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Temporal changes as event boundaries: Processing and memory consequences of narrative time shifts ☆

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Abstract

Readers comprehend narrative texts by constructing a series of mental models of the situations described in the text. These models are updated when readers encounter information indicating that the current model is no longer relevant, such as a change in narrative time. The results of four experiments suggest that readers perceive temporal changes in narrative texts as event boundaries, and that when a temporal change is encountered during reading, readers are slower and less able to accurately retrieve prior information from memory. However, the slower responses following temporal changes may be due to processing costs associated with the temporal change, rather than decreased availability in memory. The results of these experiments suggest that readers may use event boundaries as a means for controlling the contents of memory.

Keywords: Situation models; Event perception; Memory; Text comprehension

When readers are trying to comprehend a text, they construct models of what the text is about (see Zwaan & Radvansky, 1998, for a review). These models have been studied under the rubrics of schemata (Rumelhart, 1977; Rumelhart & Ortony, 1977), scripts (Schank & Abelson, 1977), mental models (Johnson-Laird, 1983), and situation models (van Dijk & Kintsch, 1983). The current series of studies focuses on situation models, which are representations of a particular situation at a particular point in a text.

Situation models are said to capture information about a number of different dimensions of the narrated situation, such as the spatial and temporal location of an event, the characters and objects present, characters' intentions and goals, and the causal relations between characters and objects (Gernsbacher, 1990; Zwaan & Radvansky, 1998). Situation models are not simply images of the characters, etc., in a given scene, but are thought to be representations that capture the relations between components of the scene (Johnson-Laird, 1983). That is, they are not simply a series of static "snapshots," but are instead structured representations with an

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arrangement of components that corresponds to the real-world structure of the situation. These models are necessarily finite, and actively maintain a limited amount of locally relevant material at any given point in time (e.g., O'Brien, Rizzella, Albrecht, & Halleran, 1998). Situation models do not represent everything that has been mentioned in a story, but incorporate only information that is relevant to the understanding of the situation at hand.

Understanding that a situation model represents a spatially and temporally bounded event leads to a strong prediction about the sorts of variables that should influence the construction of situation models during text comprehension. Specifically, readers should update situation models whenever the text indicates that something in the situation has changed significantly, where significance depends on previous experiences with similar events (Zwaan & Radvansky, 1998). For example, if a person is reading about a woman watching a movie, and then reads a sentence such as, "Seven hours later she was fast asleep," the reader should update his or her situation model based on the general knowledge that movies rarely last more than 2–3 h (Anderson, Garrod, & Sanford, 1983). This dependency of situation model construction on real-world experience and knowledge of real-world events suggests that reading about events should be tied to the perception of events in the real world, and that the perception of events in the real world should be structured in such a way as to facilitate this breakdown of activity.

The prediction that readers should explicitly structure text such that the boundaries of narrated events correspond to the boundaries of real-world events is consistent with a number of current models of text comprehension (Kintsch, 1988; O'Brien & Myers, 1999; O'Brien et al., 1998; Zwaan, 2004; Zwaan & Radvansky, 1998). However, the claim that readers should explicitly perceive boundaries in narrated events is entailed by only two of these theories: the event-indexing model (Zwaan, 1999; Zwaan & Radvansky, 1998), and the immersed experiencer model (Zwaan, 2004). Both of these models rely on the assumptions that readers parse text into a series of discrete events in order to construct a coherent representation of the activities described by the text, and that this parsing of activity is dependent on real-world experience with and general knowledge about the structure of events.

The view from narrative comprehension that a continuous discourse is interpreted as a string of discrete events echoes proposals from linguistics. The semantics of events and their parts can be accounted for by models developed to account for objects and their parts (Jackendoff, 1991). Syntactic constructions for describing events are thought to reflect conceptual structures in which events are represented as discrete entities, and grammatical structures allow speakers to refer to the contents of a single event or package multiple events into larger structures (Bohnemeyer, Enfield, Essegbey, & Kita, 2004). These proposals provide accounts of features of event language including aspectual structure, which differentiates constructions such as "is climbing" from "climbs" (Landman, 1992; Moens & Steedman, 1988; Parsons, 1990).

The view that continuous discourse is interpreted as a string of discrete events also echoes results from the perception of real-world events. Research on the perceptual structure of real-world activities suggests that people can and do segment ongoing everyday activities into discrete events. One technique for studying the structure of perceived events involves asking observers to watch movies of everyday activities and segment them into meaningful units of activity (Newtson, 1973). Observers agree to some extent about the locations of these boundaries between events (Newtson, 1976; Zacks, Tversky, & Iyer, 2001), but there are also reliable individual differences as to where these boundaries occur (Newtson, 1976; Speer, Swallow, & Zacks, 2003).

If the process of constructing a new situation model during narrative comprehension depends on segmentation processes similar to those observed in the perception of real-world events, then readers should perceive changes in the various dimensions of situation models (time, space, etc.) as event boundaries between consecutive events. This explicit perception of temporal and spatial changes as event boundaries has been observed in studies using clips from films (Magliano, Miller, & Zwaan, 2001), but has not been observed during text comprehension.

A number of researchers have now suggested that situation changes should modulate readers' memory for the objects, locations, etc., in narrative texts (see Zwaan & Radvansky, 1998, for a review). That is, when readers encounter a break in any of the various dimensions of a situation model, they may form a new situation model, or shift the focus of the model to a new aspect of the situation. If readers construct new situation models when the narrated events move beyond the boundaries of real-world events during reading, then encountering an event boundary should reduce the speed and accuracy with which previously presented information is accessed from memory.

This hypothesis has received indirect support from previous studies in which readers have been slower to retrieve previously mentioned objects following changes in characters, time, or spatial location (Glenberg, Meyer, & Lindem, 1987; Rinck & Bower, 2000; Rinck, Hähnel, Bower, & Glowalla, 1997; Rinck & Weber, 2003; Zwaan, 1996; Zwaan, Madden, & Whitten, 2000). For example, one study asked participants to read a sentence that changed the narrative time (e.g., "An hour later…"), or held it relatively constant (e.g., "A moment later…"), and then presented a word that had been presented prior to the temporal reference (Zwaan, 1996). Readers were slower to identify the word following "An hour later" than following "A moment later," suggesting that the temporal change led readers to build a new situation model. In a similar study using changes in spatial location (Rinck & Bower, 2000), readers first memorized a map of a building containing a number of objects in various locations, then read brief stories describing a character's path through the building. When the character had moved to a new location, readers were slower to verify the origin of objects related to prior locations, suggesting that readers had constructed new situation models based on the character's change in location.

Although these sorts of studies have found evidence that readers are slower to identify prior information following changes in various situation model dimensions, they have not tested whether changes in situation model dimensions reduce readers' abilities to accurately retrieve prior information. In addition, they have not presented evidence that readers use these types of changes to structure their reading and understanding of the situations described in the text.

The studies reported here focused only on changes in the temporal dimension of narrative texts to test the hypotheses that temporal changes are explicitly perceived as event boundaries, and that these event boundaries have consequences for the memory of information presented prior to the temporal change. These hypotheses were tested in a series of four experiments using a naturalistic reading paradigm. The first experiment tested the hypothesis that temporal changes would be explicitly perceived as boundaries between meaningful units of activity. The second experiment tested the hypothesis that encountering this type of event boundary would adversely affect readers' ability to accurately remember prior information. The third experiment used a non-intrusive reading time measure as a converging test of this hypothesis, and the fourth experiment demonstrated that response time measures in these and similar paradigms are not necessarily measuring memory retrieval processes.

Experiment 1

The first experiment used an event segmentation procedure to test the hypothesis that temporal changes in narrative text are explicitly perceived as event boundaries. In a typical event segmentation paradigm, participants watch a movie of an everyday event, and are asked to segment the activity in the movie by pressing a button when they believe one meaningful unit of activity ends and another begins (Newtson, 1973). This segmentation procedure has been shown to reliably measure perceptual event boundaries in movies of everyday events (Newtson, 1976; Speer et al., 2003). To the extent that the cognitive processes involved in perceiving discrete events in movies are similar to those involved in perceiving discrete events in narrative text, this procedure should generalize to identifying event boundaries in narrative text.

Participants in the first experiment read a series of continuous narrative texts describing everyday events. While reading the narratives, participants were asked to identify the points where they believed one meaningful unit of activity ended and another began. The situation model view makes two predictions regarding the relationship between temporal changes and event boundaries. First, if temporal changes in narrative text are perceived as event boundaries, then participants should be most likely to identify those boundaries immediately prior to a temporal change. Second, if time is a salient dimension of situation model construction, then sentences containing temporal references (e.g., "A moment later…") should be more likely to be identified as event boundaries than other sentences in the narratives.

Method

Participants

Thirty-six participants (ages 18–34, 23 women) volunteered to participate in Experiment 1 for course credit or a $10/h stipend. Another five participants failed to complete the study according to the task instructions and were excluded from the analyses. Informed consent was obtained in accordance with the guidelines set by the Human Studies Committee at Washington University.

Materials

Ten short narratives were used in Experiment 1. The narratives each contained 25 sentences, and followed a single character through an everyday activity. (Materials for this and all following studies can be found online at http://iac.wustl.edu/~dclweb/stimuli.html). Each narrative was presented as a single paragraph, on one side of a single piece of paper, and participants used a pen to draw a line between two words at the points they perceived as event boundaries.

Design and procedure

Each narrative used in this and all following studies consisted of six trials made up of four types of sentences: *object*, *time-shift*, *anaphor*, and *introduction* (see the top panel of Fig. 1 for an example of a trial from the "camping" narrative). The purpose of the object sentences was to present a critical object that would be referred to in the anaphor sentence. The purpose of the time-shift sentences was to change the narrative time ("An hour later…") or leave it relatively constant ("A moment later…"). The anaphor sentence contained an anaphoric reference to the critical object presented in

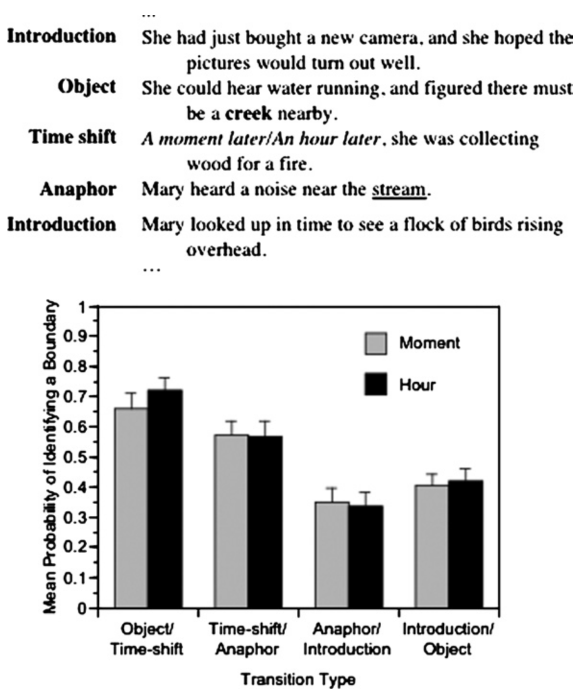

Fig. 1. The top panel shows the format of the trials, broken down into the different sentence types to highlight the narrative structure. The bottom panel shows that participants were most likely to perceive event boundaries at the object/time-shift transition, and they perceived more event boundaries at these transitions when they preceded "An hour later…" than when they preceded "A moment later…" Error bars in all figures represent standard errors.

the object sentence. A pilot experiment determined that participants accurately identified the anaphoric references with the appropriate critical objects.[1] In Experiments 3 and 4, these anaphor sentences were used to test the availability in memory of the critical object from the object sentence. The purpose of the introduction sentences was to prepare the reader for the next trial, by introducing the novel information required to move the stories along.

The narratives did not contain major changes in the characters' locations nor in the characters' higher-order goals, but minor changes in other dimensions were necessary to form a cohesive narrative (e.g., changing the objects with which the characters were interacting); these changes were limited to the less critical introduction sentences. Following an initial sentence that introduced the character and the main goal of the story, this sequence of four sentences (a trial) repeated six times within each narrative. In Experiment 1, the critical feature of these narratives was the presence or absence of a temporal change in the time-shift sentences. During debriefing, none of the participants in this or any of the latter experiments reported that they had noticed the trial structure, nor did they report any problems in comprehending the narratives.

To insure that "An hour later…" and "A moment later…" appeared equally often for every time-shift sentence across participants, two sets of the 10 narratives were produced. To construct the first set, each narrative was randomly assigned a set order of temporal changes (e.g., hour, moment, moment, hour, hour, and moment). The second set was constructed by reversing this assignment (e.g., moment, hour, hour, moment, moment, and hour). Each participant was randomly assigned to one of the two sets.

After providing informed consent, participants were given a packet of narratives. Participants were instructed to read each narrative one at a time, and to place a line between two words whenever they thought one unit of meaningful activity ended and another began. They were informed that there was no right or wrong way to do this task, and that the experimenters were simply interested in where the participants thought one meaningful unit of activity ended and another began.

Scoring and analysis

Unsurprisingly, participants chose to place the majority of event boundaries at periods, where one sentence ended and the next began. This pattern was consistent across participants, with an average of 88% of participants' event boundaries placed at sentence boundaries. To simplify reporting, only those segment boundaries identified at sentence boundaries were used in the analysis. For each participant, the probability of placing segment boundaries at the transitions between each type of sentence (object/time-shift, time-shift/anaphor, anaphor/introduction, and introduction/object) was calculated for each temporal change condition ("A moment later…" and "An hour later…"). A 2×4 repeated measures analysis of variance (ANOVA) tested the effects of temporal change ("A moment later…" and "An hour later…") and transition type (object/time-shift, time-shift/anaphor, anaphor/introduction, and introduction/object) on the perception of event boundaries. This analysis was conducted with participants and narratives as random factors to insure the generalizability of results across stories as well as participants (Clark, 1973). For ease of reporting, t_P and F_P refer to the statistics from the analysis by participants, and t_N and F_N refer to the statistics from the

[1] Twenty participants were given printed versions of the narratives used in the current experiments, with the anaphoric references, as well as three additional nouns, underlined. For each of the underlined words, participants were instructed to identify the word in the narrative that was the referent of the underlined word. Participants accurately identified referents for an average of 96% ($SEM = 0.61$) of the anaphoric references, and identified referents for only 8.67% ($SEM = 2.23$) of the additional, non-anaphor underlined words.

analysis by narratives. α was set at .05 for all statistical tests in this and all following experiments.

Results

The bottom panel of Fig. 1 shows the mean probability of perceiving event boundaries for each of the two temporal change conditions, at each of the four types of sentence transitions. The object/time-shift transition produced the highest probability of identifying segment boundaries, followed by the time-shift/anaphor transition, the introduction/object transition, and the anaphor/introduction transition. These differences were statistically significant, $F_P(3,105) = 36.18$, $p < .001$, $F_N(3,27) = 99.91$, $p < .001$, and simple effects tests showed that each type of transition was reliably different from the other three types of transitions.

There was a non-significant trend for a higher probability of identifying segment boundaries in the hour condition than in the moment condition across all transition types, $F_P(1,35) = 3.47$, $p = .07$, $F_N(1,9) = 3.02$, $p = .12$. However, this effect was driven by the difference between the hour and moment conditions in the object/time-shift transition, leading to a reliable interaction between transition type and temporal change, $F_P(3,105) = 2.93$, $p = .04$, $F_N(3,37) = 3.02$, $p = .05$: there was a reliable difference between the moment and hour conditions only at the object/time-shift sentence transition, $t_P(35) = 2.82$, $p = .01$, next largest $t_P(35) = -.74$, $p = .47$, $t_N(9) = 2.90$, $p = .02$ (next largest $t(9) = 1.09$, $p = .30$).

Discussion

The results of Experiment 1 suggest that readers perceive changes in narrative time as event boundaries. Participants were more likely to mark event boundaries preceding "An hour later…" than preceding "A moment later…" In addition, participants were more likely to mark event boundaries preceding any temporal change, compared to other types of sentences. In evaluating these two effects, it is important to emphasize that the first was tightly controlled by changing "A moment later…" to "An hour later…," while holding the surrounding story context constant, whereas the second may reflect incidental differences between the temporal change sentences and other sentences (i.e., item effects).

The finding that readers were more likely to identify an event boundary preceding a temporal change complements previous studies that have observed slower reading times for sentences that contain temporal changes relative to sentences that do not contain temporal changes (Anderson et al., 1983; Rinck & Weber, 2003; Zwaan, 1996). It is important to note that all of the activities in the current set of narratives were constructed such that the events described typically lasted minutes, rather than hours or days. This construction was critical to insure that the temporal changes would lead readers to update their situation models. As others have shown, the ability of the temporal changes to initiate situation model updating depends critically on the expected duration of the narrated situation (Anderson et al., 1983).

The results of the current study suggest that effects of temporal changes on reading time may be due to processing that occurs when a temporal change is identified as the boundary point between two events. When people were asked to explicitly identify perceptual units of activity in the narratives, they were able to do so, and identified boundaries between the units at exactly the points that were predicted by recent models of text comprehension (Zwaan, 2004; Zwaan & Radvansky, 1998).

Experiment 2

In standard memory paradigms involving the retention of lists of words or digits, it is well established that greater amounts of intervening information, rather than a longer duration, between an item and its subsequent reappearance lead to a greater likelihood that the original information will be forgotten (Waugh & Norman, 1965). However, the situation model view advocated here suggests that in narrative reading, it may be that *neither* time nor the sheer amount of intervening information is the critical determinant of memory. Rather, when reading a narrative text, the availability of information in memory should depend on whether or not that information is related to the current situation model. Information that is related to the current model should be maintained in an active state in working memory, where it is readily available to aid in comprehension, whereas information related to the story as a whole but not the current situation should be maintained in a more permanent and less accessible memory store, such as long-term working memory (Ericsson & Kintsch, 1995; Ericsson & Delaney, 1999)—if it is maintained at all.

This view makes an interesting and testable prediction for narrative comprehension: The number of intervening sentences between the first mention of story-relevant information and a subsequent reference to that information should have little effect on the availability of that information in memory. Rather, the primary determinant of the availability of prior information should be whether or not the information is related to the current event. Several studies have shown that participants are slower to respond to identify objects that are spatially or temporally dissociated from the current narrative situation (Glenberg et al., 1987; Rinck et al., 1997; Zwaan, 1996; Zwaan & Radvansky, 1998), and the results of one recent study have suggested that situation changes can have more powerful effects on memory retrieval speed than the number of intervening sentences (Rinck & Bower, 2000). However, these previous studies share two important methodological features. First, they used response latency as the primary measure of memory availability. Second, these studies were arranged such that memory trials following the situation changes always presented information that required a "yes" response. In studies that used yes/no recognition (e.g., Zwaan, 1996), the tested object had been previously presented in the story, and for those studies in which participants verified the location of an object, the object–location pair was always correct (e.g., Rinck & Bower, 2000). These features allowed the experimenters to optimize detection power for effects on response time, but they fail to provide an assessment of memory accuracy. In such paradigms, it is possible that participants responded more slowly following temporal or spatial shifts due to the processing of the shift itself. To establish that changes in situation model dimensions affect the retrieval of previous mentioned information, it is important to test whether memory accuracy is reduced following a change in a situation model dimension. The current experiment tested memory accuracy using a yes/no recognition paradigm in which temporal changes, as well as the number of intervening sentences between the mention of the critical object and the memory test, were varied.

Method

Participants

Forty-one undergraduates (ages 18–21, 27 women) volunteered to participate in this study for course credit or a $10/h cash stipend. Informed consent was obtained in accordance with the guidelines set by the Human Studies Committee at Washington University.

Materials

The original 10 narratives used in Experiment 1 were used in Experiment 2, with an additional 10 narratives to increase the power of the design. As in Experiment 1, each narrative contained six trials, composed of an object, a time-shift, an anaphor, and an introduction sentence. In addition to these sentences, trials in Experiment 2 also contained 0, 1, or 3 filler sentences between the object and time-shift sentences (see Fig. 2). These filler sentences were constructed around characters' thoughts and intentions, or around more detailed descriptions of the story, rather than around events that would require the passage of a large amount of narrative time or a change in the characters' locations.

To test the availability of information in memory, old and new probe words were added to each trial within the narratives. Within each narrative, these old and new probe words were matched on frequency, concreteness, familiarity, imageability, number of letters, and number of syllables using the MRC Psycholinguistic Database

	…
Introduction	She had just bought a new camera, and she hoped the pictures would turn out well.
Non-Critical Probe	football
Object	She could hear water running, and figured there must be a **creek** nearby.
Fillers (0, 1, or 3)	It was fairly warm outside, but Mary knew it would be much cooler during the night.
	She had brought an extra blanket to keep herself warm.
	Although she had not liked carrying the extra weight on her hike, she knew she would appreciate it later.
Time shift	*A moment later/An hour later*, she was collecting wood for a fire.
Critical Probe	creek
Anaphor	Mary heard a noise near the stream.
Introduction	Mary looked up in time to see a flock of birds rising overhead.
Non-Critical Probe	birds
	…

Fig. 2. Trials in Experiment 2 were similar to those in Experiment 1, with the addition of filler sentences and probe words (e.g., "creek"). Participants were asked to respond to probe words based on whether or not they remembered seeing the probe word in any of the preceding sentences.

(Wilson, 1988). When it was possible to match the critical objects with a new probe word on these variables, the critical objects were used as old probe words. The stories were presented using PsyScope software (Cohen, MacWhinney, Flatt, & Provost, 1993) running on a Power Macintosh G3 (Apple, Cupertino, CA). A button box and a computer keyboard were used to record participants' responses.

Design and procedure

The narratives were presented one sentence at a time on the computer screen, and the participants were instructed to read the narratives at their own pace. In addition, participants were told that they would periodically see a single word in green. When they saw one of these words, they were instructed to press one of two response buttons if the word had appeared in a recent sentence (old), and to press the other button if the word had not appeared in a recent sentence (new). The mapping of the two response buttons was counterbalanced across participants.

The probe words of interest appeared immediately after the time-shift sentences, before the anaphor sentences. The old probe words were nouns taken from the critical object sentence. The new probe words did not appear anywhere in the narratives, and were words that participants had not encountered in previous narratives. Additional probe words were included that followed the introduction sentences, before the critical object sentences, to decrease the chance that participants would notice the structure of the trials. The probe words remained on the screen until the participant's response.

Each narrative contained 12 probe words: six critical probe words following the time-shift sentences, and six non-critical probe words following the introduction sentences. The six non-critical probe words were not included in any analyses. There were an equal number of old and new probe trials within each narrative, equally distributed across the two types of probe words, and the order of the old and new probe words within each narrative was determined randomly for each participant. Because it was impossible to fully counterbalance the design within a single narrative, a full replication of the design occurred across two narratives. Overall, there were 10 trials in each cell of the experimental design. The order of the narratives and the order of the trials within each narrative were determined randomly for each participant. Due to a programming error, the first 15 participants tested did not have a fully counterbalanced design; however, the number of trials contributing to each cell in these participants did not differ by more than three trials, and there were no significant differences in cell counts for these 15 individuals.

After reading each narrative, participants were asked to answer three comprehension questions to test their knowledge of the story. These questions were included to insure that participants were able to comprehend the stories, and that they were paying attention to the stories as they were reading them (rather than only paying attention to the individual words in the sentences for the sake of the probe recognition task). Answers to the 60 comprehension questions were scored for accuracy by two raters, and the proportion of correct responses to the questions was determined by averaging the proportion correct for the two raters. The order of the narratives was determined randomly for each participant.

Analysis and scoring

One participant was excluded from the analysis due to a failure to follow task instructions. Four additional participants were excluded from the analysis due to poor performance on the critical probe trials (less than 60% accuracy in identifying previously presented probe words). The mean accuracy for the comprehension questions was 85.65% ($SEM = 0.73\%$; inter-rater reliability = .91). There were no indications that there were any outlying response times.

After data collection it was noted that some of the sentences contained grammatical errors or clauses that would not make sense in the context of certain filler sentences. These sentences (approximately 10% of the total number of sentences) were removed from the analysis in this experiment, as well as in Experiment 3 (which used the same stimuli as the current experiment). To confirm that elimination of these sentences was not systematic, the number of sentences removed from each cell in the design was analyzed using an ANOVA. There was no evidence to indicate that sentences were systematically removed from any particular cell in the experimental designs.

For each participant, the average proportion of correctly recognized trials was determined for each condition. These accuracy scores were analyzed using a repeated-measures ANOVA, with temporal change ("A moment later…" and "An hour later…"), type of probe word (old and new), and number of intervening sentences (0, 1, and 3) as the dependent variables. Average response times to accurate trials were also analyzed for each participant, using the same ANOVA structure as the accuracy analysis. One participant in the response time analysis did not have any correct responses in one cell of the design, and the mean group response time for that cell was entered in place of the missing score. As before, all analyses were conducted with participants and narratives as random factors.

Results

The proportions of correct responses to the probe words following the time-shift sentences are shown broken down by condition in the top panel of Fig. 3. Probe words following "A moment later…" were recognized more accurately than probe words following "An hour later…," $F_P(1,34) = 4.05$, $p = .05$, $F_N(1,19) = 4.42$, $p = .05$. In addition, accuracy decreased with increasing numbers of filler sentences, $F_P(2,68) = 24.62$, $p < .001$, $F_N(2,38) = 17.86$, $p < .001$. Accuracy in rejecting new probe words was at ceiling, leading to a greater proportion of accurate responses to new probe words than to old probe words, as well as statistically significant effects of temporal changes and number of intervening sentences only for old probe words (smallest $F = 5.04$, $p = .04$). Neither the interaction of temporal change and number of intervening sentences, nor the three-way interaction reached statistical significance (largest $F = 1.84$, $p = .17$). (Note that the proportion of correct responses is not a bias-free measure of accuracy. However, in this case the proportion of correct rejections of new probe words was very high and did not change across conditions, so the proportion of correct identifications of old probe words is equivalent to a bias-free measure such as a-prime or d-prime.)

Response times to correct probe trials are shown in the bottom panel of Fig. 3. In contrast to the accuracy analysis, there was not a significant main effect of temporal change on response times, nor was there a significant interaction with the number of intervening sentences or the type of probe word (largest $F = 3.11$, $p = .09$). Response times to correctly identified old probe words were slower than response times to correctly rejected new probe words, and response times to correctly identified probe words increased with increasing numbers of intervening sentences (smallest $F = 21.99$, $p < .001$). However, these effects were qualified by a reliable interaction

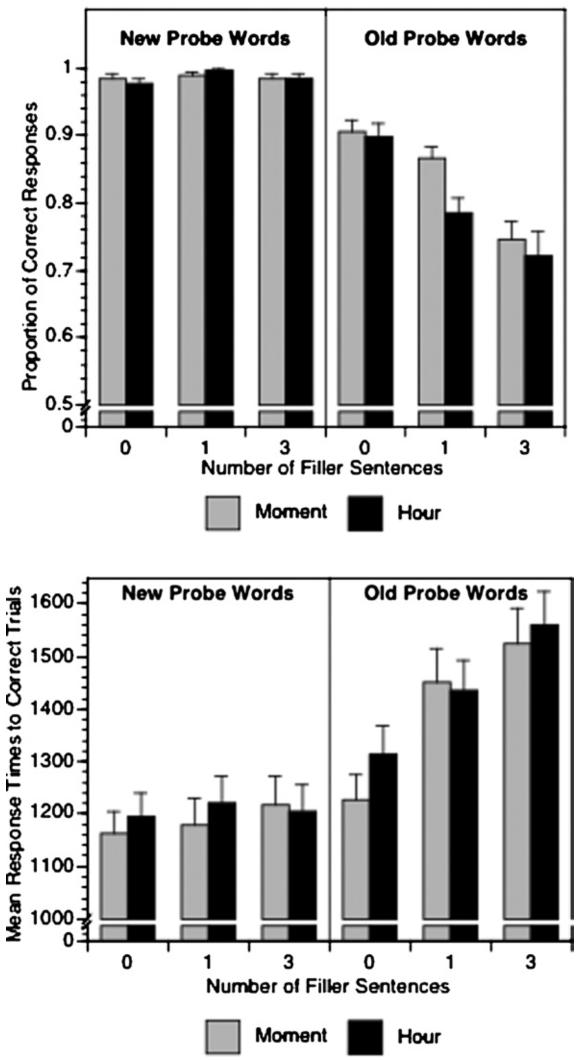

Fig. 3. The top panel shows that accurate responses to probe trials in Experiment 2 were affected by both the presence of a temporal change and the amount of intervening information. The bottom panel shows that mean response times to accurately recognized probe words increased with greater numbers of intervening sentences, but the effect of temporal change was reliable only in the 0-filler condition.

such that the number of intervening sentences influenced response times only for correctly identified old probe words, $F_P(1,34) = 17.37$, $p < .001$, $F_N(1,19) = 25.24$, $p < .001$. The three-way interaction failed to reach statistical significance, $F_P(2,68) = .05$, $p = .82$, $F_N(2,38) = .85$, $p = .44$.

Based on the a priori prediction that response times to probe words would show an influence of temporal change (e.g., Rinck & Bower, 2000), additional *t* tests tested for effects of temporal change on response times to probe words in the 0-, 1-, and 3-filler conditions. These *t* tests showed that in the 0-filler condition response times to correctly identify probe words were significantly slower following "An hour later…" than following "A moment later…" in the analysis by participants, $t_P(34) = 2.64$, $p = .01$, and this effect approached statistical significance in the analysis by narratives, $t_N(19) = 1.68$, $p = .11$. With any number of intervening sentences, response times to correctly recognized probe words did not depend on the presence of a temporal change (largest $t = .86$, $p = .40$).

Discussion

Whereas previous studies have focused on measuring the speed with which information is retrieved following a temporal change, the current experiment focused on the likelihood that prior information is forgotten following a temporal change. This question of whether information prior to a temporal change is more likely to be forgotten is separate from the question of whether information prior to a temporal change is less available: Information related to a previous model may be less available in memory, but may still be able to be retrieved given sufficient retrieval time.

The results of the current study suggest that temporal changes influence the accuracy of the retrieval process, as well as the speed with which prior information can be retrieved. Participants were less able to recognize a previously presented word when a temporal change intervened between the first presentation of the word and the subsequent memory test, and they were slower to make this recognition decision following a temporal change.

It is surprising that the number of intervening sentences produced a large effect on both the accuracy and response time measures. Using an explicit memory test, Rinck and Bower (2000) failed to find an effect of the number of intervening sentences on response times, and observed a large effect of temporal change on response times following up to six intervening sentences. One possible explanation for the difference between the studies is that participants in the Rinck and Bower study may have generated richer situation models, leading to stronger effects of temporal change on availability. In that study, participants memorized the layout of a building, and used these mental maps to help them construct situation models when reading about a character traveling through the memorized building. During the test phase, participants made judgments in which they had to use the memorized layout of the building to guide their responses, rather than simply judging whether or not an item was present in the text itself.

The addition of the explicit memory test in Experiment 2 may have encouraged readers to focus on the text-base, rather than focus on generating detailed situation models, because they were able to respond solely on the basis of whether that word was recently presented in the story. In the same way, the awkward sentences in the stimuli may have led readers to construct poorer situation models than those of the readers in previous studies. However, two points argue against these interpretations. First, participants scored relatively high on the comprehension tests, indicating that they were reading and comprehending the narratives. Second, the temporal changes had an influence on retrieval accuracy. If participants were not processing the temporal changes as such, then there should not have been an influence of temporal changes on memory performance.

Experiment 3

The results of Experiment 2 establish that temporal changes in narratives can influence the ability to retrieve prior information from memory. However, the explicit recognition paradigm used in Experiment 2 and in studies by other researchers differs in many ways from the normal process of reading. To generalize the results of these studies to discourse comprehension, it is necessary to know whether temporal changes influence memory retrieval in ongoing discourse. Therefore, the current experiment used anaphoric references to obtain an online measure of memory availability. This design was based on the hypothesis that to comprehend an anaphoric reference, readers must access the memory representation of the object to which the anaphor referred. If the mention of the object and the anaphoric reference are separated by a temporal change, and temporal changes influence the availability of the object in memory, anaphor reading times should be slowed following a temporal change. A similar hypothesis was tested by Anderson et al. (1983), but that study failed to produce conclusive results.

Like Experiment 2, the current study contrasted the effects of temporal changes and the number of intervening sentences on memory for previously presented information. If the amount of intervening information has a large effect on the availability of information in memory when reading narrative text, then reading times for sentences containing anaphoric references should be modulated by the number of intervening filler sentences between the object and time-shift sentences. However, if the presence of temporal change decreases the availability of information in memory, then reading times for sentences containing anaphoric references should be modulated by the presence of a temporal change, regardless of the number of intervening sentences.

Method

Participants

Thirty-six undergraduates volunteered to participate in this study for course credit or a $10/h cash stipend (ages 18–25, 19 women). Informed consent was obtained in accordance with the guidelines set by the Human Studies Committee at Washington University.

Materials

The narratives used in Experiment 3 were identical to those used in Experiment 2, with the exception that there were no probe words (see the top panel of Fig. 4).

Design and procedure

Each participant was instructed to read all 20 narratives at his or her own pace. The narratives were presented one sentence at a time, centered on the computer monitor in 24 point Arial font. They were instructed to press a button as soon as they had finished reading and comprehending each sentence. Participants were again given three comprehension questions following each narrative to ensure that they were paying attention to the stories (inter-rater reliability for the two raters was .96).

Analysis

Accuracy in responding to the comprehension questions was relatively high ($M = 87.96\%$, $SEM = 1.06\%$),

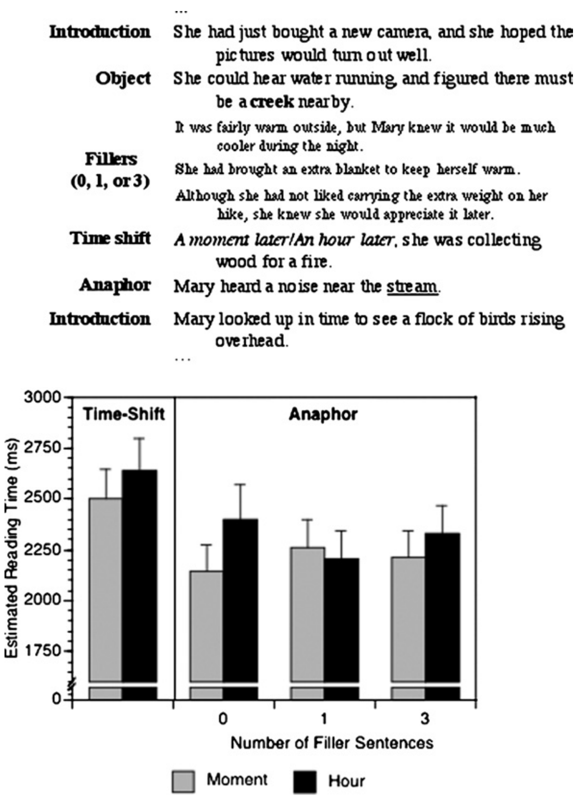

Fig. 4. The format of the trials in Experiment 3 is shown in the top panel. The bottom panel shows that reading times increased following a temporal change, or any number of intervening sentences.

and there was no evidence from these scores that anyone had failed to comprehend the narratives. Inspection of overall sentence reading times revealed only one outlying reading time (46 s to read a timeshift sentence); this reading time was excluded from the analysis of the timeshift sentences. As in the previous experiments, the data were analyzed with participants and narratives as random factors, and the statistics for each analysis are again denoted by the appropriate subscripts.

Linear regression was used to generate estimates of reading speed while controlling for sentence length (Ferreira & Clifton, 1986; Trueswell, Tanenhaus, & Garnsey, 1994). For each of the 36 participants included in the analyses (analysis by participants), and for each of the 20 narratives (analysis by narratives), two linear regressions were carried out predicting reading times for each sentence based on the number of syllables in that sentence. One regression predicted reading times for the timeshift sentences, and the other regression predicted reading times for the anaphor sentences. The residuals from these regressions were averaged within each timeshift condition for the timeshift sentences, and within each of the six design cells for each participant for the anaphor sentences. The average residuals for the timeshift sentences were subjected to a paired-samples *t* test with timeshift as the independent variable, and the average residuals for the anaphor sentences were subjected to a 2×3 within subjects ANOVA, with timeshift and number of intervening sentences as the two independent variables. To simplify interpretation of the results, the graph in Fig. 4 reflects estimated response times for sentences of mean syllable length. These response times were generated for each condition by estimating the response times for mean-length sentences for each participant based on their regression equation, and then adding their mean residual for a given experimental condition to this mean length response time estimate.

Results

Estimated reading times for the time-shift and anaphor sentences are shown in the bottom panel of Fig. 4. The analysis of the residuals showed that reading rates for the time-shift sentences beginning with "An hour later…" were significantly slower than reading rates for time-shift sentences beginning with "A moment later…," $t_P(35) = 3.06$, $p = .004$, $t_N(19) = 2.51$, $p = .02$.

This effect was mirrored in the anaphor sentences, with the analysis of residuals showing slower reading rates following "An hour later…" than following "A moment later…" $F_P(1,35) = 6.43$, $p = .02$, and $F_N(1,19) = 10.11$, $p = .0005$. The number of intervening sentences by itself did not affect reading rates for the anaphor sentences, $F_P(2,70) = .37$, $p = .69$, $F_N(2,38) = .05$, $p = .95$. However, it did reliably interact with temporal change, $F_P(2,70) = 5.62$, $p = .005$, $F_N(2,38) = 3.79$, $p = .03$. This interaction occurred because only reading rates in the 0-filler condition showed a significant effect of temporal change in both analyses, $t_P(35) = 2.97$, $p = .004$, $t_N(19) = 3.26$, $p = .004$ (the effect in the 3-filler condition was statistically significant only in the analysis by participants, $t_P(35) = 2.04$, $p = .05$, $t_N(19) = 1.76$, $p = .09$).

Discussion

Sentences containing a temporal change were read more slowly than sentences that did not contain a temporal change. This result converges with the results of previous studies (Anderson et al., 1983; Zwaan, 1996; Zwaan et al., 2000), and extends these results to a continuous reading paradigm in which multiple temporal changes are present within a single narrative. Whereas previous studies have placed temporal change sentences only at the end of narratives, where the effects of temporal changes may be amplified by explicit knowledge that the narrative is ending, the current study placed temporal changes throughout the narrative texts. These results demonstrate that temporal changes have an influence on reading times during online comprehension of narrative texts.

The most important experimental hypothesis tested in Experiment 3 concerned the anaphor sentences: that the primary determinant of memory for objects in a narrative is whether the object was mentioned during the current event. Overall reading times for the anaphor sentences provided clear support for this hypothesis. The introduction of a temporal change between the mention of an object and an anaphoric reference to that object slowed reading for the anaphor sentences, but the number of sentences intervening between the two did not by itself influence reading times.

The interaction of temporal change and the number of intervening sentences is consistent with the pattern of response times observed in the previous experiment: Response times to probe words were only influenced by the presence of a temporal change in the absence of intervening information. In addition, introducing filler sentences between the critical object and the subsequent anaphoric reference to that object in the "A moment later…" condition produced a decrease in availability comparable to the overall effect of reading "An hour later…" This effect was non-linear: One intervening sentence appears to be as detrimental to reading times as three intervening sentences, and any number of intervening sentences is as detrimental as a temporal change. The fact that the effect of temporal change was present mainly in the absence of intervening sentences, and that the effect of the filler sentences was non-additive, suggests that the filler sentences themselves may have been far enough off topic to induce readers to update their situation models. (Consistent with this interpretation, filler sentences were read quite slowly; however, this data point could reflect incidental features of the particular filler sentences used here.) This interpretation is supported by recent studies (Rinck & Weber, 2003) demonstrating that a protagonist shift or a spatial shift slowed reading times to the same degree as a combined protagonist and spatial shift.

The reliable main effect of temporal change suggests that event boundaries decrease the availability of prior information in memory. However, there is an alternative explanation for the results obtained in Experiment 2, and those obtained in previous studies (e.g., Anderson et al., 1983; Rinck & Bower, 2000; Zwaan, 1996; Zwaan et al., 2000). There may be costs associated with processing temporal changes that carry over to subsequent tasks (such as reading or responding to a probe word). These processing costs may be due to general cognitive processes, such as shifts of attention, or they may be the result of more specific processes, such as updating situation models. This processing cost explanation has nothing to do with the availability of prior information in memory. Instead it suggests that slower reading times for anaphor sentences, and slower response times to recognize prior information may both result from a slowdown in processing associated with the temporal change that carries over to influence the speed of subsequent processing in the anaphor sentences. It is essential to determine which of these explanations accounts for the slowed reading times and slowed probe recognition times following temporal shifts, since many theories of text comprehension are based in part on the assumption that information is less available after a situation model is updated (e.g., Zwaan & Radvansky, 1998). The fourth experiment was designed to test whether the slower reading times for anaphor sentences following temporal changes are due to a general decrease in processing resources, or due to a change in the availability of the critical object in memory.

Experiment 4

Experiment 2 established that in a direct memory test, accuracy for identifying previously presented objects is reduced following a temporal change, and Experiment 3 found that anaphoric references to those objects were slower following a temporal change. One possibility is that the slower anaphor reading times observed in Experiment 3 are the result of the reduced memory found in Experiment 2. However, an alternative possibility is that the memory accuracy and reading time effects are both caused by the presence of a situation change, but that these two effects are due to two different mechanisms. The reduction in recognition memory accuracy following a temporal change may reflect reduced memory activation, as predicted by the situation model view. However, the slower reading of the anaphor sentences following a temporal shift observed in Experiment 3 and in previous studies using probe recognition times may reflect residual processing of the temporal change itself, rather than reduced memory availability.

If the slower reading of anaphor sentences following temporal changes observed in Experiment 3 is due to memory availability, it should be possible to eliminate that slowing by removing the anaphoric references from the critical sentences. However, if slower reading times for sentences following temporal changes reflect residual processing of the temporal change, then temporal changes should slow reading of subsequent sentences regardless of whether or not they contain anaphoric references. Experiment 4 was conducted to distinguish between these two possibilities. The design was similar to Experiment 3, with two changes: On half of the trials the anaphoric references were removed from the sentences following the timeshift sentences, and to maximize the power of the design, the filler sentences were eliminated.

Method

Participants

Forty participants volunteered to participate in Experiment 4 for course credit or a $10/h stipend (ages 18–40, 23 women). One participant failed to complete the task according to the task instructions and was excluded from the analyses, and seven participants with poor spoken English (all non-native English speakers) were also excluded from the analyses. Informed consent was obtained in accordance with the guidelines set by the Human Studies Committee at Washington University.

Materials, design, and procedure

The narratives used in Experiment 4 were modified versions of those used in Experiment 3. The main differences were that filler sentences were not included in these narratives, and the anaphor sentences were modified such that for each anaphor sentence, an additional sentence was created that did not contain an anaphoric reference. Where necessary, the object and introduction sentences were modified to be consistent with these additional sentences. Critically, each timeshift sentence remained constant regardless of whether or not the following sentence contained an anaphoric reference.

For each narrative, the order of the temporal changes was randomly determined. A second version of the narrative was created that had this order reversed. Each of these two narratives was then assigned to a *reference* condition, in which all the anaphor sentences contained anaphoric references to previous information, and to a *no-reference* condition, in which none of the anaphor sentences contained anaphoric references to previous information. Thus, there were four versions of each narrative used in Experiment 4. The orders and conditions of these narratives were counterbalanced across participants.

The design and procedure for this experiment were similar to those described for Experiment 3. Each participant read 10 narratives in the reference condition, and 10 narratives in the no-reference condition, with each narrative containing three timeshift sentences beginning with "A moment later…" and three timeshift sentences beginning with "An hour later." Following each narrative, participants were again given three questions to test their comprehension of the narratives.

Analysis

Accurate responding for the comprehension questions was relatively high ($M = 84.38\%$, $SD = 7.59\%$; inter-rater reliability = .93). As in Experiment 3, two linear regressions were carried out for each of the 32 participants included in the analyses (analysis by participants), and for each of the 20 narratives (analysis by narratives), to predict reading times for each sentence based on the number of syllables in that sentence. The residuals from these regressions were then averaged within each temporal change condition (moment and hour) for the timeshift sentences, and within each of the four condition × temporal change cells for each participant (non-anaphor-moment, non-anaphor-hour, anaphor-moment, and anaphor-hour) for the anaphor sentences. The residuals for the timeshift sentences were subjected to a paired-samples t test with temporal change as the independent variable, and the residuals for the anaphor sentences were subjected to 2 × 2 within subjects ANOVAs, with condition and temporal change as the two independent variables. To simplify interpretation of the results, the graph in Fig. 5 was generated using the estimation procedure described for Experiment 3.

Results

Estimated reading times for the anaphor and timeshift sentences are shown in Fig. 5. As in the previous experiment, reading rates for the timeshift sentences were slower for sentences containing "*An hour later…*" than for sentences containing "*A moment later…*," $t_P(31) = 4.51, p = .0001$, $t_N(19) = 4.12, p = .0006$.

Mean residuals for the anaphor sentences were larger following "*An hour later…*" than following "*A moment later…*," indicating that reading rates were increased for anaphor sentences that followed a temporal change, $F_P(1,31) = 4.56$, $p = .04$, $F_N(1,19) = 4.68$, $p = .04$. Anaphor sentences in the reference condition were read more slowly than anaphor sentences in the no-reference condition, and this difference was statistically significant in the analysis by participants, $F_P(1,31) = 4.37, p = .04$, but not in the analysis by narratives, $F_N(1,19) = 0.19$, $p = .66$. The effect of temporal changes on reading rates for the anaphor sentences was present in both the reference and no-reference conditions, and there was no evidence for an interaction between these two variables, $F_P(1,31) = .0003, p = .99, F_N(1,19) = .02, p = .89$.

…

Introduction	She had just bought a new camera, and she hoped the pictures would turn out well.
Object	She could hear water running, and figured there must be a **creek** nearby.
Time shift	*A moment later/An hour later*, she was collecting wood for a fire.
Anaphor	Mary heard a noise near the <u>stream/in</u> the sky.
Introduction	Mary looked up in time to see a flock of birds rising overhead.

…

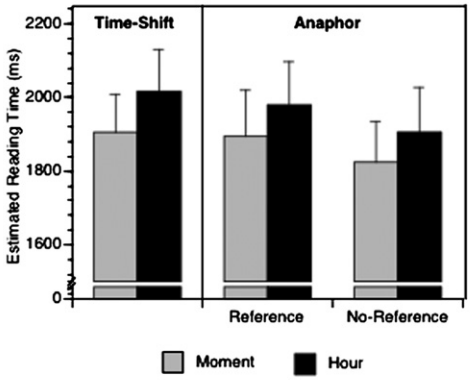

Fig. 5. The format of the trials in Experiment 4 is shown in the top panel. The bottom panel shows that estimated reading times for both reference and no-reference anaphor sentences increased following temporal changes.

Discussion

The results of the current experiment suggest that the slowed reading times for sentences following temporal changes observed in Experiment 3 are not necessarily due to more effortful memory retrieval processes. In the current experiment, sentences that followed a temporal change resulted in slower reading times than sentences that did not follow a temporal change, regardless of whether or not the sentences contained a reference to prior information. These data demonstrate that the presence of a temporal change is sufficient to cause slower reading times in subsequent sentences, regardless of the memory retrieval demands present in those sentences. That is, retrieval demands do not appear to lead to a unique increment in reading times following temporal changes.

These results argue against the interpretation that the effects of event boundaries on anaphor sentence processing in Experiment 3, and in previous studies using response time measures, are necessarily due to retrieval demands. By this account, the effect of temporal changes in Experiment 3 is due to carryover in the processing associated with updating the situation model. In Experiment 3, responses were slowed following either a temporal change or a filler sentence, suggesting that the filler sentences themselves led to situation model updating.

It should be noted that the no-reference anaphor sentences in Experiment 4 still had some connections to prior information, because it is impossible to create a coherent narrative without mentioning certain consistent aspects of the narrated situation (e.g., characters, locations, etc.). However, these references were generally the same in the reference and no-reference conditions, mentioning characters or locations that were present throughout the story. Therefore, even if participants were retrieving some previous information in both the reference and no-reference conditions, reading times for anaphor sentences in the reference condition should have been larger than reading times for anaphor sentences in the no-reference condition. The lack of a reliable interaction between temporal change and reference condition argues against the conclusion that the general slowing observed in reading times for anaphor sentences was due to equivalent retrieval demands.

The general processing costs associated with temporal changes may be due to the extra processes involved in setting up a new situation model, shifting the focus of attention to the new situation, or in readers' conscious elaboration of the story situation to account for the missing story time. These processes may not be completed by the time the reader has moved on to the anaphor sentence, and may therefore interfere with the reader's ability to read and comprehend sentences (or respond to probe items) following temporal changes.

Do these data entail that temporal changes do not affect memory availability? No. In fact, the results from studies in which memory accuracy is used as a dependent measure (e.g., Experiment 2), and from studies in which the response time measure of memory availability is delayed long enough to offset carryover processing costs (e.g., Anderson et al., 1983) suggest that temporal changes do influence the availability of prior information in memory. However, the finding that sentences with no anaphoric references were read more slowly following a temporal change establishes an important negative result: Response slowing following a temporal change is not sufficient by itself to prove reduced memory in narrative reading, when that response slowing could be due to carryover processing costs from previous sentences. This conclusion applies to previous studies of recognition memory using response latency, as well as to the results of Experiment 3.

General discussion

The first goal of the current series of studies was to determine whether readers perceive temporal changes as event boundaries between consecutive episodes of activity in narrative text. The results clearly suggest that they do. Readers were more likely to perceive an event boundary at the points at which a temporal reference indicated a change in narrative time ("An hour later…") than at any other points in the narratives. In addition, they were quite likely to identify event boundaries at these locations even when the temporal reference did not change narrative time ("A moment later…"). Although the present data do not rule out the possibility that this latter effect could be due to incidental differences between the sentences of different types, it suggests that any temporal reference may provide an anchor point for establishing an event boundary. A related possibility is that readers may interpret an author's mention of time as an indication that an important new interval of time has begun, even when the temporal delay is minimal.

The second goal of these studies was to test the hypothesis that, during reading, encountering an event boundary would reduce the availability of recently presented information in memory. This hypothesis was tested by measuring the effects of temporal changes on memory for prior information. The results of Experiment 2 demonstrated that temporal changes decreased readers' ability to accurately retrieve information presented prior to the temporal change. Participants were less likely to correctly identify a word that had appeared in a previous sentence following "An hour later…" than following "A moment later…," and there was some evidence to suggest that they were also slower to respond to these words following a temporal change.

Experiment 3 demonstrated that readers were slower to read sentences that contained anaphoric references to previous information following "An hour later…" than following "A moment later…" At first glance, it appears that these data provide additional support for the hypothesis that temporal changes decrease the availability of information related to previous situation models in memory. However, the results of Experiment 4 leave open the possibility that the reading time measure used in Experiment 3 and in previous studies (e.g., Rinck & Bower, 2000; Zwaan, 1996) may not be measuring memory retrieval processes. Instead, response time measures may be capturing a carryover in processing costs associated with the temporal change. When readers in Experiment 4 read sentences that did not contain additional references to prior information, they were as slowed by a temporal change as they were when they read sentences that contained references to prior information. These results suggest that increased response times following situation changes are not sufficient to conclude that memory retrieval has been impaired by the situation change.

The results of Experiments 2 and 3 support the hypothesis that intervening information and temporal changes both influence the availability of prior information in memory. However, reading times for sentences containing anaphoric references in Experiment 3 did not increase further as the number of filler sentences between the mention of the critical object and its anaphoric reference was increased from one to three. Reading three sentences between encountering the critical object and reading its anaphoric reference slowed reading times to the anaphor sentences to the same degree as reading one intervening sentence. In addition, the increase in reading times following any number of intervening sentences was equivalent to simply reading "An hour later…" rather than "A moment later…" These results suggest that the filler sentences may have induced changes in other situation model dimensions, which led readers to construct new models, or shift the readers' focus away from the protagonist's current goals. A new model or a shift in the focus of an existing model would both serve to increase processing costs and possibly reduce the availability of prior information in memory. The filler sentences generally refer to a character's thoughts or observations, and switching from an external to an internal focus may have led readers to create a new situation model (Clark, 1996). This result poses an interesting question for future studies, as most of the related research has focused on concrete changes in characters, time, and space.

In contrast to the reading time results in Experiment 3, explicit recognition memory in Experiment 2 was strongly influenced by the amount of intervening information between the presentation of an item and a subsequent memory test. The results of these two studies represent a significant dissociation between the processes underlying explicit recognition and ongoing reading, in closely comparable experimental paradigms. It is possible that the degree to which intervening information and temporal changes influence explicit recognition is dependent on the strength of the situation model representation. In previous studies that have not found influences of intervening information on memory availability (e.g., Rinck & Bower, 2000), readers have memorized detailed information about the narrated situation, such as building layouts. This additional information may have led the readers to develop more detailed situation models. It may be the case that increasing the amount of detail readers can use to build situation models influences the relative contributions of intervening information and situation changes to memory retrieval. Future studies should explore this possibility. The dissociation between reading time and recognition measures in Experiments 2 and 3 also carries a methodological implication: Conclusions about ongoing reading from explicit memory tests require assuming that common processes govern the speed and accuracy of both, and these assumptions should be tested when possible.

The data presented here extend previous findings on the use of situation models in text processing (Anderson et al., 1983; Glenberg et al., 1987; Rinck & Bower, 2000; Zwaan, 1996; Zwaan & Radvansky, 1998). By using trials embedded in continuous narratives and by obtaining direct measures of readers' segmentation of the narratives, they form one bridge between perception and text processing. As is the case in the perception of everyday events, readers appear to structure textual input by segmenting it, and this has consequences for ongoing processing. The fact that principles of perceptual processing accounted for patterns of text comprehension has an important theoretical implication: It provides support for models proposing that text comprehension relies on parsing incoming text into a series of discrete units (e.g., Zwaan, 2004; Zwaan & Radvansky, 1998), and suggests that other models of text comprehension should explicitly incorporate this process. One important direction for future research will be to compare the results of these segmentation and memory paradigms to predictions from minimalist and non-simulation based theories of text comprehension (McKoon & Ratcliff, 1992; van Dijk & Kintsch, 1983).

The present data support a second theoretical implication: Event structure appears to play a significant role in guiding memory under some circumstances. The fact that memory for information in a current event was more available than memory for information in a previous event lends support to the theory that readers cope with the large amounts of information presented in texts by constructing a series of modestly sized situation models (Gernsbacher, 1990; Zwaan & Radvansky, 1998). When a reader reaches a boundary between events, previously presented information may be less likely to be relevant, and it is therefore adaptive to cease maintaining it in a highly activated state. This is a form of cognitive control that can be contrasted with the more general processes of rehearsal and memory updating that have been proposed to account for proactive interference in memory for materials such as word lists (Waugh & Norman, 1965).

Future studies will need to explore whether changes in other situation model dimensions are perceived as event boundaries, the degree to which these other changes interact with each other, and the implications of these changes for retention of information presented in text. For example, one question that should be addressed is whether event boundaries are more likely to be perceived in a sentence that contains changes in two dimensions, such as time and space, than a sentence that contains a change in only one dimension. There is some evidence supporting this claim in film comprehension (Magliano et al., 2001), but it is not clear that these results extend to text comprehension. Once the relationship of multidimensional changes to text comprehension is established, it will be possible to further explore the effects of these changes on the retention of information presented in the context of narrative texts (e.g., Rinck & Bower, 2000; Rinck & Weber, 2003; Scott Rich & Taylor, 2000).

To understand an extended narrative is an impressive cognitive feat, one that requires coordinating attention, working memory and long term memory over extended periods. These data and others paint a picture of the cognitive control mechanisms that allow readers to comprehend extended narratives. The two key components of that picture are segmentation and memory updating: Readers segment narratives at those points when significant aspects of the situation described by the narrative changes, they use those segments to guide reading, and they may use the same segments to guide memory updating.

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