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Different Kinds of Causality in Event Cognition

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Narrative memory is better for information that is more causally connected and occurs at event boundaries, such as a causal break. However, it is unclear whether there are common or distinct influences of causality. For the event boundaries that arise as a result of causal breaks, the events that follow may subsequently become more causally connected to it as people seek to understand why the break occurred and the consequences of it. Thus, although a causal break has no prior causal connections, it may be linked to many pieces of subsequent information, thereby ultimately affecting memory for it. As such, better memory would be due to increased final causal connectivity, not to being an event boundary of the causal break, per se. The current study had people read and recall narratives that were coded for causal breaks and causal connectivity. The results revealed slower reading times and better memory for causal breaks and faster reading times and better memory with increased prior causal connections. Although there were more causal connections in total for causal break sentences, they each influenced processing, which suggests separate factors impact memory.

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INTRODUCTION

A number of factors influence the ease of narrative comprehension and memory for narrative texts. At the situation model level (Johnson-Laird, 1983; Gernsbacher, 1990; van Dijk & Kintsch, 1983; Zwaan & Radvansky, 1998), as noted by the Event Indexing Model (Zwaan, Magliano & Graesser, 1995), this can include a wide variety of factors, including shifts in space, time, story characters, character goals, and causality. The current study focuses on the influence of causal processing on event cognition. Specifically, the aim of the current study is to explore the influence of causal connectivity and causal breaks as reflected by reading times and recall memory. We consider each of these types of causal influences separately and then consider how they might be related to each other.

Causal Connectivity

Causal connectivity refers to how well integrated a unit of text is with others in a narrative as a function of how often it serves as the cause and/or effect of other units of text. The structure of causal relations is an important part of theories of event cognition, such as the Event Horizon Model (Radvansky, 2012; Radvansky, Krawietz, & Tamplin, 2011; Radvansky & Zacks, 2011, 2014). Here, we define the presence of a causal connection between two units of text using the criteria outlined by van den Broek (1988). For a causal link to be identified four criteria need to be met. First (temporal priority), one event must precede another in time. Second (operativity), the first event must be operating when the second begins. Third (necessity), the first event must happen for the second to follow. Finally, the fourth criterion (sufficiency) is that the first event is sufficient to cause the second to occur.

As an example of causal connectivity, consider the passage in Table 1. Here, the sentence “The professor announced that they would sit and wait for it to come back on” is causally connected with two of the sentences before it. Here, the sentences “The entire test was supposed to be given on the overhead projector” and “Suddenly, the power went out and the room went dark” satisfy the criterion of temporal priority because they all describe events that occur before the events described in the sentence that follows these two. The first two sentences satisfy the criterion of operativity because the test was being given on an overhead projector and the power went out when the professor made the announcement to wait. They also satisfy the criterion of necessity because the taking of the exam, with the overhead projector and the power going out, are all that are needed for the professor to make the announcement to sit and wait.

Causal connectivity has an impact on comprehension and memory in two ways (cf. Langston & Trabasso, 1999). First, there is the *prior causal connectivity*

TABLE 1
Sample Story Text Used in the Experiment

1.	Allison was going to be late for work.
2.	She had stayed up late studying for a microbiology exam that was scheduled for 7:30 pm that day.
3.	To make matters worse, her job was a good 15 minute walk from her apartment.
4.	She jumped out of bed and headed to the shower.
5.	After work at the Bagel Bistro she would have to rush to her classes at the local community college.
6.	She wanted to look nice because she would not be making it home until much later that night.
7.	**She showered and was dressed in 5 minutes.**
8.	Her cat was sitting next to her work shoes playing with her shoe laces.
9.	She distracted the cat with treats, and grabbed the shoes.
10.	She packed them in her backpack because she would need to wear her snow boots to walk to work.
11.	She grabbed an energy bar for breakfast and bundled up to head out into the −2 degree weather.
12.	She hurriedly wrapped her new pink scarf around her neck and covered her damp hair with the matching hat her friend Cassandra had bought her and walked to work.
13.	When she got in, Allison began putting her stuff into her locker.
14.	Cassandra was getting there at about the same time.
15.	**It looked like she had dented her car.**
16.	They both threw their snowboots into their locker and got out their work shoes.
17.	Allison was sliding her shoe on and found a mouse in the toe.
18.	She screamed.
19.	She pulled her foot out of the shoe immediately and shook it out over the trashcan.
20.	It fell out and she cautiously put the shoe back on.
21.	After work Allison put on her snowboots and carried her work shoes out with her.
22.	She got to class early and went over her notes one more time before the exam.
23.	This part of the final would involve identifying pictures of microorganisms that they had studied over the course of the semester.
24.	The professor arrived and started passing out answer sheets.
25.	The entire test was supposed to be given on the overhead projector.
26.	**Suddenly, the power went out and the room went dark.**
27.	**The professor announced that they would sit and wait for it to come back on.**
28.	Ten minutes passed, and then 25.
29.	Finally, after 35 minutes the professor canceled the exam.
30.	All of the students gathered their stuff to leave.
31.	Allison was so glad to have the evening off to rest.
32.	It had been a long day.

Note. Sentences in bold correspond to critical sentences in the causality analyses.

Causal Break–Low Connectivity: Sentence 15, no prior causal connections and not connected to any sentences later on.

Causal Break–High Connectivity: Sentence 26, no prior causal connections and connected to Sentences 27, 28, 29, and 30 later on.

Causal Nonbreak–Low Connectivity: Sentence 7, connected to Sentences 4 and 6 in the prior text and Sentence 12 later on.

Causal Nonbreak–High Connectivity: Sentence 27, connected to Sentences 25 and 26 in the prior text and Sentences 28 and 29 later on.

of the information in a sentence with what has occurred before the current sentence in the narrative. This prior causal connectivity is relevant during on-line processing, such as reading. Second, there is the *final causal connectivity* of an item with all the information from a text, both that which came before it and that which came after it. This final causal connectivity is what is relevant during later memory retrieval for what was learned from a text.

Causal connections have a meaningful impact on narrative processing. Turning first to prior causal connectivity, of central importance, the presence of causal connections facilitates comprehension, as revealed by faster reading times (Radvansky & Copeland, 2000; Singer, Haldorson, Lear, & Andrusiak, 1992). When there is a causal connection of a text unit with other previously read aspects of a narrative, it can be more clearly understood how that information fits into the context of the larger story at that point in reading, what role it plays, and why the event is happening. This is in comparison with events described in a text that have no clear connection with the rest of the prior part of the narrative. When lower prior causal connectivity is encountered, the reader would need to engage in elaborate inference making, which can take time, thereby slowing down reading times. Events that do not have a clear causal connection with the rest of the prior text are causal breaks, which are known to increase reading times (e.g., Zwaan et al., 1995).

In general, as the number of causal connections increases, there is a reduction in reading time (Keenan, Baillet, & Brown, 1984; Myers, Shinjo, & Duffy, 1987). However, it should be noted that in these earlier studies, people were only presented with sentence pairs. The measure of reading time of the second sentence was evaluated as a function of its causal strength to the first, not the number of prior causal connections. There has not been an extension of this to more complex texts and in terms of the number of causal connections. This is a point of resolution provided by the current study. In essence, information that can easily be more causally integrated with a larger number of other text elements that have already been read should be easier to process, resulting in faster reading times. Thus, the prediction is that an increase in number of prior causal connections should result in faster reading times.

Turning now to final causal connectivity, in addition to the influence of causal connectivity on online processing, as reflected in reading times, it has been found that events that are causally connected on the whole of a narrative are better remembered than events that are not connected (Radvansky & Copeland, 2000; Sundermeier, van den Broek, & Zwaan, 2005; Trabasso, Secco, & van den Broek, 1984). Moreover, the more causal connections there are to an event, the better it will be remembered and the faster it will be retrieved (O'Brien & Myers, 1987; Radvansky, Copeland, & Zwaan, 2005; Trabasso & Sperry, 1985; Trabasso & van den Broek, 1985; van den Broek, 1988). Larger numbers of final causal connections ultimately make information more central to the story and more likely to be retrieved later. One way to think about this, in terms of traditional cognitive psychology, is that the greater number of associations with an item, the greater the probability that activation will spread to that item, leading it to be more likely to be retrieved.

Causal Breaks

The other influence of causality on comprehension and memory is that of causal breaks. As noted earlier, causal breaks occur when information is encountered in a text that has no prior causal antecedent. As such, it can be defined as being an event that has no prior causal connections. For example, in Table 1, the sentence "Suddenly, the power went out and the room went dark" is a causal break because there were no prior explanation was given in the text for why this might happen. At that point a reader would need to draw on their knowledge of what had been read up to that point, along with their general world knowledge, to make an inference about why this occurred (e.g., Klin, 1995). As such, a causal break is an opportunity for a reader to detect an event boundary. This is supported by work showing that people explicitly indicate event boundaries at event breaks (e.g., Magliano, Kopp, McNerney, Radvansky, & Zacks, 2012), as well as work showing that reading times increase when people encounter a causal break (e.g., Zwaan et al., 1995), consistent with the idea that event updating needs to occur.

Previous work has shown that reading times increase when people encounter causal breaks (Bloom, Fletcher, van den Broek, Reitz, & Shapiro, 1990; Fletcher & Bloom, 1988; Magliano, Baggett, Johnson, & Graesser, 1993; McNerney, Goodwin, & Radvansky, 2011; Singer et al., 1992; Trabasso & Sperry, 1985; Trabasso & van den Broek, 1985; van den Broek & Lorch, 1993). One explanation of this, from the perspective of the Event Indexing Model (Zwaan et al., 1995), is that readers are tracking various types of information during reading, including causality. When causal breaks occur, then this serves as an event boundary and the reader needs to update their situation model (for a review see Zwaan & Radvansky, 1998), and this updating process takes time. This is a general processing issue and is not unique to causality.

Moreover, beyond the event boundary that occurs as a result of the break with the prior causal connections at the time of reading, it is also often the case that additional information is read later in a text that explains why that event occurred or the consequences of that event. It is unusual for causal breaks to occur for no reason in a narrative and not have the author provide a reason for this, in one way or another, or to use it as a motivator for further actions. Because of this expectation, a reader may adopt a "wait and see" stance in the anticipation that subsequent text will clarify the reason for the otherwise unexpected activity (van den Broek, Risden, Fletcher, & Thurlow, 1996). When such explanations are provided by the subsequent text, then causal connections are made from the causal break sentence to the later material. These additional causal connections contribute to the final causal connectivity of the information.

Thus, causal breaks can potentially influence memory in terms of either the absence of prior causal connectivity, resulting in an event boundary, or in terms of final causal connectivity. In terms of the absence of prior causal connectivity resulting in an event boundary, this can be interpreted broadly in line with theories of event cognition, such as Event Segmentation Theory (Swallow, Zacks, & Abrams, 2009; Zacks, Speer, Swallow, Braver, & Reynolds, 2007). A number of studies have found that information that is presented at event boundaries is remembered better than information that occurs away from such boundaries. To greatly oversimplify, the idea behind Event Segmentation Theory is that cognition is making predictions about what will happen next, with the base assumption being that things will stay more or less the same. When a prediction violation occurs, this triggers an opening of attention gates, causing an increase in the encoding of information present at such times, which, in the case of reading, would include the sentence that conveyed the unexpected information. The detail of the model and the neurological support for it can be found in expositions of Event Segmentation Theory. For our purposes, causal breaks can serve as event boundaries, and so it is not surprising that memory would then be better for causal breaks. So, the argument from Event Segmentation Theory is that when an event boundary is encountered, such as a causal break, there is an increase in processing overall, and, as a consequence, any information that is being processed at that time is more likely to be encoded.

The potential importance of subsequent causal connections, and final causal connectivity, on memory can be seen in a study by Radvansky and Copeland (2000). In this study, people read texts that contained spatial descriptions that conveyed either a functional (e.g., standing below a bridge while it is raining) or a nonfunctional spatial relation (standing below a bridge while trying to read a map). The nonfunctional spatial relation can be viewed as causal break because the prior text does not provide any motivation for this action. Moreover, there is no consequence for this nonfunctional relation in the following text. Although reading times were longer for the nonfunctional sentences, memory was poorer. As such, this provides motivation for the possibility that better memory for causal breaks might be due to the degree of final causal connectivity, not their role as an event boundary. That said, the complete absence of any connection of the nonfunctional material with other elements of the narratives in the Radvansky and Copeland study may have marked this information for no rehearsal, leading to overall poorer memory. It also does not directly address our concern of determining the source of better memory for causal break information that is later integrated with other text elements as is typically the case.

Causal Connectivity and Causal Breaks

Therefore, at this juncture, it is clear that both the number of causal connections and the presence of causal breaks can influence narrative comprehension and memory. At one level, these appear to be different factors that have distinct influences. These factors can be separated out by considering whether a sentence has any prior causal connections at the time it is read and by the final level of connectivity it has with other sentence in the text. This distinction between causal connectivity and causal breaks is made clearer by considering Table 1 in which sentences that are either causal breaks or not and are low or high in causal connectivity are identified in the story. In this way we can assess the degree to which causal breaks and causal connectivity can affect cognition and performance. Specifically, increased causal connectivity could lead to faster reading times and better memory (cf. Radvansky & Copeland, 2000). In comparison, causal breaks lead to slower reading times and better memory.

The issue of primary concern here is whether these two phenomena reflect the operation of distinct ways that causal information is used by cognition or whether they reflect the operation of common causal information processes. That is, is it the case that some results reported in the literature actually reflect a confounding of one of these factors with the other? It could be that the differential processing of causal breaks could actually reflect an influence of causal connectivity.

In terms of online comprehension and reading, the reason people slow down when a causal break is encountered is because there are no prior causal connections supporting that information at that point. Because there is difficulty integrating the current information with what has gone before, this signals a need to engage in an event segmentation process. Thus, a causal break is a condition in which there are no prior causal connections and a need to engage in event segmentation, which produces slower reading times.

Note also that although there may be no prior causal connections with an event in a narrative, it does not mean that none will be established after that point in the narrative as the causal break is explained and its consequences are presented. This would compose the final causal connectivity of the information. As subsequent material is read, this information could be causally connected back to the sentence containing the causal break, thereby increasing the causal connectivity of that information in the context of the larger narrative. As such, according to a *causal connection exclusivity view*, it is possible for an event that occurs at a causal break in a narrative to later result in a memory representation of that text which has a large number of causal connections to that event. If so, then it is possible that a superior memory for causal breaks could arise because of an increased number of causal connections tied to that event.

In comparison, from the perspective of the *Event Horizon Model* (Radvansky, 2012; Radvansky et al., 2011; Radvansky & Zacks, 2014), causal connectivity and causal breaks serve as two different kinds of event information that can influence comprehension and memory. The Event Horizon Model is a collection of five principles: (1) events are segmented at points of major change, (2) a working event model captures the current event, (3) people establish causal connections among events and their elements, (4) there is facilitation for attribute retrieval across events, and (5) there is competition for event model retrieval for related, but distinct, events. Principles 1 and 3 are most relevant here.

According to this view, causal breaks serve as a means of segmenting the stream of action into separate event models, consistent with the first principle. So, consistent with Event Segmentation Theory, when segmentation occurs, information associated with that segmentation is more likely to be processed and stored as a result of the encounter with an event boundary. As a result, information associated with an event boundary will be better remembered. In comparison, causal connectivity serves as a form of linking relations (Radvansky & Zacks, 1997) that serve to join together multiple event models and to give meaning and importance to the various elements involved in an event. These causal connections can then be used as retrieval pathways to access different event components and event models. Thus, causal connectivity also aids memory but through a different mechanism. As such, for the Event Horizon Model, although these are both types of causal information and both can improve memory, they are serving different roles in event cognition and so should have separate influences on performance.

Experiment

The aim of the current experiment was to assess the influence of causal breaks and causal connectivity on narrative comprehension and memory. Although it seems clear that memory would be directly influenced by the number of causal connections with a given element of text, it is unclear whether the role of serving as a causal break would also show a benefit for an item separate from that imparted by the number of causal connections. If the event boundary role that causal break information is playing during reading is confounded with an increase in the number of subsequent causal connections (cf. Klin, 1995), then, according to a causal connection exclusivity view, when causal connectivity is accounted for, there would be no added processing influence of information also having served as a causal break as the event description is unfolding. However, if, as suggested by the Event Horizon Model, causal connectivity and causal breaks are qualitatively different types of event information, then it is expected that they will both contribute to comprehension and memory.

METHODS

Participants

Eighty-nine people (59 women) from the University of Notre Dame participated for partial course credit. The data from 15 participants were dropped for failing to meeting a criterion of 70% recognition accuracy on comprehension questions, suggesting they were not actively attending to the stories they were reading.

Materials

Twenty narratives ranging from 17 to 35 sentences long ($M = 24.8$; $SD = 4.3$) were used. These narratives had been previously scored for event shifts using the criteria specified by the Event Indexing Model (e.g., Zwaan, 1999; Zwaan et al., 1995; Zwaan & Radvansky, 1998; Zwaan, Radvansky, Hilliard, & Curiel, 1998). In terms of the causal breaks, which is our focus here, there were 1 to 4 causal breaks ($M = 2.2$; $SD = 1.1$) per story. Thus, we could compare performance on these items relative to the other narrative sentences that did not convey a causal break.

These narratives were also scored for the number of causal connections for each sentence using the criteria outlined by van den Broek (1988) (i.e., temporal priority, operativity, necessity, and sufficiency). Comparing each story sentence with all the other story sentences, it was found that each sentence had 0 to 11 causal connections ($M = 3.2$; $SD = 1.7$) with other sentences in the narrative. The number of causal connections that were theoretically identified by this process can be used to assess the impact of causal connectivity on performance. Furthermore, to evaluate reading times and identify causal breaks, each sentence was also scored in terms of the number of *prior* causal connections. Here, again, causal breaks always had zero prior causal connections from the sentences already encountered in the text, although they could have causal connections with subsequent material.

For each narrative, there were five comprehension questions that had one-word answers. These questions were used to ensure that people had actually read the narratives. Performance on these comprehension questions is not considered beyond their utility to identify people who were not actively attending to the story material.

Procedure

After reading and signing an informed consent form, participants were given the 20 narratives to read. These narratives were presented in a random order for each person. They were first given the title of the narrative and then read each story, one sentence at a time. The stories were presented on a computer, and participants pressed the space bar with their left hand to advance to the next sentence. Reading times were collected. After reading each narrative, participants were given the comprehension questions to answer. Responses to these questions were made by pressing one of two buttons on a computer mouse held in the right hand.

After all the narratives were read, participants received blank packets to write down their free recalls. On each page of the packet, participants were prompted with each title of a story and told to recall as much as possible. These recalls were written on the packet pages. There was no time limit for the recall phase.

RESULTS

To assess the impact of causal breaks and causal connectivity on text memory, we separated the presentation of the results into three sections. First, we considered the influence of causal breaks, then the influence of causal connectivity, and finally their combined influence. For the reading time analyses, a reading time was dropped if it was either less than 50 ms per syllable or greater than 2,000 ms per syllable. This was done because such times were either impossibly fast or excessively long. This trimming procedure resulted in a loss of .5% of the reading time data. For the recall task, the data were scored using a gist criterion. A given sentence was scored as recalled if the propositional content was present in what was reported by the participant. That is, the basic propositional idea units were identified in each story, before scoring, and if an idea was present in a given person's recall of the story, apart from the actual wording, it was marked as included.

Causal Connectivity

First, in terms of causal connectivity, data were analyzed in terms of the number of prior causal connections to that sentence at the time of reading. The reading time data are shown in Figure 1. As can be seen, overall, reading time was faster as the number of *prior* causal connections increased, $F(6,432) = 44.60$, $MSE = 674$, $p < .001$, $\eta^2 = .38$. A correlation of the mean reading times per syllable and the number of causal connections was significant, $r = -.87$, $p = .01$. This is consistent with the idea that it is easier to read sentences that are better causally integrated with what has gone before in the rest of a text.

The recall data are shown in Figure 2. As can be seen, overall, recall was better as the number of *total* causal connections increased, $F(11,572) = 76.96$, $MSE = .04$, $p < .001$, $\eta^2 = .60$. A correlation of the mean recall rate (in proportions) and the number of causal connections was significant, $r = .90$, $p <$ .001. This is consistent with previous research showing it is easier to remember information that is more highly causally connected in the text as a whole.

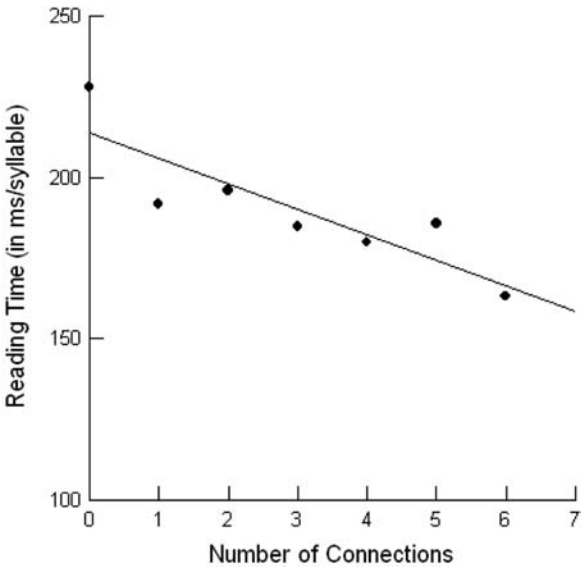

FIGURE 1 Reading time rates (in ms per syllable) as a function of the number of causal connections with a story sentence. In essence, the more causally connected a sentence was, the faster it was read. This is likely because it was easier to integrate that information into the surrounding story context.

Causal Breaks

Consistent with prior work, sentences were read more slowly when they contained a causal break ($M = 241$ ms per syllable; $SD = 65$) compared with when they did not ($M = 192$ ms per syllable; $SD = 46$), $F(1,72) = 96.63$, $MSE = 905$, $p < .001$, $\eta^2 = .57$. This is consistent with the idea that the causal break is serving as an event boundary and that people are updating the situation models at that point. In terms of later recall accuracy, participants were more likely to recall a sentence if it contained a causal break ($M = .54$; $SD = .13$) than if it did not ($M = .31$; $SD = .12$), $F(1,72) = 632.86$, $MSE = .003$, $p < .001$, $\eta^2 = .91$. Again, this is consistent with work showing that information at event boundaries may be remembered better (e.g., Swallow et al., 2009). Thus, causal breaks had an influence during reading, and this also resulted in superior memory for those items.

Combining Causal Connectivity and Causal Breaks

The question of central interest for this study is whether the influence of causal breaks is due to the processing at an event boundary or whether this is due to the

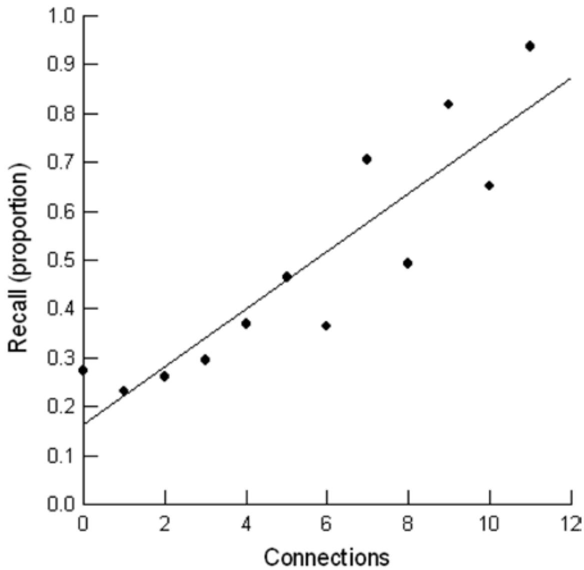

FIGURE 2 Recall rates (in proportions) for story sentences as a function of the number of causal connections a sentence had with other sentences in a story. In essence, the more causal connections with a sentence, the higher the rate of recall memory.

number of causal connections that later follow from that event. This is a valid concern because an analysis of the number of causal connections for the causal break and nonbreak sentences revealed that, for the story as a whole, the causal break sentences had more causal connections ($M = 3.92$) than the nonbreak sentences ($M = 3.11$), $F(1, 1982) = 38.88$, $MSE = 2.71$, $p < .001$, $\eta^2 = .20$. Again, note that these causal connections for the break sentences occurred for sentences that followed the break. Therefore, is the superior memory for the causal break sentences because they are event boundaries, as suggested by the Event Horizon Model, or because they have a greater number of causal connections, consistent with a causal connection exclusivity view?

To assess whether any effect of causal break sentences is being driven by the number of causal connections as compared with any cognitive processing specific to event boundaries, for each person we did a multiple regression analysis using the presence or absence of causal breaks as one factor and the number of causal connections as another. We then assessed whether the standardized regression coefficients across people were significantly different from 0. This analysis revealed that both causal breaks and connectivity had a significant impact on reading times. Using only prior causal connections to assess reading times, the presence of causal breaks resulted in slower reading times ($M = .096$), $t(72) = 8.48$, $p < .001$, whereas increasing numbers of causal connections resulted in faster reading times ($M = -.043$), $t(72) = 5.75$, $p < .001$.

One issue about the prior analysis is that although it is simple and direct, a number of factors can influence reading times that were not accounted for. As a companion analysis, we analyzed the reading time data using the regression analysis method developed by Lorch and Myers (1990) and extended to event model processing by Zwaan et al. (1995). For this analysis, separate regression analyses were done on the reading time data for each subject, taking into account both text-based and event-based variables. The text-based variables used here for each sentence were the number of syllables, serial position, mean word frequency, and number of new arguments. The event-based variables included many used in prior studies, including spatial shifts, time shifts, new entities, and new goals. Of central importance here, this analysis also included causal breaks (also typically found in most analyses of this type) and number of causal connections. The mean standardized regression coefficients are shown in Table 2. Of particular importance, in this analysis both causal breaks and causal connectivity were significant predictors of reading time (the presence of causal break increased readings times and greater causal connectivity decreased reading time). Overall, this suggests that the influence of causal breaks on reading time is largely separate from the number of causal connections.

In addition to the effects of causal breaks and causal connectivity, the analysis of the standardized regression weights revealed significant influences of all the text-based factors. Moreover, there were significant influences of spatial shifts and character goals, consistent with many previous studies. The effect of time shifts were not significant, although this has been observed before (e.g.,

TABLE 2
Mean Standardized Regression Coefficients for the Reading Time Data and Whether They Differ From Zero

Text-Based Factors			
Syllables	*Serial Position*	*Mean Frequency*	*New Arguments*
.542*	−.061*	−.040*	.108*

Event-Based Factors					
Space	*Time*	*Entity*	*Goal*	*Causal Breaks*	*Causal Connectivity*
.016*	−.005	−.002	.031*	.054*	−.015*

*$p < .05$.

Radvansky, Zwaan, Curiel, & Copeland, 2001; Zacks, Speer, & Reynolds, 2009), including in studies in which the texts were not written to explicitly assess temporal shifts (McNerney, Goodwin, & Radvansky, 2011). Finally, there was no significant effect of new characters, which is unusual, and it is unclear why it did not emerge in this particular dataset.

For the analysis of the recall data, all the causal connections were taken into account. Only causal breaks and causal connectivity were considered because none of the low-level factors known to affect reading times (e.g., number of syllables) was likely to have played a major role in retrieval during this task. A logistic multiple regression analysis including break and connectivity revealed that both had a significant impact on recall memory. The presence of causal breaks resulted in better memory ($M = .62$), $t(1983) = 6.56$, $p < .001$, as did increasing the number of causal connections ($M = .48$), $t(1983) = 5.75$, $p < .001$; Moreover, the interaction was not significant, $t < 1$, further supporting the idea that these influences were largely separate.

DISCUSSION

Previous research has shown that narrative comprehension and memory are affected by both the number of causal connections with an item and whether that item served as a causal break during the reading of the text. In general, reading times are facilitated by causal connectivity but slowed when causal breaks are encountered. Moreover, memory is better as the number of causal connections increases and for items that served as causal breaks. The aim of the current study was to assess whether these two influences of causal information on narrative comprehension and memory reflect the same or different mental constructs. The results of our analysis of reading time and recall data of a collection of 20 stories revealed that both factors contributed to performance but their contribution was separable.

These results are inconsistent with the idea that the previously observed memory benefit found with causal breaks is due to a confounding of causal breaks and causal connectivity in prior research, as would be consistent with a causal connection exclusivity view. Instead, these data are more consistent with theoretical views of event cognition, such as the Event Horizon Model, which specify causal connectivity and causal breaks playing different roles in how event information is processed and remembered.

In terms of causal connectivity, the Event Horizon Model stipulates that causal connections are a vital aspect of relating various event models to one another. Causal connections are a kind of linking relation that joins various event representations together. These are important because other sorts of linking relations can easily be derived, such as temporal relations that are often not well encoded into memory (e.g., Friedman, 1993). Finally, causal relations are often grounded in event entities that are actually or potentially interacting with other event components.

Causal information gives meaning to events in the sense that they convey why a certain sequence of events occurred as compared with another. As such, causal connections serve as the backbone for narrative structure, giving the information organization, which can facilitate both comprehension and later memory. Causal connections also give importance to some events over others, allowing people to consistently and regularly identify which events are subjectively more important than others.

In comparison, causal breaks serve a different role in event cognition. People need to segment a series of events into subcomponents at sensible places. That is, they need to identify event boundaries. There are a number of ways to do this. For example, jumps in space and time can serve as clear event boundaries. Causal breaks play a similar role. When something happens that is unexpected based on what has happened before, this is a strong indicator that a new event is operating and that a person needs to construct a new event model. Thus, consistent with the Event Horizon Model, causal breaks serve a segmentation role, leading to different event models being created. The points at which such segmentation occurs are themselves favored in memory because they help define and index different events. As such, this information will be better remembered (Newtson & Engquist, 1976; Swallow et al., 2009).

The current findings also provide some additional insight into the finding of a general inverted U function for the influence of causal relatedness on later memory in the narrative comprehension literature. Specifically, memory for text is poor when there are very low levels of causal relation and very high levels of causal relation but better for moderate levels of causal structure (Keenan et al., 1984; Myers et al., 1987). Myers et al.'s account is a levels of processing account. Essentially, items that involved moderate levels of causal structure require a degree of inference to make the needed connection between two otherwise isolated sentences. When the connection is more explicit and obvious, fewer inferences need to be made, and there is less processing and memory is poorer. When the connection is absent, no inferences can be drawn, and there is less processing and memory is poorer. Keep in mind that this work involved sentence pairs in which the causal strength of a second sentence given the first was manipulated. Although there is something to the Myers et al. account, it is also the case that this pattern of data may be explained by the presence of event boundaries provided by causal breaks and the degree of causal connectivity working together to provide an index of later memory performance,

From the perspective of the current study, when causal relations between two sentences are very weak (e.g., Joey went to a neighbor to play. The next day his body was covered with bruises), there is more of a causal break because it is not clear why the second event is happening, and no causal connectivity because they are largely unrelated to one another. The causal break may lead to superior memory because of the presence of an event boundary, but only for the second sentence because it is the one that conveys the event boundary. However, it is not clear how the second follows from the first, and the lack of causal connections impairs performance. As such, memory is moderate overall because there is modest support from the causal break but none from causal connectivity.

In comparison, when causal relations between two sentences are very strong (e.g., Joey's big brother punched him again and again. The next day his body was covered with bruises), there is no causal break because the second sentence is strongly connected to the first. However, there is a clear cause and effect relationship between the first event and the second. As such, memory is moderate overall because there is no support that could be gained from a causal break, but there is some from causal connectivity.

However, when causal relations between two sentences are moderate (e.g., Racing down the hill Joey fell off of his bike. The next day his body was covered with bruises), there is a causal break here because the second sentence is not a necessary consequence of the first. However, still, a clear cause and effect relationship can be derived and inferred between the first event and the second. As such, memory is better overall because there is some memory support that could be gained from a causal break, as well as some gained from the presence of causal connectivity.

In sum, causal breaks encountered during reading and the prior and final causal connectivity of text information influence comprehension and memory. However, the way in which they do so appears to be qualitatively different. Causal connections play a role in structuring and organizing various pieces of event information, whereas causal breaks help serve to identify event boundaries. This further clarifies the importance of causal information in event cognition, and the nature of that influence.

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