assess individual differences in reading skill, the Nelson-Denny reading comprehension test was administered. This test consists of seven short literature passages and a total of 38 multiple-choice comprehension questions about the passages.

To assess individual differences in literature knowledge, 10 multiple-choice literature questions were employed. The questions were generated by developing questions based on books that are commonly read in high school. A list of books which are customarily read in high school were obtained from study guides by Bellmore-Merrick Central High School District. Questions were developed from the brief study guides and included various aspects of the books such as the characters, plot, setting and authors (<http://www.bellmore-merrick.k12.ny.us/guides.html>). An example question is:

Which of the following most closely captures the central theme of "Animal Farm"?

- a. environmental problems
- b. struggle in the animal kingdom
- c. vulnerability of the socialist system to corruption
- d. problems in capitalist society

Procedure

The participants were first administered the Nelson-Denny test, with a 15-minute time limit. Upon completion of the Nelson-Denny test, students were administered the literature knowledge test.

After completing the literature knowledge test, students were presented with the four narrative texts. Using E-Prime (2000), these texts were presented on a computer screen, with black text on a white background. The texts were displayed one sentence at a time, with the title of each story preceding the text. Participants read each text one sentence at a time, and were instructed that they could continue to the next sentence by pressing the space bar. Reading times for each sentence were recorded in milliseconds. At the end of each text, participants were notified that they had finished the text, and that they could proceed to the next text by pressing the spacebar. After reading each text participants were asked to type everything they could remember about the text. When they had finished typing their recall, participants again pressed the space bar, which took them to the title of the next text. Having the students recall the texts helped to ensure that they read them for comprehension. Because the goal of this study is to investigate the role of causation in online comprehension, we report here only the reading time results.

Results

All reading times which fell outside of two standard deviations of the grand mean were excluded from these analyses. These outliers constituted 5% of the data. Additionally, four participants were excluded from these analyses because their overall reading times fell outside of two standard deviations of the grand mean.

In order to check that the participants' scores on prior knowledge and reading ability were not highly correlated with each other, a Pearson's bivariate correlation was performed. Participants' performance on prior knowledge was significantly but only weakly correlated with performance on reading ability, $r = .318, p < .05$. Because

of this weak correlation we can be reasonably confident that reading skill and literature knowledge are to some extent measures of different constructs.

To determine the extent to which reading time was influenced by reading ability and literature knowledge, we performed a median split on the scores of both the Nelson Denny and the literature knowledge test, with cases falling exactly on the median excluded. As such, 20 participants were designated *higher skill* and 18 as *lower skill*; and 18 participants were designated *higher knowledge* and 20 as *lower knowledge*. The higher skill participants correctly answered a significantly higher proportion of questions ($M = .686$, $SD = .093$) than the lower skill participants ($M = .402$, $SD = .066$), $t(36) = 10.686$, $p < .001$. The higher knowledge participants correctly answered a significantly higher proportion of questions ($M = .606$, $SD = .094$) than the lower knowledge participants ($M = .235$, $SD = .106$), $t(33) = 10.977$, $p < .001$).

To examine the possibility that antecedents and consequences contributed unique variance to reading time, a series of hierarchical regressions were conducted. Sentence reading times (divided by the number of words) for all participants, high skill participants, low skill participants, high knowledge participants, and low knowledge participants served as the dependent variables. To determine the unique contribution of antecedents, consequences were added into the first step of the regression, then antecedents were entered into the second step. To determine the unique contribution of consequences, antecedents were added at the first step, and then consequences were added at the second step. The results of these regressions are summarized in Table 1. A negative beta weight indicates that reading times decreased (i.e., became faster) as the number of causal connections increased. The mean reading times for each group as a function of forward antecedents and backward consequences are presented in Figures 1 and 2.

Table 1: Unique variance contributed by antecedents and backward consequences.

		β	Std. Error	R^2	ΔR^2
All	Ant.	-.50.19*	14.49	0.106	.097*
	Con.	-.49.26*	21.38		
Higher Skill	Ant.	-.39.45*	14.18	0.074	.065*
	Con.	-.42.66*	20.92		
Lower Skill	Ant.	-.63.99*	16.53	0.125	.118*
	Con.	-.55.68*	24.38		
Higher Know.	Ant.	-.40.02*	15.17	0.067	.059*
	Con.	-.42.98	22.38		
Lower Know.	Ant.	-.68.88**	16.41	0.147	.135**
	Con.	-.65.29*	24.22		

* Significant at the .05 level.

** Significant at the .01 level.

For the participants overall, both antecedents and consequences explained unique variance of the reading times. This trend was mirrored in all groups except for the higher knowledge groups, where antecedents explained unique variance, but consequences did not. This provides evidence that participants of varying ability and knowledge levels integrate causal information and update their situation models accordingly during online comprehension. Although backward consequences did not significantly predict reading times for higher knowledge participants, the trend approached significance, $p = .057$.

To test for interactions between reading skill and knowledge differences, the difference in mean reading times were computed between the low and high skill, and low and high knowledge participants. These differences were then correlated against the number of antecedents and consequences in each sentence. The results of these correlations are presented in Table 2.

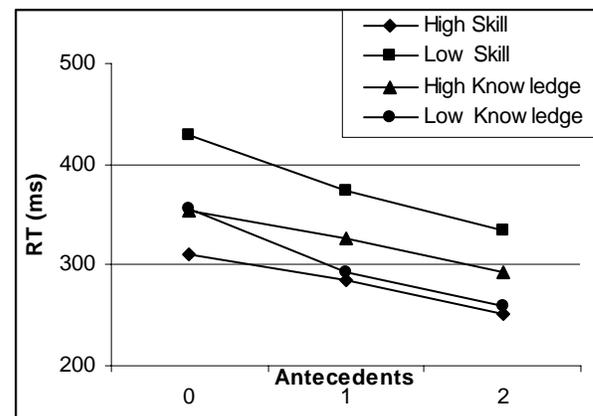


Figure 1: Reading times as a function of forward antecedents.

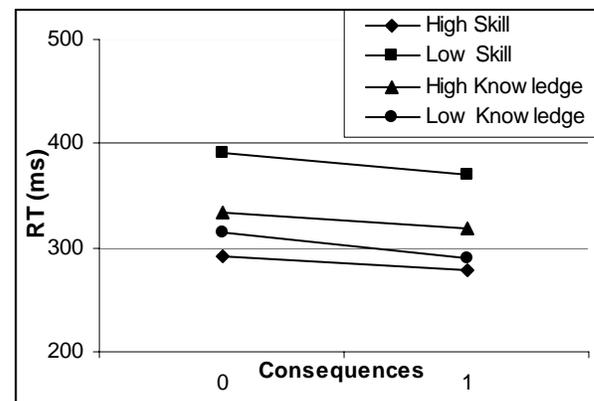


Figure 2: Reading times as a function of backward consequences.

The difference between higher and lower knowledge participants correlated significantly with the number of forward antecedents connected to a sentence ($r = -.23$, $p < .05$), suggesting that the difference between the higher and lower knowledge groups decreased as the number of forward antecedents increased. The negative correlation

between differences in reading skill and the number of forward antecedents connected to a sentence was also significant, ($r = -.19, p < .05$), suggesting that the differences between the higher and lower skill groups decreased as a function of number of forward antecedents connected to a sentence.

Table 2: Correlations between knowledge, skill, antecedents and backward consequences.

	Antecedents	Backward Consequences
Knowledge Difference	-0.19*	-0.04
Skill Difference	-0.23*	-0.00

* Significant at the .05 level.

As can be seen in Figures 1 and 2 (and as suggested by the correlations in Table 2), the differences in reading times appear to diminish for the high and low knowledge and high and low skill groups as the number of antecedents increase. But it is unclear if there are significant group differences when antecedents are present or absent. To further explore these interactions we conducted *t*-tests between each level of knowledge and skill, for each level of causal connection. We collapsed the number of connections into a present group (1 and 2 connections) and an absent group (0 connections) for each type of connection. The mean reading times per word for each skill and connection group are presented in Table 3. The reading times for the higher skill participants were significantly faster than the lower skill participants when antecedents were present ($t(74) = 15.979, p < .001$, and when antecedents were absent, $t(38) = 9.729, p < .001$. There were no differences between levels of knowledge when antecedents were absent, $t(38) = .194, p = .847$, but lower knowledge participants read significantly faster than higher knowledge participants when antecedents were present, $t(75) = 6.223, p < .001$.

Table 3: Mean reading time (ms) as a function of presence of forward antecedents.

Ant. Presence	Group	Mean RT Per Word	SD
Absent	Higher Skill	310.20	101.81
	Lower Skill	429.33	138.33
	Higher PK	352.96	109.28
	Lower PK	356.61	159.28
Present	Higher Skill	277.31	91.68
	Lower Skill	364.95	94.91
	Higher PK	319.31	97.45
	Lower PK	285.59	75.75

Discussion

The purpose of this study was to investigate the extent to which forward antecedents and backward consequences explain unique variance in reading time, and to investigate the possible interaction between levels of reading skill and literature knowledge in the influence of these connections. Our results further contribute to previous work with respect to causal consequences because the results suggest that, counter to the findings of Magliano et al. (1993), readers are able to generate causal consequence inferences during comprehension. However, the causal consequences explored in the present study were not predicting future events but rather explaining previously unexplained events. This is consistent with work that argues that readers generate inferences in the service of maintaining coherent situation models (Graesser et al., 1994).

We further found that both types of connections explained unique variance for all groups except for the higher knowledge group, where backward consequences did not contribute unique variance over and above forward antecedents. What cognitive mechanisms could explain the lack of reliance on backward consequences for higher knowledge readers? At this point our data do not pinpoint an explanation for this finding. Nonetheless, it is probable that readers of high literary knowledge possess schematic knowledge of narrative and literary story structure. As such, even though some events in the story remain unexplained, these readers may be able to infer explanations based on their previous experience with literature.

Recent research by Meyer and Wijekumar (in press) highlights the importance of a reader's domain knowledge in creating a representation of the text. Indeed, Bartlett's study on schema knowledge (1932) clearly demonstrates the role of schema production on comprehension (see also, Kintsch, 1998). Accordingly, readers who are highly knowledgeable about story structure may not rely on the information presented in backward consequences because they have already formed predictions about the described situation before they encountered these backward consequences.

For example, imagine a mystery novel in which the reader is given a general framework of events that led to a particular crime. As the novel continues, the reader may be presented with additional information and events that explain previous events in the text (for instance, the story could open with the robbing of a bank, and by the end of the story, it has been revealed which character robbed the bank, and why). A reader who is intimately familiar with the workings of mystery novels may not need these subsequent explanations to understand the events of a text, because their story schemas for how events typically occur allow them to infer the cause. When the cause is finally encountered in a text their situation model does not need to be updated. A reader who is unfamiliar with these stories may benefit from backwards explanations, as they have not developed a sufficient schema for mystery stories. In this way, readers with more experience reading narrative texts

would benefit less from backward causal relations in the text, whereas a reader who is less knowledgeable about story structures would benefit.

Another compelling finding in this study is that lower knowledge participants read sentences with causal antecedents significantly faster than the higher knowledge participants. There are several possible explanations for this phenomenon. Causality may be a more basic level of the situation model, allowing all readers to track changes in that dimension. Indeed, causality has been shown to be routinely tracked by readers (Therriault, Rinck, & Zwaan, 2006). Other aspects of the situation model however, such as spatiality, may be more accessible to readers with higher knowledge of literature because of their schemas of where and when actions usually take place. Thus, the fluctuations in reading time seen in high knowledge readers may be reflective of other dimensions of the situation model, while lower knowledge readers track only the more basic aspects, like causality. However, such an explanation is only speculation at this point, and further experimentation would need to be conducted to validate such a hypothesis.

Another explanation of the decrease in skill and knowledge differences due to presence of antecedents may be related to findings by Gernsbacher and Faust (1991). That is, less skilled readers require more context for successful updating than high skilled readers. In the context of the current study, an increase in antecedents increases the amount of relevant context. A similar possibility exists for high vs. low knowledge participants. In this case, knowledge schemas for literature structure may provide a sufficient "macro-context" for the high knowledge readers, whereas low knowledge readers rely mostly on context provided by the text.

In sum, these results provide further evidence for the utility of causal network analyses in studies of reading comprehension. The current research advances the field by demonstrating that many readers are sensitive to directional changes in causality, and are able to process consequences online, if the consequence explains previously unexplained ideas or events in the text

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