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Causal Coherence and the Availability of Locations and Objects

During Narrative Comprehension

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Abstract

The aim of this study was to examine whether locations of objects are encoded and available to the reader at different points in a narrative depending on their causal relevance. Participants in five experiments read narratives in which the spatial relation between an object and its location either did or did not provide a causal explanation for a later critical event. Object and location target words were presented to participants immediately before or after the critical event. Speeded-recognition response times to target words demonstrated that both locations and objects were re-activated, but only after they became causally relevant. The results suggest that the causal structure of a text can influence the availability of spatial information and that at least some spatial relations are encoded during reading and are available to the reader when needed to build coherence.

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Causal Coherence and the Availability of Locations and Objects

During Narrative Comprehension

Comprehenders of a narrative can mentally represent many dimensions of the world described by a text, including spatial relations, temporal information, goals, and causal structure. With regards to the dynamics of availability of spatial information during reading, especially concerning locations of protagonists, the research findings have been inconsistent. Whereas some results suggest that readers do not keep track of detailed spatial information without special instructions to do so (Albrecht & O'Brien, 1995; Hakala, 1999; Zwaan & van Oostendorp, 1993, 1994), other results suggest that readers do keep track of spatial information even when not explicitly instructed to do so (Bower, Black, & Turner, 1979; de Vega, 1995; Glenberg, Meyer, & Lindem, 1987; Levine & Klin, 2001; O'Brien & Albrecht, 1992). To clarify these seemingly inconsistent results, it is useful to discover factors that contribute to the availability and maintenance of spatial information during regular reading (see Levine & Klin, 2001; Zwaan & Radvansky, 1998). In the experiments that follow, we tested whether the causal relevance of spatial information affects the availability of previously mentioned locations and objects in a text.

Researchers generally agree that successful comprehension of a narrative entails representing a model of the situation described by the text (Graesser, Singer, Trabasso, 1994; Johnson-Laird, 1983, 1989; Perfetti, 1989; Radvansky & Copeland, 2000; Radvansky, Zwaan, Curiel, & Copeland, 2001; Zwaan, Langston, & Graesser, 1995; Zwaan, Magliano, & Graesser, 1995; Zwaan & Radvansky, 1998). These situational representations are described as mental models (Johnson-Laird, 1983) or situation models (van Dijk & Kintsch, 1983). The process of creating a situation model allows readers to understand things that are not explicitly stated in the text. In some instances readers will draw inferences about the spatial relations between objects or the causal relation between events. For example, in comprehending the sentence, "Three turtles were sitting on a log and a fish swam beneath them," readers routinely infer that the fish swam

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beneath the log (Bransford, Barclay, & Franks, 1972). Similarly, during the construction of a

situation model, readers may attempt to explain causes of events as they proceed through a text

(Fletcher, Hummel, & Marsolek, 1990; van den Broek, 1990). For example, imagine a narrative

in which the protagonist goes to the dentist one morning to get his wisdom teeth pulled. Later that

night, his cheek is swollen. Drawing from a rich set of life experiences, a reader can easily infer

that the character's visit to the dentist *caused* his cheek to be swollen. Comprehension of a

passage therefore involves much more than the processing of individual sentences; it also involves

the construction of a rich representation of the situation to which the text refers (Hess, Foss, &

Carroll, 1995).

Another important aspect of the construction of situation models is its dynamic nature.

Elements can fluctuate in terms of their availability in the reader's working memory as the reader

proceeds through the text (Kintsch, 1988; Myers, O'Brien, Albrecht, & Mason, 1994; van den

Broek, Young, Tzeng, & Linderholm, 1999). To a certain extent, fluctuations of elements depend

on their function in the context of the narrative. For example, with respect to causal information

readers focus their attention on the last state or event that has causes but (as yet) no consequences

in the preceding text (Fletcher, Hummel, & Marsolek, 1990). With respect to spatial

representations, the proximity of an object to the protagonist in the world described by the story is

sufficient to influence readers' representations. For example, readers keep an object more active in

working memory when that object is on or near the main character than when it is distant from the

main character (Glenberg, et. al., 1987).   Findings such as these support the notion that the

reader's efforts to construct a situation model based on the text strongly affect the dynamic

availability of causal and spatial information.

There is some debate as to whether spatial information plays a central role in a reader's

representation during normal reading and to what extent it can influence the availability of

objects. The results of some studies suggest that readers represent detailed spatial information

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which, in turn, affects the availability of related items in memory (Morrow, Bower, & Greenspan, 1989; Morrow, Greenspan, & Bower, 1987; Morrow, Leirer, Altieri, & Fitzsimmons, 1994; Rinck & Bower, 1995; Wilson, Rinck, McNamara, Bower, & Morrow, 1993). In these studies, the spatial distance between the protagonist and certain objects in the layout of the story affected the availability of those objects in a probe identification task, with response times being fastest when objects were in the same room as the protagonist. In addition, participants are able to verify spatial relations from different characters' perspectives (de Vega, 1994).   However, task demands and instructions likely play an important role in the maintenance of spatial information. In many of the studies mentioned above, readers were instructed to memorize the layout of a building or a description of a layout before reading a text about it. Apparently, the spatial model was formed before rather than during the reading of the text. Zwaan, Radvansky, Hilliard, & Curiel (1998), in a replication of the Morrow et al. (1987, 1989) studies, showed that only readers who had previously memorized the layout kept track of spatial changes in the story, whereas readers who had not previously memorized the layout did not do so. In other words, when the task requires readers to track spatial information, either by instructions or the type of response task, it seems that they do so.

     Additional research suggests that in the absence of explicit instructions to maintain spatial models, readers do not expend much effort to maintain them (Hakala, 1999; Zwaan & Oostendorp, 1993, 1994) and usually do not form spatial representations other than those explicitly stated in the text (Langston, Kramer, & Glenberg, 1998). Such failures in representing spatial information over the course of reading at times have been taken as evidence that readers do not form spatial models during "normal reading." However, it seems reasonable that textual properties may encourage readers to develop spatial models and represent location information more fully. For instance, when reading about objects that are in different locations, readers have been shown to mentally update the representation of the protagonist's location if one of the

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objects is later mentioned by means of an anaphoric referent (de Vega, 1995). Also, readers immediately infer a change in the protagonist's location even in the absence of task demands if the location information is sufficiently elaborated (Levine & Klin, 2001). In general, the lack of consistent findings of spatial influences during normal reading indicates the need for a guiding principle that can account for the different results and can predict when and how readers will use spatial information (Radvansky & Copeland, 2000).

Our aim was to determine whether causality may influence the conditions under which readers represent spatial information during reading. There is considerable evidence that readers routinely represent the causal structure of events (e.g., Fletcher, Hummel, & Marsolek, 1990; Trabasso, & Magliano, 1996; Trabasso & Suh, 1993; van den Broek, 1994; van den Broek & Lorch, 1993). For example, readers judge events on the causal chain of events in a narrative as more important (Trabasso & van den Broek, 1985) and recall them more frequently (Black & Bower, 1980; Trabasso & van den Broek, 1985; Omanson, 1982; Wolman & van den Broek, 1993) than events that are not part of the main causal chain. In fact, the motivational and causal dimensions have been called the "backbone of situations constructed during narrative comprehension," and readers will even search beyond the contents of working memory during reading to make global causal connections that build this 'backbone' (Graesser, et. al., 1994). Because causal information is crucial for the comprehension of a narrative it seems reasonable that spatial or location information is encoded and updated if it lies on the causal path of the narrative (Zwaan, van den Broek, Truitt, & Sundermeier, 1996; Zwaan & Radvansky, 1998). Based on the critical function of causality in narratives, we hypothesize that spatial relations are more available to a reader when they are used in an attempt to explain a critical event compared to when the same information is not needed to explain such events.

We tested this hypothesis using a three-pronged approach, as suggested by Magliano & Graesser (1991). The first prong is to use theoretical models to develop materials possessing the

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desired properties. We used causal network theories (e.g., Causal Inference Maker, van den

Broek, 1990; Trabasso & Sperry, 1985) to construct texts in which a critical event necessitated an

explanation at a coherence break. In one version, particular spatial information was both necessary

and sufficient for providing the explanation. According to the model, an inference incorporating

the spatial information would be generated at the coherence break. In the other version the same

spatial information was not a part of the explanation and the inference would not be generated.

The second prong is to empirically test the materials under ideal reading conditions, for example

by using a think-aloud procedure (Experiment 1). Finally, the third prong is to test our hypotheses

using a speeded, on-line paradigm. To test our hypotheses, we assessed the activation of location

and object information in a series of response time experiments to discover whether readers

actually encode and reinstate spatial information while reading. Experiments 2a and 2b were

designed to test the availability of the *location* during on-line comprehension with a probe

recognition task both before and after the critical event. In Experiments 3a and 3b, we similarly

tested the availability of the *object.*

Experiment 1

A reader does not always come to a text with the same expectations, background

knowledge, and mental alertness. Therefore it is useful to discover what a reader is able to do and

comprehend under the most ideal circumstances (Magliano & Graesser, 1991). The purpose of

the first experiment was to discover to what extent readers activate spatial/location information

when given an unlimited time to read and think about each sentence as it relates to others. Using

a think-aloud procedure, participants were instructed to read short narratives and to think aloud at

the completion of each sentence (Ericsson & Simon, 1998; Pressley & Afflerbach, 1995). If

readers are encoding and later activating spatial information during the coherence break, then one

would expect that readers would mention a specific object more often during reading the outcome

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sentence of a narrative in which the object and its location are causally relevant to that outcome than of a narrative in which the object and its location are not causally connected to the outcome.

Method

      Participants. Eighteen undergraduate students who were enrolled in an introductory Psychology course at the University of Minnesota participated in this experiment. Extra credit in the course was given to each student for participation in the study. All students spoke American English as their first language and had normal or corrected to normal vision.

      Materials. Twelve short narratives consisting of inference situations depicting everyday life events were generated. Each story consisted of five sections: (a) an introduction giving general background information about characters, settings, and plot, (b) critical spatial information that included an object, a preposition (in, on, by), and a location, (c) at least three sentences of filler material that was irrelevant to the spatial information, (d) a critical sentence describing the unexpected outcome, and (e) a continuation of the story if required for narrative flow. The mean length of the narratives was 16.5 sentences. Sentence complexity was almost exclusively limited to one-verb main clause constructions. Subordinate clauses were prepositional or adverbial phrases of five or fewer words.

      There were two versions of each story, depending on the causal role of the spatial information. In the *causally-relevant* (or experimental) version, the object, preposition, and location were causally connected to the outcome so that, taken together, they were necessary for the outcome to occur. In the *non-causal* (or control) version, the object and location were not causally connected to the outcome. Differences between the two versions were kept to a minimum. The appendix contains an example of the narratives in both versions. The stories were constructed so that neither the object nor the location alone was causally sufficient to produce the outcome. Also, the texts were made to avoid prompting forward inferences about the outcome

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before its actual occurrence and to separate the critical sentence from the outcome sentence by

filler material.

Design. The twelve experimental stories were randomly divided into two sets of six.

Participants were randomly assigned to one of the two sets. For each set of six stories, half of the

participants received three stories in their causal version and three stories in their control version.

The other half of the participants received the complement. The order of the narratives in the

presentation phase was randomly determined for each subject.

Procedure. Participants were tested individually. They read the stories one sentences at a

time from unlined index cards and were asked to verbalize aloud their thoughts for each sentence.

A practice narrative preceded the six experimental stories. Prompts indicating the importance of

talking were provided occasionally when there was silence for more than ten seconds.

Participants' utterances were tape-recorded throughout the duration of the study. Total testing

time per individual was generally between 30 and 45 minutes.

Results

An alpha level of .05 was used for all statistical tests that follow. Effects were analyzed

by participants (F_1 or t_1) and by items (F_2 or t_2). The average proportion of texts for which the

object was mentioned at the critical point (the outcome) was greater in the causally-relevant

condition ($M = .47$, $SD = .135$) than in the control condition ($M = .09$, $SD = .055$), in an analysis

by participants, $t_1(17) = 11.12$, $p < .01$, as well as in an analysis by items, $t_2(11) = 3.75$, $p = .0015$.

The very low number of mentions in the control condition along with the greater number of

mentions in the causal version supports the manipulation of the texts and furthermore suggests

that readers, when given ample time and resources, reinstate object information only when this

information is causally relevant by virtue of its spatial relation to the outcome of a story.

Experiment 2a

In Experiment 1, objects that were part of critical spatial information were mentioned in think-aloud protocols more often after the critical sentence in the causally-relevant condition than in the control condition, suggesting that readers reinstated object information when its spatial relations were causally important to the outcome sentence. In the next two experiments we investigated whether readers encode location information during unprompted reading and whether they make inferences about spatial information when it is causally relevant to the text. In Experiment 2a, a probe word representing the spatial location of the object was presented to participants immediately after the critical or outcome sentence—the point at which an inference involving the location would provide a causal explanation for the outcome in the experimental condition. Participants were instructed to indicate as quickly and accurately as possible whether the target word had been encountered previously in the text. Response times and accuracy to the target were recorded. If readers use location information in causal explanations about a surprising event and if location information is accessible to the reader as he/she is processing the outcome, then the participants' responses to the probe word would be faster and/or more accurate in the causally-relevant version of text than in the control version. If readers do not make inferences about location or do not have access to this information then there would be no significant difference in the response time and accuracy to the probe word between the two conditions.

Method

     Participants. Thirty-seven undergraduate students taking an introductory psychology class at the University of Minnesota participated in this experiment for extra credit. All participants spoke American English as their first language and had normal or corrected to normal vision.

     Materials. The materials were the same as in Experiment 1. The location words were presented as targets. In addition to the 12 experimental stories, 12 filler stories similar in length and style were constructed and matched with a target word that did not occur in the text.

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Design. Each participant read the 12 experimental stories and 12 filler items. Because each participant only saw a particular story in either the causally relevant version or the control version during the on-line task, the stories were randomly assigned to two lists each containing six causal versions and six non-causal versions. Both lists of stories were counterbalanced across participants. The order of stories was randomly determined for each participant.

Apparatus. Stimulus presentation and data collection were controlled by an IBM PC computer utilizing Micro Experimental Laboratory version 2.0 software (Psychology Tools Inc.). Presentation of the text was self-paced and responses were made on a four-button response box accurate to within one millisecond.

Procedure. Participants were told that they were participating in an experiment involving comprehension of text. They were instructed to read each text at their own normal reading rate and that each text reading would be followed by two tasks —a recognition task and a comprehension task. After these tasks were explained, participants completed a practice trial. If problems were noted, the instructions were clarified and another practice trial was completed.

Each participant placed his or her left-hand index finger over the left-most button of a four-button response box and his or her right-hand-index finger and right-hand-second finger over the two right-most buttons. Each story was presented in the vertical center of the screen, one clause at a time. Participants advanced lines of text by pressing the left-most button of the button-box with their left index finger. Immediately after reading the critical sentence in the experimental stories, participants made speeded recognition judgments to the target word. A row of five asterisks appeared in the center of the screen for 500 ms and was immediately replaced by a word. Participants indicated whether they had seen this word previously in the story. For half of the trials the word appeared in the story, and for the other half of the trials (i.e., for the filler stories) the word did not appear. To insure that the decision task was not trivial, the filler words were balanced in length and word frequency with the target words (see Kucera & Francis, 1967)

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and were constructed so that they were related to a word in the story. Participants made "yes" responses with their right index finger and "no" responses with the second finger of their right hand. Participants were instructed to respond as quickly as possible to the word while being as accurate as possible. Immediate accuracy feedback was given for 1000 ms. Response times from the onset of the target word and accuracy rates were recorded. After participants finished reading each story, they were presented with a yes/no comprehension question to prevent superficial understanding and strategic responses to the probe task. Feedback was given in the same manner as for the target word. An example question is presented in the appendix. Participants read 24 stories—6 experimental, 6 control, and 12 fillers—and completed the experiment in an average of 35 minutes.

Results

Participants' response times and accuracy rates were the dependent variables of interest in this experiment. All data from any participant who experienced difficulties with the computer program or who was not a native speaker of American English were excluded from the analysis. Response times were analyzed separately by condition and all data points faster than 200 ms and all incorrect responses were eliminated. A cutoff was established in which 2.5% of the longest response times for correct responses in each condition were removed (see Ratcliff, 1993). When more than 75% of a participant's or an item's scores were removed, the entire set of scores for that participant or item were not considered.

Table 1 presents mean accuracy rates and mean response times to the probe words. Response times to the probe word were significantly faster in the causally relevant condition than in the control condition, $F_1(1,36) = 5.33$, $MS_e = 29737$, $p = .03$; $F_2(1,11) = 4.87$, $MS_e = 10709$, $p = .05$. Accuracy rates between the experimental condition and the control condition did not statistically differ [both Fs < 1]. Accuracy rates to the comprehension questions in the causally

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relevant condition ($M = 87\%$, $SD = .18$) did not statistically differ from those in the control

condition ($M = 84\%$, $SD = .17$) [both Fs < 1].

<div align="center">Experiment 2b</div>

In the previous experiment, the location probe word was more highly activated in the

causal version than in the control immediately after the outcome sentence, suggesting that an

inference about the spatial information had been made. These results are in accord with those from

Experiment 1. It is possible, however, that these results are not caused by inference generation

but by differences in the extent to which location information was activated after its initial

introduction but before the target statement. Experiment 2b was designed to test this possibility:

Here, the probe word was presented immediately *before* the outcome sentence. If the causally

relevant and control conditions in Experiment 2a differ in the maintenance or prior activation of

location after it was mentioned in the text, then the response to the location probe would be faster

and/or more accurate in the causally-relevant condition than the control condition. In contrast, if

there is no differential activation prior to the outcome statement, then there would be no

significant differences in response time and accuracy of the target word between the control and

causally-relevant versions of the story.

Method

Participants. Thirty-eight undergraduate students taking an introductory psychology

class at the University of Minnesota participated in this experiment for extra credit. All

participants spoke American English as their first language and had normal or corrected to normal

vision.

Materials. Materials were identical to those in Experiment 2a.

Design and Apparatus. The design and apparatus were identical to that in Experiment 2a.

Procedure. The procedure was the same as the one in Experiment 2a, except that the

probe word was presented *before* the critical sentence instead of after it.

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Results

Table 1 presents the mean accuracy rates and mean response times to the probe words. Neither response times nor accuracy rates differed significantly between conditions in either the by-subject analysis or the by-item analysis [all Fs < 1]. Thus, there was no evidence that location information was re-activated or maintained prior to the outcome sentence. Accuracy rates to the comprehension questions in the causally relevant condition ($M = 91\%$, $SD = .14$) did not statistically differ from those in the control condition ($M = 89\%$, $SD = .15$) [both Fs < 1]. To confirm that the pattern of response-time results differed between Experiments 2a and 2b (targets presented after and before the outcome, respectively), the data from both experiments were analyzed together with experiment as the between-participants factor. The interaction between causal condition and experiment was significant in an analysis by participants, $F_1(1, 73) = 3.82$, $MS_e = 16517$, $p = .05$; $F_2(1,22) = 2.06$, $MS_e = 9458$, $p = .17$, indicating that response times for location information were faster in the causally-relevant condition than in the control condition only after a causal-explanation inference was generated (Experiment 2a)[1].

<div align="center">Experiment 3a</div>

The results from experiments 2a and 2b reflect differences in processing of location between the causal and non-causal conditions. Specifically, participants responded more quickly to the location probe after—but not before—reading the outcome sentence when it was causally relevant to that outcome than in the control condition. This suggests that the location word was reinstated when it was necessary to provide a causal explanation for the critical outcome sentence. By implication, this means that the location had originally been encoded.

Experiments 3a and 3b addressed the issue of whether the object was reinstated. Based on our hypothesis that the object and location are connected in the situation model, one would expect patterns similar to those observed for locations in Experiments 2a and 2b. In Experiment 3a, the object probe word was presented to participants after the outcome sentence. If readers

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make inferences relevant to object information only when it is causally relevant to the outcome, then participants' response time to the target words would be faster in the causally-relevant version of text than in the control version. In contrast, if readers do not reinstate the object or do not encode the object information, then there would be no differences in response times between the two conditions.

Method

  Participants. Forty-one undergraduate students taking an introductory psychology class at the University of Minnesota participated in this experiment for extra credit.

  Materials. Materials were the same as in Experiments 2a and 2b with the exception that the object words were used as targets.

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

Results

  Table 1 presents the mean accuracy rates and mean response times to the probe word. Response time to the probe word was significantly faster in the causally relevant condition than in the control condition, $F_1(1,40) = 11.29$, $MS_e = 14309$, p = .002; $F_2(1,11) = 6.08$, $MS_e = 6876$, $p = .03$. Accuracy in the experimental condition was not significantly greater than the accuracy in the control condition [both Fs < 1]. Accuracy rates to the comprehension questions in the causally relevant condition ($M = 90\%$, $SD = .13$) did not statistically differ from those in the control condition ($M = 91\%$, $SD = .12$) [both Fs < 1].

<div align="center">Experiment 3b</div>

  In Experiment 3a, the object probe word was presented before the outcome sentence. If the experimental and control conditions in Experiment 2a differ in the maintenance or prior activation of the object after it was mentioned in the text, then the response to the object probe would be faster and/or more accurate in the causally-relevant condition than the control condition. In contrast, if there is no differential activation prior to the target, then there would be no

significant differences in response time and accuracy of the target word between the control and

causally-relevant versions of the story.

Method

Participants. Forty-three undergraduate students taking an introductory psychology class

at the University of Minnesota participated in this experiment for extra credit.

Materials. Materials were the same as in Experiment 3a.

Procedure. The procedure was identical to the one used in Experiment 3a, except that the

probe word was presented *before* the critical sentence instead of after it.

Results

Table 1 presents the mean accuracy rates and mean response times to the probe word.

Neither speed nor accuracy of responses to the probes differed significantly between conditions

either by subject analysis or by item analysis [both Fs < 1]. Thus, there was no evidence that

objects were re-activated or maintained prior to the outcome sentence. Accuracy rates to the

comprehension questions in the causally relevant condition ($M = 93\%$, $SD = .12$) did not

statistically differ from those in the control condition ($M = 94\%$, $SD = .10$) [both Fs < 1]. Causal

condition interacted with experiment in the combined analyses of Experiments 3a and 3b, $F_1(1,$

$82) = 6.31$, $MS_e = 14410$, $p = .014$; $F_2(1, 22) = 2.66$, $MS_e = 7542$, $p = .12$, indicating that response

times for object information were faster in the causally-relevant condition than in the control

condition, but only after a causal-explanation inference was generated.   Furthermore, a one-tailed

t-test comparison on response times in the causally relevant condition revealed that response times

to object target words presented after the outcome sentence were significantly faster than response

times to targets presented immediately before the outcome sentence in an analysis by subjects, $t_1=$

1.73, $p = .04$. The results for Experiments 3a and 3b demonstrate that an object is reinstated

after—but not before—an outcome sentence only when it provides a causal explanation for the

outcome. Thus, the results for objects parallel those obtained for locations. Both are encoded

during reading and available for later processing. Furthermore, they are reinstated at a later point in the text when and only when they are causally relevant.

<div align="center">Discussion</div>

The results from five experiments demonstrate that during reading information concerning spatial relations is reactivated when needed for causal coherence. The results of Experiments 2b and 3b suggest that these activations were indeed *re*-activations. They were not the result of simple maintenance in working memory: neither object nor location were activated prior to the outcome sentence. Furthermore, the fact that object and location information was reinstated implies that the association was encoded at some level during initial reading. This spatial association was accessible during reading of the remainder of the narrative although it was only re-activated when *needed* for coherence.

It is conceivable that activation of the targets in the experimental condition (when probed after the critical sentence) could have been obtained if there were maintenance of the spatial information before the critical sentence. In the present study the relation between object and location (i.e. ticket stub in Mark's pocket) could have remained more available (than neutral information) seeing as it might be considered an unfulfilled goal or condition with consequences. Such maintenance has been observed for unsatisfied goals, resulting in greater availability of these goals relative to completed goals (Lutz & Radvansky, 1997). However, this possibility did not extend to the spatial information in our studies. In Experiments 3a and 3b, participants responded significantly more slowly to object targets presented before the outcome than to those presented after the outcome. This pattern of results does not support an interpretation that the objects related to an unfulfilled goal were continuously maintained in memory until the critical outcome, promoting shorter response times to the target. Furthermore, in those experiments in which participants were probed with the target *before* the outcome sentence (2b and 3b), response times to targets in the control and causally relevant conditions did not differ. This also suggests that the

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spatial information (potential unfulfilled goal) was not maintained immediately prior to the

outcome, else one would have expected to observe shorter response times to the probe in the

causal condition relative to the control condition.

Another possible explanation is that our results reflect decreased availability of the

spatial information in the control texts rather than increased availability of the spatial information

in the experimental texts[2]. With respect to goals, for instance, Lutz and Radvansky (1997)

observed that failed goal information remained more available than completed goal information,

and concluded that this was due to "both an increased availability of failed goal information and a

decreased availability of completed goal information (relative to failed goal information)" (p.

308). Additional evidence has supported the notion that readers suppress irrelevant information

during reading (e.g., Gernsbacher & Faust, 1991; Gernsbacher, Keysar, Robertson, Werner, 2001;

Linderholm, Gernsbacher, van den Broek, Neninde, Robertson, Sundermeier, 2004). Therefore, it

is possible that the outcome sentence in the control condition in these experiments might have led

the reader away from thinking about the target spatial information because it was no longer

relevant, decreasing its availability. However, there was a negligible difference between

responses to the object and location probes before versus after the outcome in the control versions

of the text[3]. Therefore, suppression alone does not adequately account for the results in the

current study because there was no decrease in availability of location and object information in

the control text versions.

Our results and interpretations are consistent with existing models of text comprehension.

For example, the conclusion that spatial information may be encoded and may be retrievable at

later points in reading without having been maintained in short-term memory is compatible with

notions of long-term working memory (Ericsson & Kintsch, 1995), of implicit focus on

information connected to the protagonist in a story (Garrod & Sanford, 1990), and with resonance

theories of text representation and retrieval (Myers & O'Brien, 1998; O'Brien, Raney, Albrecht, &

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Rayner, 1997). Indeed, of the many dimensions of textual information that readers may track during reading, spatial information is most likely to be encoded at relatively low levels (Zwaan, Langston, & Graesser, 1995). The finding that this information is reactivated when needed for coherence is compatible with other models of comprehension such as the Landscape model in which the activation of information at each point during reading is a function of the current text input, strength of encoding of earlier information, and—relevant to the current study—the function that information fulfills in establishing coherence (van den Broek, Young, Tzeng, & Linderholm, 1999).

The conclusion that causal relevance determines the re-activation of previously read spatial information allows us to better answer the question concerning the circumstances in which readers represent and update spatial information while reading a text. Whereas instructions and reader goals can influence the availability of spatial information, it is also likely that the functionality of spatial information in a text can influence its availability. According to the functionality principle, readers are more likely to incorporate spatial information into their situation model if the spatial relations are functional (Radvansky & Copeland, 2000; see also Carlson-Radvansky & Radvansky, 1996). Consistent with these earlier findings, our results suggest that in the absence of certain specific instructions or goals, non-elaborated spatial information is re-activated during reading only if it is functional, for instance when it establishes causal coherence.

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Appendix

Sample story used in all experiments

It was a crisp morning with a chill in the air and frost on the trees. However the sun was bright and streaming through the window of the Nielsen's bedroom. The light shone on Mark, whose sleep was being greatly disturbed by this dawn, and his eyes were forced to open and greet a new day. Now Mark couldn't help smelling the scent of bacon and toast downstairs. As he looked to a bundle of empty sheets next to him, he realized that his wife June was preparing breakfast. The couple chatted while they ate and soon Mark realized he had to go to work. At work, Mark quickly dodged into his office to get away from the crowd. He was surprised to see someone in his chair. It was Gena, and the two talked about their plans to go out to this exquisite restaurant and then a play tonight.   The date was set. After eating lobster at the restaurant, Gena and Mark went to Macbeth.   They entered the large auditorium, got their reserved tickets at the counter, and headed to the doors.

[control version]

Mark stuffed his gloves in his pants pocket so that he could have both hands free to help Gena take off her beautiful shiny fur. Gena put their ticket stubs in her purse.

[causal version]

Mark stuffed their ticket stubs in his pants pocket so that he could have both hands free to help Gena take off her beautiful shiny fur. Gena put her gloves into her purse.

Then they took a seat near the middle of the theater. The play was excellent. Exhausted by a long day at work followed by this cultural experience, Mark and Gena parted ways, kissed passionately, and went to their homes. The next morning was frigid and foggy. The sun did not awaken Mark.

[PROBE BEFORE]

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Instead, he was startled by his wife's voice coming from the laundry room which was getting

closer and closer, "Mark, you are seeing another woman!"

[PROBE AFTER]

*** pocket ***   [location probe]

*** ticket ***   [object probe]

Question: Did Mark and Gena spend the night together?

Note. Location probes were used in Experiments 1, 2a, and 2b. Object probes were used in

Experiments 3a and 3b. The critical sentences are italicized here only for the purposes of

illustration.

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Footnotes

[1] Two additional experiments were conducted in which speed was emphasized more than accuracy in the instructions to participants. There was a significant 10% difference in accuracy rates to targets in experimental vs. control conditions when probed after the critical sentence. When probed before the critical sentence there was a non-significant 1% difference in accuracy rates between experimental and control conditions. In these experiments, there were no significant differences in response times. These results on accuracy provide convergent evidence for those obtained for response times in Experiments 2a and 2b.

[2] We thank Arthur Glenberg for suggesting this possibility.

[3] The difference in response times to targets presented before and after the outcome sentences in the control (non-causal) version was not significant, all t's < 1.

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Table 1

Mean Response Times in Milliseconds and Mean Accuracy Rates

for Probe Words in Experiments 2 and 3.

	Experimental		Control	
Experiment	M	SD	M	SD
Response Times				
Location probe				
after outcome (2a)	1220	290	1312	317
before outcome (2b)	1296	287	1307	303
Object probe				
after outcome (3a)	1119	226	1208	260
before outcome (3b)	1207	240	1203	241
Accuracy Rates				
Location probe				
after outcome (2a)	.86	.19	.88	.13
before outcome (2b)	.90	.22	.87	.23
Object probe				
after outcome (3a)	.94	.25	.94	.27
before outcome (3b)	.95	.23	.94	.25