

Interactive Dimensions in the Construction of Mental Representations for Text

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To detail the structure and format of memory for texts, researchers have examined whether readers monitor separate text dimensions for space, time, and characters. The authors proposed that the interactivity between these individual dimensions may be as critical to the construction of complex mental models as the discrete dimensions themselves. In the present experiments, participants read stories in which characters were described as traveling from a start to a final location. During movement between locations, characters engaged in activities that could take either a long or short amount of time to complete. Results indicate that accessibility for the spatial locations was a function of the passage of time. The authors interpret this as evidence that the interactive nature of text dimensions affects the structure of representations in memory.

In the biography *Seabiscuit: An American Legend* (Hillenbrand, 2001), the titular thoroughbred and his jockey Woolf must battle an unfair start by rival horses during the running of the Hollywood Gold Cup:

Leaning around the far turn, Woolf drew a bead on Specify again. Incredibly, the horse was still rolling along. A pang of fear went through Woolf. Ligaroti was somewhere behind him; bumped and pinched hard on the backstretch, he had been knocked too far back, and would finish a fast-closing fourth. Woolf knew he could easily beat the others, but he was beginning to worry that he couldn't catch Specify. Dropping flat in the saddle, he gave his mount two taps with the whip and clucked in his ear. Up in the booth, caller Joe Hernandez saw him do it, and shouted into the microphone, "And here comes Seabiscuit!" (p. 235–236)

The situation in this paragraph suggests movement, sounds, and events that are only implicitly described in the narrative. For example, Hillenbrand's description does not mention the horses' precise locations on the track. However readers may still construct vivid mental representations that encode the locations of Seabis-

cuit, Specify, Ligaroti, and the rest of the field. In this example, readers' mental representations may be influenced by, among other things, knowledge of horseracing history, the expected speed of thoroughbreds, and the amount of track believed to have been covered in the description of the race. Readers' representations of the situation described by this excerpt may be a function not only of spatial information (e.g., "Ligaroti was somewhere behind him"), but also temporal descriptions (e.g., "he was beginning to worry that he couldn't catch Specify") and action-based statements (e.g., "he gave his mount two taps with the whip and clucked in his ear"). The combination of these spatial, temporal, and activity-based cues may or may not influence readers' expectations that Seabiscuit will have enough time or ground to overcome Specify. The goal of this article is to evaluate the interactivity of available narrative cues and the impact of such interactivity on readers' narrative representations.

Traditional models of text comprehension outline the types of memory representations that readers may construct. The *tri-partite theory of text representation* offered by van Dijk and Kintsch (1983) suggests that readers encode the specific words described in a text (a surface-level representation), the ideas conveyed in meaning-based propositional units (a text-based representation), and the information described by a text but not directly mentioned in a text (a situation model representation). Situation models are believed necessary for readers to construct inferences and adequately comprehend text (Glenberg, Meyer, & Lindem, 1987; van Dijk & Kintsch, 1983; Zwaan & Radvansky, 1998). Because readers can potentially encode many different details (e.g., character goals, temporal sequences of events, spatial relations between locations), a considerable amount of research has been devoted to examining which dimensions readers encode into situation models. The *event-indexing model* has received considerable empirical support as a description of the dimensions readers track while reading (Zwaan, Langston, & Graesser, 1995; Zwaan, Magliano, & Graesser, 1995). According to this model, readers maintain mental indices for the passage of time, the organization of

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space, the relations and intentions of characters and objects, and the causal structure of events in narratives.

The event-indexing model, however, makes no claim about the processes by which these indices are encoded into complex memory representations. To address this issue, researchers have appealed to Gernsbacher's *structure-building framework* (1990). This framework outlines the processes by which readers construct representations of events described in texts. When new events are read, new mental substructures are constructed, resulting in a more elaborated representation. As a result of this process, old structures may become less accessible from memory. The process theory suggested by the structure-building framework has been mapped directly onto the structural theory outlined by the event indexing model (e.g., Zwaan, Langston, et al., 1995; Zwaan, Magliano, et al., 1995). The combination of the two theories provides one account of the underlying cognitive processes at work during situation model construction. As a text is read, information relevant to a specific dimension is encoded. For each dimension or index, a new substructure along that dimension may be developed, making the old information less accessible from memory. Discontinuities or expectancy violations for specific dimensions further decrease the accessibility of prior information.

Researchers have examined the linguistic cues in texts that help readers build mental structures for particular dimensions. To illustrate, one area that has received extended interest has been the use of temporal markers in linguistic discourse. It has been suggested that these cues can operate as signals for the encoding, application, reactivation, and deactivation of information from mental representations (Bestgen & Vonk, 2000; Carreiras, Carriedo, Alonso, & Fernandez, 1997; Madden & Zwaan, 2003; Rapp & Gerrig, 2002; Zwaan, 1996; Zwaan, Madden, & Whitten, 2000). For example, Magliano and Schleich (2000) presented stories that included sentences indicating either an ongoing imperfective aspect or a completed perfective aspect. After reading one version of the story, participants determined whether a verb phrase had appeared in the text. Participants took longer to identify verb phrases from stories containing completed activities than from stories containing ongoing activities. These results suggest that the degree to which readers encode events as completed can influence the accessibility of those events from memory.

Temporal cues are but one dimension for which readers may construct representations in situation models. Our contention is that text representations are constructed through the interactivity of multiple text dimensions that include temporal cues as only one possibility. According to this view, other dimensions including space, characters, and plot-based causality can impact the structure of temporal representations. To take a specific example, character actions in a narrative can provide cues for the temporal qualities of an event. Activity is often associated with expectations about behavior that are grounded in personal experience, including the likelihood of an activity being completed, the difficulty of an activity, and the amount of time encompassed by an activity (e.g., Barsalou, 1999a; Barsalou, Huttenlocher, & Lamberts, 1998; Kaschak & Glenberg, 2000; Rapp & Gerrig, 1999; Rapp & Gerrig, 2002; Zwaan, 1996; Zwaan, 1999). These temporal durations can be perceived as relative to a specific, explicit period of time (e.g., "He cooked the popcorn in the microwave," which may take a predetermined amount of time as mandated by cooking directions) or as implicit and associated with more general expectations (e.g.,

"He cut down the tree" should take an extended amount of time to complete, whereas "He cut down the string" should take a shorter amount of time, while neither is associated with a specific temporal duration). The implicit durations associated with character activity may be as critical a cue for structuring temporal events in memory as explicit descriptions of time shifts and verb aspect.

In our view, then, it should be the case that the interactions between text dimensions matter. We suggest, therefore, that these dimensions function interactively to influence readers' construction and updating of situation models. According to this hypothesis, interactivity will impact the construction and application of situation models by defining the structure and organization of events as, for example, whether those events are ongoing or completed or whether they encompass one activity or multiple activities. The earlier excerpt from *Seabiscuit* provided an example for which real-world knowledge about the passage of time, character movement, and qualities of the environment collectively impact readers' expectations about the spatial situation. That is, readers' knowledge about a particular text dimension (e.g., the temporal duration implied by the speed of racehorses' movement) may inform expectations about other dimensions (e.g., the spatial layout or distance between the horses in the race). As we have outlined, information in one dimension may cue readers to segment or structure memory representations along a second dimension. In *Seabiscuit*, information about speed may help readers to generate expectations about where the racehorses are located on the track.

The present research begins to examine this notion of interactivity among text dimensions and whether this interactivity matters. Although there is some suggestion that readers can encode multiple discrete text dimensions, researchers have not explicitly investigated how one dimension (e.g., time, space, or character-based information) may be useful for encoding a second dimension. For example, consider the following story:

1. Joe was working diligently on his term paper.
2. Joe had been laboring for quite some time in the library.
3. He began to feel kind of hungry.
4. He decided to get something to eat from the diner.
5. Joe gathered his things and left.
6. Outside, he noticed a stick on the ground.
7. He pulled out a small pocket knife from his bookbag.
8. Joe began to whittle away at the stick while he walked.
9. He carved the stick into a small flute.
10. He put the finishing touches on it just as he arrived.
11. The smells of cooking burgers and French fries made his mouth water.
12. He stepped up to the counter and ordered a grilled cheese sandwich.

After reading this story, what expectations might readers have about the relative locations of the library and diner? Evidence suggests that readers conduct mental simulations (cf. Barsalou, 1999b; Kahneman & Tversky, 1982) to evaluate aspects of the situations described in texts. Readers are likely to conduct a similar form of mental simulation when considering Joe's activity during movement between the two locations. If Joe engages in an activity associated with a long temporal duration (e.g., carving a stick into a flute) while moving between the library and the diner, the implication is that the two locations are spatially distant from one another. Suppose, however, that Sentence 9 described a different activity:

He carved his initials right on the stick.

In this case, readers may believe that the spatial distance between the two locations is not very large because the process of carving initials into a stick should take a relatively short time to complete. For both versions of this story, the temporal durations of activities can serve as a cue for the spatial qualities of text locations. In other words, these dimensions can interact in the construction of readers' situation models. Specifically, expectations and beliefs about the durations of these events structure whether they should take a long or short amount of time to complete, and inferences about traveled distance are a function of those temporal estimates.

To examine the validity of our interactive claim, we evaluated whether expectations about character activity can provide readers with an indication about the relations between locations. We did this by examining the accessibility of text information following the introduction of an event shift or change in the spatial or temporal situation described in the ongoing text. One potential outcome of this process, which we will call the *rigid-boundary hypothesis*, suggests quite broadly that event shifts result in uniform decreases in the accessibility of prior text information. According to this view, for the story about Joe described above, accessibility for the start location should decrease in a consistent fashion regardless of the passage of time or amount of spatial movement by the character. There is some evidence for this view. Certain types of temporal shifts (e.g., explicit time shifts such as "an hour later" vs. "a day later") result in similar decreases in accessibility for previously mentioned information despite apparent differences in temporal magnitude (Zwaan, 1996).

A competing hypothesis suggests a more interactive influence of text dimensions on situation models following event shifts. This view argues that readers' real-world expectations and beliefs about the temporal and spatial qualities of events will influence the structure of situation models. According to this view, changes in accessibility should be a function of the relevant magnitude, duration, or size associated with an event shift. This *flexible-boundary hypothesis* suggests a graded or continuous effect of narrative shifts compared with the categorical shift suggested by the rigid-boundary hypothesis. Locations interpreted as spatially distant from the protagonist's current location should be less accessible from memory than narrative locations in close proximity to the protagonist (Levine & Klin, 2001). The flexible-boundary hypothesis suggests that representational boundaries are not strictly a function of the introduction of new text events and event shifts but are also a function of readers' background knowledge and expectations about the concomitants of time, space,

characters, and causality. Again, there is some evidence for this view: Zwaan (1996) demonstrated that particular discrepancies in chronological distance (e.g., explicit time shifts such as "a minute later" vs. "a day later") can differentially influence the accessibility of text information prior to the time shift. The following studies compared these two hypotheses as well as the degree to which shift statements need to explicitly demarcate the distances traveled in order to influence memory for text.

The rigid- and flexible-boundary hypotheses differ in their predictions concerning the accessibility of narrative information preceding the introduction of an event shift. However, it is important to note that both hypotheses similarly rely on the notion that new text events initiate the construction of mental substructures in memory. In addition, they both share the deictic view that information in the narrative here-and-now should be more accessible than information from the past or future (Bower & Morrow, 1990; Morrow, 1994; Morrow, Bower, & Greenspan, 1989; Morrow, Greenspan, & Bower, 1987).

Thus, our experiments were designed to test the notion that nonspatial text dimensions influence representations of spatial locations. We examined whether interactivity between dimensions occurs, and if so, whether it influences construction processes in a specific way (on the basis of expectations about events and in line with the flexible-boundary hypothesis) or more broadly (on the basis of the uniform encoding of event shifts and in line with the rigid-boundary hypothesis). In Experiments 1A and 1B, we examined whether explicit spatial statements generally have an impact on the accessibility of spatial locations. These experiments provided a baseline for evaluating the interactive effects of other dimensions on representations of spatial locations. In Experiment 2, we specifically examined whether statements conveying information about the passage of time would influence the accessibility of location information from memory in a similar way. In Experiment 3, we evaluated whether these interactions actually matter by examining whether results could be attributed to tracking only a single, discrete temporal dimension. Our results demonstrate that the interactive nature of text dimensions facilitates the construction of rich representations in situation models.

Experiment 1A

To begin this set of studies, we evaluated whether explicit information from a single, discrete dimension (in this case, space) would influence the structure and accompanying accessibility of spatial information from situation models. If so, these experiments would provide a baseline for later evaluation of interactivity by allowing us to compare those accessibility patterns with patterns obtained within a single dimension. In Experiment 1A, participants read a series of stories that described a character moving from a start location to a final location. Each story included an explicit statement that described characters traveling a long or short physical distance between locations (e.g., "Emily walked four miles." vs. "Emily walked four blocks."). Following each story, participants completed a probe word recognition task. For critical experimental items, the probe word was one of the two locations mentioned in the story. We recorded recognition times and error rates to probe words, as well as reading times for distance statements. Our predictions for the probe task were based on the two hypotheses outlined in the beginning of the present article. The

rigid-boundary hypothesis predicts main effects of distance and location and little in the way of an interaction. That is, recognition times should decrease uniformly with an event shift regardless of the magnitude of the shift. In contrast, the flexible-boundary hypothesis predicts an interaction between distance and location such that recognition times will differ as a function of the magnitude of the shift. That is, there should be a larger decrease in accessibility for start location probes following long shifts compared with the same start location probes following short shifts. Both hypotheses predict a main effect of location: Participants should take less time to recognize final locations than start locations. Because final locations represent the current “here-and-now” of the story, they should remain in reader focus and accessible from memory (Bower & Morrow, 1990). We did not have specific predictions about error rates.

Method

Participants. Thirty-six Tufts University undergraduates participated in this study for course credit. All participants were native English speakers.

Apparatus. The experiment was run on two Macintosh G3 computers using Superlab software. Participants were seated in front of a color monitor with their hands resting on the keyboard. They used buttons on the keyboard to make appropriate responses. The sentences were displayed in the center of the screen in standard upper- and lower-case type.

Materials. To begin this experiment, we wrote 20 stories, each 12 sentences long (see Appendix A for examples). The first sentence introduced a main character, and the second sentence introduced the character’s starting location. The 3rd and 4th sentences provided a reason for the character to travel to a final location. The 5th through 8th sentences served as a transition for the character to prepare to travel to the final destination. The actual start and final locations were not mentioned in the 5th through 8th sentences. The 9th sentence of each story explicitly described either a *short-distance statement* (i.e., “Emily walked for four blocks.”) or a *long-distance statement* (i.e., “Emily walked for four miles.”). Distance statements always described a spatial distance of either 4 blocks or 4 miles, and were therefore equated for length across stories (mean number of words for long and short-distance statements = 5.25). The 10th through 12th sentences described the character reaching and remaining at the final location, without explicitly mentioning either the start or final location. Following the final sentence of the story, participants saw a recognition probe for either the start or final location (*location probe*). Across all 20 experimental passages the probes mentioned story locations and therefore required *yes* responses.

In addition to the experimental stories, we also wrote 20 filler stories. All filler stories were 12 sentences long. The filler stories described a similar range of scenarios as the experimental stories. Although the stories did not include character movement between two locations, several of the stories described characters intending to travel to a location at a later time point. Each filler story included a single recognition probe, and there was only one version of each filler item. For the fillers, recognition probes never occurred in the stories, and the correct response was always *no*. These probes were not limited to locations, but also included objects and verbs. We wrote three practice stories, none of which included distance information. We also included a secondary task to ensure that participants carefully read the stories (as well as to serve as baseline data for a future experiment). After 10 randomly selected stories (5 experimental and 5 filler), participants were instructed to write down a sentence to continue the story by using a sheet of paper and a pen located next to the computer.

Design. Overall, there were four versions of each experimental story varying as a function of distance statement (long vs. short) and location probe (start vs. final). Using a Latin square design, we constructed four

story lists; thus, each story appeared in a different version on each list. The 20 filler stories were added to these lists. Each participant read one version of each experimental story and all fillers in a different random order.

Procedure. Participants began with three practice stories to become acquainted with the stimulus format and keyboard controls. Participants were instructed to read each story line-by-line for comprehension. Each story began with the prompt “Prepare for the next story” followed by the first line of the story. Participants read through each story at their own pace, pressing the space bar to advance. The last line of each story was followed by a recognition probe in blue text presented in the center of the screen and surrounded by six asterisks. Participants indicated *yes* (i.e., “This word appeared in the story.”) or *no* (i.e., “This word did not appear in the story.”) by pressing either of the appropriately labeled (*Q* or *P*) keys on the keyboard. Their response was followed by a 1,000-ms pause before the prompt for the next story appeared. Participants had to respond to the recognition probe within 3,000 ms, otherwise the words *TOO SLOW* appeared for 2,500 ms. Their response, or lack of response, was followed by a 1,000-ms pause before a prompt for the next story appeared on the screen.

Results and Discussion

Table 1 presents the results of Experiment 1A. Participants failed to respond before the deadline 1.5% of the time, and these responses were not included in our analyses. We also eliminated decision times falling more than three standard deviations above the mean. This resulted in a loss of an additional 1.8% of the data. None of the participants expressed awareness of the purpose of the experiment. However, during the debriefing, 26 of the participants reported noticing the preponderance of distance statements across the experimental session. This is not surprising given the consistency of the distance statements across stories and our goal of presenting explicit spatial statements conveying distance information. The remaining 10 participants expressed recognition only after being told that 20 of the stories contained sentences with explicit distance information.

To assess the reliability of our data, we carried out analyses with both participants (F_1) and items (F_2) as random variables. We analyzed recognition times for correct responses to probe locations. The results were consistent with the flexible-boundary hypothesis. The interaction between location and distance was reliable: Participants were slower to recognize start locations after reading long-distance statements in comparison to their recogni-

Table 1
Means and Standard Deviations for Correct Recognition Probe Times and Distance Statement Reading Times for Start Locations (L1) and Final Locations (L2) in Experiment 1A

	Correct recognition probe times		Distance statement reading times	
	L1	L2	L1	L2
Long-distance statement				
<i>M</i>	1,420	1,284	1,288	1,320
<i>SD</i>	291	314	618	709
Short-distance statement				
<i>M</i>	1,347	1,368	1,393	1,373
<i>SD</i>	266	287	631	638

Note. All probe and reading times in ms.

tion of start locations after reading short-distance statements, significant by both participants and items, $F_1(1, 35) = 13.68$, $MSE = 16,053$, $p < .005$; $F_2(1, 19) = 6.62$, $MSE = 26,430$, $p < .05$. The main effect of location was also significant: Participants took longer to recognize probe words for characters' start locations ($M = 1,384$ ms) than for final locations ($M = 1,326$ ms), significant by participants and marginal by items, $F_1(1, 35) = 4.86$, $MSE = 24,558$, $p < .05$; $F_2(1, 19) = 4.04$, $MSE = 15,645$, $p = .059$. There was no main effect of distance (both F s < 1).

To further evaluate recognition times, we conducted planned comparisons using paired t tests (Bonferroni corrected) with both participants (t_1) and items (t_2) as random variables. Following long-distance statements, participants were 136 ms slower to recognize probes for start locations than for final locations, significant by participants and items, $t_1(35) = 4.39$, $p < .005$; $t_2(19) = 3.09$, $p < .01$. Participants were 73 ms slower to recognize probes for start locations following long-distance statements compared with start locations following short-distance statements, marginally significant by participants and items, $t_1(35) = 1.95$, $p = .059$; $t_2(19) = 2.02$, $p = .058$. Participants were also 84 ms slower to recognize probes for final locations that followed short-distance statements as compared with cases in which final location probes followed long-distance statements, marginal by participants only, $t_1(35) = 1.96$, $p = .058$; $t_2(19) = 1.41$, $p > .10$. No other comparisons were significant (all t s < 2).

Analyses of error rates for recognition responses showed no main effects or interaction ($M = 29\%$ incorrect for start locations following long distances, 29% incorrect for start locations following short distances, 34% incorrect for final locations following long distances, and 34% incorrect for final locations following short distances; all F s < 1.9). We also analyzed reading times for distance statements (e.g., "Emily walked for four blocks." vs. "Emily walked for four miles.") to evaluate whether distance effects could be identified at encoding (see also Table 1). Reading time analyses helped suggest whether readers were expending special effort to encode a particular type of statement. Analyses revealed that participants took 79 ms longer to read short-distance statements ($M = 1,383$ ms) than long-distance statements ($M = 1,304$ ms), significant by participants but not by items, $F_1(1, 35) = 4.53$, $MSE = 233,904$, $p < .05$; $F_2(1, 19) = 2.30$, $MSE = 424,925$, $p > .10$. No other effects were significant (all F s < 1.4). These results suggest that readers may have had more difficulty reading short-distance statements than long-distance statements. More importantly, the reading time pattern does not match the recognition probe data, providing little direct evidence for the encoding view.

The pattern of recognition times is more consistent with a flexible-boundary hypothesis (compared with a rigid-boundary hypothesis) for stories including explicit distance information. Most surprisingly, participants demonstrated shorter recognition times to identify final locations after reading long-distance statements than after reading short-distance statements. Recall that both the rigid- and flexible-boundary hypotheses suggest that final locations will be equally accessible following either short- or long-distance statements. Although this comparison did not reach significance, we address a potential reason for this contrary result. One possibility is that the long-distance statements may have been particularly effective at instantiating expectations that characters had reached their final destinations, whereas short-distance statements may have been less effective at conveying a sense of

completed movement. For participants, the spatial cue "four blocks" may not have been an appropriate distance for a character to travel before arriving at a final location. Note that this explanation also fits the reading time data.

We conducted Experiment 1B to address this possibility directly. Therefore, the purpose of Experiment 1B was two-fold. First, we examined whether the inclusion of distance statements that explicitly described characters arriving at their final locations would reduce the advantage for final location probes following long, as compared with short, distance statements. Second, we wished to provide additional support for the flexible-boundary hypothesis by replicating the critical interaction. Recall that whereas the rigid boundary hypothesis predicts little in the way of an interaction between distance and location, the flexible boundary hypothesis suggests that recognition times for start locations should differ as a function of intervening spatial distances.

Experiment 1B

Method

Participants. Forty-two University of Minnesota undergraduates participated in this study for course credit. All participants were native English speakers. Four participants' data were eliminated for a failure to follow experimental instructions. Two participants' data were eliminated because they self-reported reading disabilities on completion of the experiment.

Apparatus. The apparatus was identical to that in Experiment 1A, except the experiment was run on three Dell personal computers equipped with Superlab software.

Materials. In Experiment 1A, it was never explicitly mentioned that characters had arrived at their destinations (the final locations); this information had to be inferred. In addition, characters were described as traveling either 4 blocks or 4 miles: For all cases, characters traveled four units of distance. In Experiment 1B, we changed these qualities of the experimental stories. We modified the experimental stories from Experiment 1A to include explicit mention of characters arriving at their final locations (see Appendix A for examples). To do this, we revised the ninth sentence of each story to include the words "to his/her location" (depending on the gender of the character) at the end of the sentence. We also changed the numerical units for the distance statements to better differentiate between short and long statements. Therefore, participants read a description of a character that had traveled either a short or long physical distance between locations (i.e., "Emily walked three blocks to her destination." vs. "Emily walked five miles to her destination."). Distance statements always described a spatial distance of either 3 blocks or 5 miles (mean number of words for long- and short-distance statements = 8.35). In all other ways, the materials were identical to those presented in Experiment 1A.

Design. The design was identical to Experiment 1A.

Procedure. The procedure was identical to Experiment 1A.

Results and Discussion

Table 2 presents the results of Experiment 1B. Participants failed to respond before the deadline 1.3% of the time, and those responses were not included in our analyses. We also eliminated decision times falling more than three standard deviations above the mean, resulting in a loss of an additional 1.1% of the data. None of the participants expressed awareness of the purpose of the experiment. However, during the debriefing, 24 of the participants reported noticing the preponderance of distance statements across the experimental session. Twelve participants expressed recogni-

Table 2
Means and Standard Deviations for Correct Recognition Probe Times and Distance Statement Reading Times for Start Locations (L1) and Final Locations (L2) in Experiment 1B

	Correct recognition probe times		Distance statement reading times	
	L1	L2	L1	L2
Long-distance statement				
<i>M</i>	1,452	1,256	2,118	2,173
<i>SD</i>	249	232	471	566
Short-distance statement				
<i>M</i>	1,322	1,256	2,080	2,164
<i>SD</i>	210	203	406	542

Note. All probe and reading times in ms.

tion only after being told that 20 of the stories contained sentences with explicit distance information.

Preliminary examination of the item means revealed that participants took much longer to respond to one particular item in comparison with the rest of the item list. Mean responses for that item in two of the four conditions fell either three standard deviations (in the long-distance statement by final location condition) or two standard deviations (in the short-distance statement by start location condition) above the mean for the respective condition. This item described a scenario in which a character was described walking through a shopping center. For this item, unlike the others, the two locations (a cafeteria and florist) were subsumed under a single larger location (the shopping center), effectively creating three locations. As well, it is unclear what it means to walk several blocks or miles through a shopping center. The term *blocks* is not very informative because a block could refer to a set of cross-street boundaries, aisles, or even shop kiosks. In addition, although it is plausible that one could walk several miles inside a shopping center (as in the case of exercising), it seems less likely when the goal is to reach a particular store in that mall. None of the other items described a character remaining inside a particular location while traveling to two specific subsumed locations. This item did not yield a similar outlier pattern in Experiment 1A (in which stories did not contain the explicit completion “to his/her destination”). For consistency, we reran all analyses from Experiment 1A with this item removed. Removal of the item did not change the nature of any effects obtained in Experiment 1A. Therefore, we analyzed the data in Experiment 1B after removing this problematic item.

For Experiment 1B, we first analyzed recognition times for correct responses to probe locations. The data were, again, supportive of the flexible-boundary hypothesis. Participants were slower to recognize start probes after reading long-distance statements in comparison with recognizing start probes after reading short-distance statements. This interaction was significant by participants and marginal by items, $F_1(1, 35) = 8.78$, $MSE = 12,979$, $p < .005$; $F_2(1, 18) = 2.99$, $MSE = 24,501$, $p = .098$. For the main effect of location probe, participants took longer to recognize probes for start locations ($M = 1,387$ ms) compared with final locations ($M = 1,256$ ms), significant by participants and items, $F_1(1, 35) = 33.39$, $MSE = 18,597$, $p < .001$; $F_2(1, 18) = 16.26$,

$MSE = 19,901$, $p < .005$. For the main effect of distance statement, participants took longer to recognize probes following long-distance statements ($M = 1,354$ ms) compared with short-distance statements ($M = 1,289$ ms), significant by participants but not by items, $F_1(1, 35) = 8.78$, $MSE = 17,402$, $p < .01$; $F_2(1, 18) = 2.86$, $MSE = 17,706$, $p > .10$.

We conducted planned comparisons for the data as in Experiment 1A. The comparisons for the most part replicated the findings from the earlier experiment. After reading long-distance statements, participants were 196 ms slower to recognize probes for start locations than for final locations, significant by participants and items, $t_1(35) = 5.82$, $p < .001$; $t_2(18) = 3.78$, $p < .001$. Participants were 130 ms slower to recognize probes for start locations following long-distance statements compared with cases in which start probes followed short-distance statements, significant by participants and items, $t_1(35) = 5.04$, $p < .001$; $t_2(18) = 2.58$, $p < .05$. Participants were 196 ms slower to recognize probes for start locations following long-distance statements compared with final locations following short-distance statements, significant by participants and items, $t_1(35) = 5.42$, $p < .001$; $t_2(18) = 3.85$, $p < .001$. After reading short-distance statements, participants were 66 ms slower to recognize probes for start locations compared with probes for final locations, significant by participants only, $t_1(35) = 2.68$, $p < .05$; $t_2(18) = 1.50$, $p > .10$. Similarly, participants took 66 ms longer to recognize start location probes following short-distance statements compared with final location probes following long-distance statements, significant by participants and marginal by items, $t_1(35) = 2.53$, $p < .05$; $t_2(18) = 1.90$, $p = .074$. There was no significant difference between recognition latencies for final locations following either long- or short-distance statements (both $ts < 1$).

We analyzed the error rates for recognition responses. Neither of the main effects nor the interaction were reliable ($M = 22\%$ incorrect for start locations following long distances, 18% incorrect for start locations following short distances, 22% incorrect for final locations following long distances, and 23% incorrect for final locations following short distances; all $F_s < 1$). We also evaluated reading times for the distance statements (see Table 2). Participants took 24 ms longer to read long-distance statements (2,146 ms) than short-distance statements (2,122 ms); however, neither of the main effects nor the interaction were reliable (all $F_s < 1.92$).

Experiment 1B demonstrates that explicit distance cues influence the structure of readers' situation models for locations described in texts. The accumulated evidence from Experiments 1A and 1B support a flexible-boundary interpretation rather than a rigid-boundary hypothesis. The data revealed that participants were slower to recognize start locations, compared with final locations, following both long- and short-distance statements. This finding is qualified by the fact that participants were slower to recognize start locations following long-distance statements as compared with when those start locations followed short-distance statements. This result is not entirely surprising because descriptions of space are readily available text cues for structuring spatial situation models. The next experiment examined whether dimensions other than space would also influence those spatial representations.

Experiment 2

In Experiment 2, we examined whether character activities, implicitly cuing distance, would result in effects similar to those demonstrated for explicit spatial cues on the recognition of location probes. Instead of reading sentences describing explicit distance statements, participants read stories that contained activity statements normally associated with specific temporal durations. A pattern of data similar to that observed in Experiments 1A and 1B would suggest that cues from nonspatial dimensions can also influence the accessibility of spatial information from readers' situation models.

Method

Participants. Thirty-six Tufts University undergraduates participated in this study for course credit. All participants were native speakers of English.

Apparatus. The apparatus was identical to that in Experiment 1A.

Materials. We modified the experimental stories from Experiment 1A to include statements describing character activity rather than statements about spatial distance. To do this, we changed the ninth sentence of each story to an *activity statement*, describing an activity that the character engaged in while moving from the start to the final location (see Appendix B for examples). There were two versions of this activity statement. *Long-activity statements* should take a long amount of time for characters to complete (e.g., "Elizabeth read some articles on linguistic communication."), whereas *short-activity statements* should take a short time to complete (e.g., "Elizabeth perused the journal's table of contents."). These statements were equated for length (mean number of words for long and short-activity statements = 11.1). Following the final sentence of each story, participants were presented with a recognition probe for either the start or final location (*location probe*).

We conducted an off-line norming study to evaluate whether the activity statements we wrote were associated with long and short temporal durations. We asked 28 native English-speaking Tufts University undergraduates to read each activity statement. Participants were each given a questionnaire with 20 pairs of action sentences. One sentence in each pair described a long version of a particular action (e.g., "Sid carved the stick into a flute.") and the other sentence described a short version of a similar action (e.g., "Richard carved his initials right on the stick.") such that each participant evaluated both the long and short versions of a statement pair. We changed the names of the characters for each sentence in such pairs; thus, the same characters were not performing multiple actions across the questionnaire and as a result, participants would be less likely to compare activity statements in a pair. We randomly placed the 40 action sentences into a questionnaire booklet. Each page contained 8 sentences for a total of five pages, and the pages of each questionnaire were randomly shuffled for each participant. The instructions read "On the following pages, please indicate in the provided blanks how long you think it would take to engage in and complete the described action. Write your answer in minutes."

Participants reported that long-activity statements should take longer to complete ($M = 55.33$ min) than short-activity statements ($M = 5.97$ min), $t_1(27) = 12.09$, $p < .001$; $t_2(19) = 5.06$, $p < .001$. These results suggested that the actions described by the long-activity statements established expectations for a longer passage of time than did the actions described by the short-activity statements. On average, participants believed that long activities would take almost 50 min longer to complete than short activities. These norming data provided us with the materials to pursue the more theoretically oriented goals of the project.

We included an additional 20 filler stories to our original set to decrease the proportion of critical items over the course of the experiment. This resulted in a total of 60 stories: 20 experimental stories and 40 filler stories. For the experimental stories, the correct response was always *yes*. For the

filler stories, correct *yes* probes followed only 10 of the stories. For the remaining 30 filler stories, the recognition probe was not included in the story, and the correct response was *no*. This balanced the number of correct *yes* and *no* responses across the entire experiment. We also included the same secondary task as in Experiment 1A.

Design. The design was identical to that in Experiment 1A.

Procedure. The procedure was identical to that in Experiment 1A.

Results and Discussion

Table 3 presents the results of Experiment 2. Participants failed to respond before the deadline 2.3% of the time, and those responses were not included in our analyses. We also eliminated decision times falling more than three standard deviations above the mean, resulting in a loss of an additional 1.4% of the data. None of the participants expressed any awareness of the goals of the experiment.

We analyzed recognition times for correct responses to probe locations. We again obtained support for the interaction predicted by the flexible-boundary hypothesis: Participants were slower to recognize probe words for characters' start locations after reading long activities compared with recognition times for start locations following short activities, significant by participants and marginal by items, $F_1(1, 35) = 9.24$, $MSE = 14,473$, $p < .005$; $F_2(1, 19) = 3.02$, $MSE = 28,124$, $p = .098$. For the main effect of location probe, participants took longer to recognize probes for start locations ($M = 1,436$ ms) compared with final locations, significant by participants and items ($M = 1,378$ ms), $F_1(1, 35) = 11.48$, $MSE = 30,180$, $p < .005$; $F_2(1, 19) = 13.04$, $MSE = 14,278$, $p < .005$. For the main effect of activity statement, participants also took longer to recognize probes following long activities ($M = 1,417$ ms) compared with short activities, significant by participants and items ($M = 1,357$ ms), $F_1(1, 35) = 6.19$, $MSE = 21,069$, $p < .05$; $F_2(1, 19) = 6.61$, $MSE = 17,227$, $p < .05$.

We conducted planned comparisons as in Experiments 1A and 1B. Following long activities, participants were 159 ms slower to recognize probes for start locations than for final locations, significant by participants and items, $t_1(35) = 4.30$, $p < .001$; $t_2(19) = 3.19$, $p < .005$. Participants were 121 ms slower to recognize probes for start locations following long activities compared with those start locations following short activities, significant by participants and items, $t_1(35) = 4.12$, $p < .001$; $t_2(19) =$

Table 3
Means and Standard Deviations for Correct Recognition Probe Times and Activity Statement Reading Times for Start Locations (L1) and Final Locations (L2) in Experiment 2

	Correct recognition probe times		Activity statement reading times	
	L1	L2	L1	L2
Long-activity statement				
<i>M</i>	1,496	1,337	2,616	2,555
<i>SD</i>	249	257	867	738
Short-activity statement				
<i>M</i>	1,375	1,338	2,566	2,452
<i>SD</i>	243	304	891	620

Note. All probe and reading times in ms.

2.86, $p < .01$. Participants were also 158 ms slower to recognize probes for start locations following long activities compared with final locations following short activities, significant by participants and items, $t_1(35) = 3.79$, $p < .001$; $t_2(19) = 4.17$, $p < .001$. No other comparisons were significant (all $t_s < 1.15$).

We analyzed the error rates for recognition responses. Neither of the main effects nor the interaction were reliable ($M = 25\%$ incorrect for start locations following long activities, 25% incorrect for start locations following short activities, 32% incorrect for final locations following long activities, and 28% incorrect for final locations following short activities; all $F_s < 2.75$). We also evaluated reading times for the activity statements (see Table 3). Participants took 77 ms longer to read long-activity statements (2,586 ms) than short-activity statements (2,509 ms); however, neither of the main effects nor the interaction were reliable (all $F_s < 1.05$).

The overall pattern of recognition times from Experiment 2 is in line with that of the previous experiments. This pattern is suggestive that other dimensions (such as time and character activity) may provide cues for encoding spatial representations, supporting the notion that interactivity among text dimensions facilitates situation model construction. However, an alternative interpretation of these results that does not place emphasis on time and space is worthy of note. The differences in accessibility for probe words may have been a function of the degree to which activity statements indicated a shift in discourse topic (to a new subject, situation, or event), rather than a shift in time or space. This alternative interpretation is based on the notion that topic shifts can lead to decreases in the accessibility of information preceding those shifts (e.g., Haviland & Clark, 1974; Lorch, Lorch, & Matthews, 1985). In principle, the data collected from Experiment 2 speak against this interpretation. If longer activity statements were consistently associated with larger discourse shifts, this should have resulted in a main effect of activity statement but little in the way of an interaction between activity statements and location probes. Nevertheless, it is entirely possible that the results of Experiment 2 were at least partially a function of the degree to which activity statements indicated a shift in overall discourse topic rather than a more specific index-based shift in time or space.

To address this issue, we conducted an off-line study to assess whether long-activity statements instantiated greater expectations for topic shifts as compared with short-activity statements. We asked 24 English-speaking University of Minnesota students to read one version of each of the 20 experimental stories and to indicate how much of a topic shift was conveyed by the activity statement. There were two versions of each story (long-activity statement vs. short-activity statement). Each story ended immediately following the activity statement, at which point participants were asked to judge the degree of topic shift conveyed by the activity statement. We randomly placed one version of each story on one of two questionnaires; each questionnaire included 30 stories (20 experimental stories and 10 filler stories). Each questionnaire page included two experimental stories and one filler, and the story pages of each questionnaire were randomly shuffled for each participant. The final sentence of each filler story always described an explicit shift (e.g., "On the other side of the world, a similar event was occurring with a boy named Kakimoto and his favorite baseball player, Tetsuo Matsui.") to provide an assessment of whether participants were correctly evaluating topic shifts. The instructions to the questionnaire described the concept of topic shifts in

detail and provided two examples (one story containing a topic shift and one without a shift). Following the examples, the instructions read, "At the conclusion of each story, you are going to be asked to think about the final sentence in relation to the rest of the story. Specifically, you are to decide how much of a topic shift is conveyed in that final sentence." Participants used a Likert scale, ranging from 1 (*no shift*) to 7 (*drastic shift*), to indicate the amount of shift.

The data from these questionnaires demonstrated that participants reported no difference in the amount of shift conveyed by the long- and short-activity statements. The mean shift rating for long-activity statements was 2.42, and the mean shift rating for short-activity statements was 2.48; these ratings were not significantly different by participants or items (all $t_s < 1$). The mean shift rating for the fillers was 5.73, which suggests that these results were not due to a floor effect for which participants were unwilling to provide ratings that indicated the existence of shift statements (and also suggests that participants indeed understood the notion of a discourse shift). These data suggest that the results of Experiment 2 were unlikely to be due to qualitative differences in the degree to which long- and short-activity statements cued reader expectations about changes in discourse topics.

Although we ruled out the topic shift hypothesis as a potential explanation for the experimental findings, at this point we cannot make any definitive claims about the particular dimensions that led to the obtained differences in recognition times. Our belief is that activity statements conveying information about time and space influenced the accessibility of locations, with time acting as a correlate for spatial proximity and spatial distance. However, another viable possibility is that participants encoded events solely based on the passage of time associated with activities, without reference to the spatial organizations implied in stories. The passage of time need not provide information about spatial distance to influence the accessibility of location information. Evidence has suggested that with long-activity statements, information preceding a shift can become less accessible solely due to longer time shifts (Rapp & Gerrig, 2002; Zwaan, 1996). With short-activity statements, early locations remain accessible because less time has passed, and they are still considered part of the current focus of the story (Bower & Morrow, 1990). This calls into question our interactive position, suggesting that text cues for particular dimensions may operate along a unitary, rather than multidimensional, set of indices. Were locations encoded along spatial and temporal dimensions or encoded along a single temporal dimension? This issue was addressed in Experiment 3.

Experiment 3

To test the interactive nature of text dimensions, we modified our stories to reduce the spatial movement described in the narratives. We rewrote the stories so that characters remained in start locations while completing their activities. The characters intended to travel to a final location but never actually left to reach that destination. Instead, characters remained at the start location while engaging in either a long or short activity. Revising our stories in this manner maintained temporal differences but eliminated the spatial components of those shifts. This allowed us to examine whether activity statements influenced accessibility by operating solely as temporal cues or if they operated through the integration of both spatial and temporal cues. If readers' representations are

structured purely by the passage of time in the stories, we would expect to obtain a pattern of data similar to that found in our previous experiments: Participants should take longer to recognize probes for start locations following long activities compared with when start probes follow short activities. If, however, readers' representations are also influenced by character movement, then the removal of spatial cues should result in similar recognition times for start locations regardless of activity length. Although this prediction is contingent on a null effect, it is nevertheless informative in contrast to the consistent pattern obtained in our previous three experiments.

Method

Participants. Thirty-six Tufts University undergraduates participated in this study for course credit. All participants were native speakers of English.

Apparatus. The apparatus was identical to that in Experiment 1A.

Materials. We modified the experimental stories from Experiment 2 (see Appendix C for examples). These stories described the same basic characters, scenarios, and objectives using a similar structure as the previous sets. Again, each story was 12 sentences long. The stories were modified to describe the character as engaging in an activity at the start location (without mentioning the start location more than once in the overall narrative). The stories concluded as the character considered leaving or prepared to leave for the final location. For the activity statements, only four required modification to remove references to movement, and again we equated these statements for length (mean number of words for long- and short-activity statements = 11.2). For some of the items it was also necessary to rewrite sentences to maintain local and global coherence, given that in these modified stories the character was only planning or preparing to leave (rather than actually doing so, as in the previous experiments). These story sentences were rewritten to contain the same number of words as their original versions from the previous experiments so as to keep them close to the original story structure. The number of filler stories and correct *yes* and *no* probes was the same as in Experiment 2.

Design. The design was identical to that in Experiment 1A.

Procedure. The procedure was identical to that in Experiment 1A.

Results and Discussion

Table 4 presents the results of Experiment 3. Participants failed to respond before the deadline 1.1% of the time, and these re-

sponses were not included as part of our analyses. We also eliminated decision times falling more than three standard deviations above the mean, resulting in a loss of an additional 1.7% of the data. None of the participants expressed any awareness of the goals of the study.

We again began by analyzing recognition times for correct responses to probe locations. Neither of the main effects nor the interaction were significant (all $F_s < 1.1$). We conducted planned comparisons using paired t tests (Bonferroni corrected), with none of the comparisons significant (all $t_s < 1$). There was no evidence of the earlier accessibility pattern with the removal of the spatial cue.

Next, we analyzed the error rates for recognition responses. Neither the main effect of activity statement nor the interaction was significant ($M = 27\%$ incorrect for start locations following long activities, 28% incorrect for start locations following short activities, 35% incorrect for final locations following long activities, and 34% incorrect for final locations following short activities; all $F_s < 1$). Participants tended to provide a higher proportion of incorrect responses for final locations ($M = 35\%$) compared with start locations ($M = 28\%$), marginal by participants only, $F_1(1, 35) = 4.07$, $MSE = .04$, $p = .051$; $F_2(1, 19) = 1.92$, $MSE = .069$, $p > .10$. Recall that the characters in these stories never visited final locations, remaining in start locations at the conclusion of the stories. We might expect participants to have had more difficulty accessing these final locations because they did not remain the focus of characters' attention as the stories unfolded (and had only been mentioned once, in the fourth sentence of each story). Had our stories placed greater emphasis on characters' intentions to visit their final locations, we might have expected readers to demonstrate better recognition for those locations (Morrow et al., 1989). Finally, we evaluated reading times for the activity statements (see Table 4). Participants took 72 ms longer to read long-activity statements (2,587 ms) than short-activity statements (2,515 ms); however, neither of the main effects nor the interaction were reliable (all $F_s < 1.1$). Because there were slight differences in the number of words composing the critical activity statements in Experiments 2 and 3, we repeated the reading time analyses based on the number of words in each statement. These analyses were entirely consistent with whole-statement reading times.

The data from Experiment 3 suggest that when spatial cues are decoupled from statements implying temporal duration, there is a change in the baseline pattern of accessibility for spatial locations. We found no differences in reaction latencies for start or final location probes. This null result should, of course, be interpreted with caution, but we point out that the main effects and interaction for recognition times were not significant with all p values exceeding .30. Experiment 3 used the same number of participants, the same methodologies and procedures, and similar stimuli to that from the previous three experiments. Therefore, we have reason to believe that had there been effects of our location and distance manipulations similar to those obtained in Experiments 1A, 1B, and 2, we would have obtained similar results. Given the p values in Experiment 2 for the overall activity statement by probe interaction (significant by participants and marginal by items) and the critical planned comparison for start probes following long-activity statements compared with final probes following short-activity statements (significant by participants and items), it is

Table 4
Means and Standard Deviations for Correct Recognition Probe Times and Activity Statement Reading Times for Start Locations (L1) and Final Locations (L2) in Experiment 3

	Correct recognition probe times		Activity statement reading times	
	L1	L2	L1	L2
Long-activity statement				
<i>M</i>	1,384	1,405	2,623	2,551
<i>SD</i>	233	301	866	652
Short-activity statement				
<i>M</i>	1,406	1,379	2,468	2,562
<i>SD</i>	255	301	770	747

Note. All probe and reading times in ms.

unlikely that these findings were spurious. The statistical comparisons were run with Bonferroni corrections, which guard against Type-1 error (incorrect rejections of the null hypothesis). Even with these corrections to the p values required for rejection of the null hypothesis, the critical findings in Experiment 2 remained significant, reducing the probability that the null interaction and critical comparison were incorrectly rejected in Experiment 2 (Rosenthal & Rosnow, 1991).

Unfortunately, a power analysis for the null effect in Experiment 3 is not possible because all power analyses assume that the null hypothesis is false (Hoeng & Heisey, 2001). This presents a challenge in assessing whether there was sufficient power to reject the null in Experiment 3. To address this issue in a different way, we conducted an explicit statistical comparison between Experiments 2 and 3 using a 2 (activity statement: long vs. short) \times 2 (location: start vs. final) analysis of variance (ANOVA) with experiment (2 vs. 3) as a between-subjects variable. This allowed us to evaluate whether the null result obtained for Experiment 3 was indeed due to differences in the experiments themselves. Evidence for this would be obtained in a significant interaction effect by experiment. We note that this analysis is based on two different experiments and thus should be viewed carefully. Nevertheless, the data from this cross-experiment analysis are informative with respect to the effects obtained in one experiment compared with the other. Consistent with this view, we found significant effects by experiment. There was an interaction of activity statement by experiment, marginal by participants and items, $F_1(1, 70) = 2.70$, $MSE = 22,999$, $p = .098$; $F_2(1, 38) = 3.97$, $MSE = 17,273$, $p = .054$. There was also an interaction of location probe by experiment, significant by participants and marginal by items, $F_1(1, 70) = 5.00$, $MSE = 34,428$, $p < .05$; $F_2(1, 38) = 2.95$, $MSE = 25,227$, $p = .094$. The three-way interaction of Activity Statement \times Location Probe \times Experiment was significant by participants and marginal by items, $F_1(1, 70) = 4.85$, $MSE = 26,807$, $p < .05$; $F_2(1, 19) = 3.83$, $MSE = 26,971$, $p = .058$. The analysis also revealed a main effect of location, significant by both participants and items, $F_1(1, 70) = 5.69$, $MSE = 32,428$, $p < .05$; $F_2(1, 38) = 4.51$, $MSE = 25,227$, $p < .05$, and a main effect of distance, marginal by participants only, $F_1(1, 70) = 2.97$, $MSE = 22,999$, $p = .089$; $F_2(1, 38) = 2.68$, $MSE = 17,273$, $p > .10$. There were no other effects (all $F_s < 1$). The evidence from these analyses suggests that the between-subjects variable of experiment indeed influenced performance. This statistical comparison, the Bonferroni corrections protecting against Type-1 errors in Experiment 2, and the similarity between Experiment 2 and Experiment 3 (in terms of methodologies, procedures, participants, and stimuli) provide convergent evidence for the validity of the null result obtained in Experiment 3.

We take these findings as suggestive that, at least for our previous experiments, readers' representations of text events rely on the interactivity of movement (space) and character activities (time) in the construction of a situation model. This interactivity results in differential accessibility for narrative locations.

General Discussion

The purpose of this set of experiments was two-fold. First, we wished to evaluate the interactive nature of the cues that influence readers' construction of multidimensional situation models. Sec-

ond, we wanted to evaluate whether the mechanisms guiding the structure of narrative representations involve general, shift-based segmentation processes or more precise, expectation-based segmentation processes. Our experiments therefore extend previous work on situation models and narrative representations. In Experiments 1A and 1B, explicit spatial distance statements influenced the representations and accompanying accessibility of story locations. This pattern served as a baseline for evaluating the interactivity of narrative indices. Participants in Experiment 2 demonstrated a similar pattern of accessibility for stories that included activity statements implying the passage of time but providing no explicit mention of spatial distance. Experiment 3 eliminated character movement, suggesting that our earlier effects were likely a result of the interactivity of multiple text dimensions.

Our results speak to the utility of the event-indexing model as an account of the features encoded by readers during their narrative experiences. Although research has described the dimensions that are tracked during reading, less work has focused on the interactive nature of those dimensions during the encoding and retrieval of text representations. There has been considerable interest in the notion of interactive event dimensions outside of the text comprehension domain (e.g., Boroditsky, 2000; McGlone & Harding, 1998). The experiments in this article embrace this view by describing how the construction and application of text dimensions, such as time and space, are mutually determined. As such, the results call into question the notion of discrete representational dimensions in event-indexing model accounts of text processing. By evaluating the interactive nature of construction processes, we can provide a more comprehensive account of how situation models are dynamically updated during narrative experiences (see van den Broek, Young, Tzeng, & Linderholm, 1999, for a review).

Of course, a process-based explanation for these results need not rely solely on the integration of multiple dimensions but rather should focus more directly on the construction of multiple mental substructures. For instance, information in the here-and-now of the text tends to remain more accessible than information from earlier text events (see Morrow, 1994, for a review). With each new event, a new substructure is built. The accessibility of earlier information is reduced as a function of being represented in a prior mental substructure. For the stories in our experiments, start locations may have become less accessible than final locations as a function of being represented in earlier substructures. When distances were large, either based on larger temporal or spatial shifts, start locations were less accessible. When distances were short, readers did not need to construct a new mental substructure and information remained readily accessible. Such a framework provides an indication of the potential processes guiding the construction of event representations during text comprehension. However, this explanation on its own fails to precisely outline when a new substructure may or may not be built. What determines whether a particular distance or shift is of sufficient size, duration, or salience to cue the construction of a new mental representation?

We argue that expectations about the range or duration of events are largely a function of readers' beliefs about the concomitants of space and time. Thus, reader expectations and background knowledge provide organizing frameworks that influence processes of situation model construction. This view, along with our results, suggests a necessary updating of structure-building theory to account for data supporting the flexible-boundary hypothesis.

Structure-building theory proposes that particular events are segmented in memory representations, resulting in differential accessibility for mental substructures depending on reader or text focus. The theory has had less to say about the malleability of that segmentation process. Our data suggest that the construction processes by which events are segmented, and substructures are constructed, may be more flexible than originally described. The underlying mechanisms for this segmentation process likely rely on readers' knowledge or beliefs about the duration and nature of events, directly influencing the structure of resulting text representations.

Our results argue against the rigid-boundary hypothesis as a general theory of situation model construction. According to the rigid-boundary hypothesis, event shifts should lead to broad, categorical reductions in the accessibility of text information from memory. Our data suggest that for cases in which time and space guide event shifts, the rigid-boundary hypothesis fails to capture the types of sophisticated processing that readers rely on for comprehension (Zwaan et al., 2000). We note, though, that it may be the case that the appropriateness of either the flexible-boundary or rigid-boundary hypothesis for describing model construction may depend on the particular dimensions studied, as well as the medium of interest. For instance, studies examining movie presentations have suggested that real-world interactions between time and space are necessary during film comprehension (Magliano, Miller, & Zwaan, 2001).

Related to this issue, continued investigation is necessary to delineate the specific contributions of space and time in an interactive model of text comprehension. This is particularly important because the findings of Experiment 3 are based largely on a null result and should be interpreted with caution. Future research should investigate the specific contributions of each index on reader memory for locations and events. For example, stories might be interrupted during character movement, such as during travel from start to final locations, at which point characters could engage in activities of variable duration. Probe latencies could reveal the time course of accessibility for text information as readers dynamically update their situation models.

Such work might also be designed to address whether text dimensions such as time and space are nested within one another or whether these dimensions are truly independent. Traditional studies have tended to treat these dimensions as separate indices (Zwaan, Langston, et al., 1995; Zwann, Magliano, et al., 1995). The alternative view, that space and time are subsumed under a larger dimension, has also been of interest, although it has received less empirical support. These opposing views may represent a continuum of representational possibilities based on the nature of a particular task. In our studies, participants were asked to recognize locations following shifts in both time and space, which may have led participants to treat the two dimensions as a unitary dimension. However, for studies that require participants to construct and apply situation models based on particular task-specific indices, text dimensions may be separated in a mental representation (e.g., Rapp, Gerrig, & Prentice, 2001; Trabasso, van den Broek, & Suh, 1989; van den Broek, 1988; Zwaan, 1996).

As previously mentioned, a growing body of research has examined the notion of separate dimensions almost exclusively, without attempting to account for the interactive nature of text dimensions (Zwaan & Radvansky, 1998). One body of research

along these lines has evaluated the dominance of particular text dimensions (Magliano et al., 2001; Rich & Taylor, 2000; Taylor & Tversky, 1997). Another body of work has demonstrated that reader preferences and beliefs can influence the likelihood that readers encode specific dimensions into their situation models (Rapp et al., 2001; Rapp & Gerrig, 2002; Taylor, Rapp, & Klug, 2002). Both sets of studies have outlined how readers' predilections for encoding particular dimensions can influence their recall of narrative events. The current project builds on these studies by including the notion that readers' prior knowledge about the interactive nature of text dimensions can facilitate the degree to which they build their narrative representations. Research in decision making has also supported this view, demonstrating that judgments of causality are based not only on event descriptions, but also on participants' expectations about the temporal intervals normally associated with those events (Hagmayer & Waldmann, 2002).

One potential question that can be raised is whether the interactive effects we have described commonly occur during general discourse experiences. Reading tasks and goals can directly influence the nature of the processes that readers rely on as they read (Magliano, Trabasso, & Graesser, 1999; Zwaan & van Oostendorp, 1993). One could argue that the movement cues in our stories may have been sufficient to signal that readers should track particular text dimensions more closely than usual. We do note, however, that participants in Experiment 2 did not report explicitly noticing such cues, yet movement effects were still obtained. In addition, although extensive work was conducted to make our experimental stories naturalistic (e.g., more similar to real-world texts), they clearly differentiate themselves from true narrative fiction and nonfiction. We contend, however, that the materials and results described in these experiments have direct analogues in everyday discourse, and as such, these effects should extend beyond our stimuli.

For example, in everyday conversation, it is not uncommon to provide directions by using activity cues to indicate distances. Consider the case in which a colleague provides driving directions for a cocktail party: "After you've passed University Avenue, keep going, keep going, keep going, keep going, until you've reached the pizzeria." These multiple instances of "keep going" are unlikely to be classified as purely spatial or temporal cues but rather provide a multidimensional cue for the amount of time and space that needs to be experienced before reaching the pizzeria. In this example, the "keep going" cue functions in a similar manner to our distance and activity statements. One could even imagine that the notion of "keep going" might generate diverse expectations in listeners depending on their propensities and willingness to drive for different distances or their expectations for how suggestive four instances of "keep going" are for actual movement. Narratives use similar techniques, and we wished to evaluate some of the underlying mechanisms involved in comprehending these situations.

We have remained agnostic with respect to the issue of automaticity in the use of linguistic cues for constructing situation models. The situation model literature has presented evidence on both sides of the argument (e.g., Clifton & Duffy, 2001; De Vega, 1995; Hakala, 1999; McKoon & Ratcliff, 1992; Morrow, 1994; O'Brien, 1995; Zwaan, Radvansky, Hilliard, & Curiel, 1998). The strong form of the automaticity argument suggests that readers

construct representations that encode event dimensions on-line. For example, evidence from research on causal structure (e.g., van den Broek & Trabasso, 1986), spatial situation models (Levine & Klin, 2001), and trait attributions (e.g., Uleman, Hon, Roman, & Moskowitz, 1996) suggests that readers may be predisposed to construct these representations on a moment-by-moment basis. The competing perspective suggests that readers construct representations if they conform to their strategies (e.g., Hakala, 1999) or help them achieve their comprehension goals for the text experience (e.g., van den Broek, Lorch, Linderholm, & Gustafson, 2001). Our studies do not allow us to make claims concerning the automaticity of construction processes. Given our results, both of the aforementioned views need to take into account the subtle types of linguistic cues (such as the activity statements presented in our stories) that can influence text processing.

As we suggested in the introduction to this article, readers rely on linguistic cues and background knowledge to help them “fill in” the missing information from text descriptions. For example, many of the details of Seabiscuit’s race for the Hollywood Gold Cup were only partially available or even entirely left out from the text. However, readers can rely on the interactive nature of text descriptions and their background knowledge to engage in those “filling in” processes. Cues for space or time, for example, can inform expectations about space, time, characters, objects, causality, and story settings. We propose that readers’ use of these cues is a natural process in comprehending texts during everyday reading. By defining these interactive cues and their impact on the comprehension of texts, we can further outline the underlying interactive nature of mental representations and clarify how those representations are constructed and updated during narrative experiences.

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Appendix A

Sample Stories From Experiment 1A and 1B (Including Recognition Probes)

Joe was working diligently on his term paper.
 Joe had been laboring for quite some time in the library.
 He began to feel kind of hungry.
 He decided to get something to eat from the diner.
 Joe gathered his things and left.
 Outside, he noticed a stick on the ground.
 He pulled out a small pocket knife from his bookbag.
 Joe began to whittle away at the stick while he walked.
 Joe walked for four miles. (long-distance statement, Experiment 1A)
 Joe walked for four blocks. (short-distance statement, Experiment 1A)
 Joe walked for five miles to his destination. (long-distance statement, Experiment 1B)
 Joe walked for three blocks to his destination. (short-distance statement, Experiment 1B)
 He put the finishing touches on it just as he arrived.
 The smells of cooking burgers and french fries made his mouth water.
 He stepped up to the counter and ordered a grilled cheese sandwich.

Location probes: library [start location], diner [final location]

Nick had a big test coming up.
 But Nick was spending too much time at the gym.
 He had finished playing basketball and it was time to work.
 He planned to walk over to his dorm room to study.
 Nick's stomach was grumbling.
 He carried his materials, including his textbook, notes, and audio cassettes of lectures.
 He decided it might be worth listening to one of the lectures on the way.
 He put the walkman headset on and listened.
 Nick walked for four miles. (long-distance statement, Experiment 1A)
 Nick walked for four blocks. (short-distance statement, Experiment 1A)
 Nick walked for five miles to his destination. (long-distance statement, Experiment 1B)
 Nick walked for three blocks to his destination. (short-distance statement, Experiment 1B)
 He hit the stop button on his walkman and pulled open the door.
 He smelled some food cooking in the building.
 His stomach seemed to gurgle in response to the smells.

Location probes: gym [start location], dorm [final location]

Appendix B

Sample Stories From Experiment 2 (Including Recognition Probes)

Joe was working diligently on his term paper.
Joe had been laboring for quite some time in the library.
He began to feel kind of hungry.
He decided to get something to eat from the diner.
Joe gathered his things and left.
Outside, he noticed a stick on the ground.
He pulled out a small pocket knife from his bookbag.
Joe began to whittle away at the stick while he walked.
He carved the stick into a small flute. (long-activity statement)
He carved his initials right on the stick. (short-activity statement)
He put the finishing touches on it just as he arrived.
The smells of cooking burgers and french fries made his mouth water.
He stepped up to the counter and ordered a grilled cheese sandwich.
Location probes: library [start location], diner [final location]

Nick had a big test coming up.
But Nick was spending too much time at the gym.
He had finished playing basketball and it was time to work.
He planned to walk over to his dorm room to study.
Nick's stomach was grumbling.
He carried his materials, including his textbook, notes, and audio cassettes of lectures.
He decided it might be worth listening to one of the lectures on the way.
He put the walkman headset on and listened.
Nick listened to almost half of a lecture. (long-activity statement)
Nick listened to the introduction of a lecture. (short-activity statement)
He hit the stop button on his walkman and pulled open the door.
He smelled some food cooking in the building.
His stomach seemed to gurgle in response to the smells.
Location probes: gym [start location], dorm [final location]

Appendix C

Sample Stories From Experiment 3 (Including Recognition Probes)

Joe was working diligently on his term paper.
Joe had been laboring for quite some time in the library.
He began to feel kind of hungry.
He thought about getting something to eat from the diner.
He was still on his diet.
From his bag he retrieved a small stick.
He also removed a pocket knife from his back pocket.
Joe began to whittle away at the stick while he sat.
He carved the stick into a small flute. (long-activity statement)
He carved his initials right on the stick. (short-activity statement)
He put the finishing touches on it and then stood up.
Thinking about eating a burger and french fries made his mouth water.
He decided he would go and order himself a grilled cheese sandwich.
Location probes: library [start location], diner [final location]

Nick had a big test coming up.
But Nick was spending too much time at the gym.
He had finished playing basketball and it was time to work.
He planned to walk over to his dorm room to study.
Nick opened his locker.
He picked up his materials, including textbooks, notes, and audio cassettes of lectures.
He sat on a bench and listened to one of the lectures before he left.
He put the walkman headset on and listened.
Nick listened to almost half of a lecture. (long-activity statement)
Nick listened to the introduction of a lecture. (short-activity statement)
He hit the stop button on his walkman and pressed the eject button.
He smelled another person's lunch in the building.
His stomach seemed to gurgle in response to the smell.
Location probes: gym [start location], dorm [final location]
