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Constructing Multidimensional Situation Models During Reading

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We examined which dimensions of the situation model (time, space, causation, motivation, and protagonist) are monitored by readers during narrative comprehension. Clause or sentence reading times were collected in three experiments and analyzed using multiple-regression analyses. Experiment 1 showed that readers monitored temporal, causal, goal-related, and protagonist-related continuity because discontinuities on these dimensions led to reliable increases in reading times. This was not the case for spatial continuity. Prior to reading, participants in Experiment 2 memorized a map of the building in which the events described in the narratives took place. There was a reliable effect of the spatial dimension, as well as of the other dimensions. In Experiment 3, participants read the narratives of Experiment 2 but without having first memorized the map. There was no effect of the spatial dimension, but the effects were again reliable for the other dimensions. Reading times increased as a function of the number of situational continuity breaks. The results are discussed in the context of the event-indexing model (Zwaan, Langston, & Graesser, 1995; Zwaan & Radvansky, 1998).

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Current theories of language comprehension propose that comprehension is tantamount to constructing a mental model, or situation model, of the states of affairs described in a text (Graesser, Singer, & Trabasso, 1994; Johnson-Laird, 1983; van Dijk & Kintsch, 1983; Zwaan & Radvansky, 1998). A considerable number of studies have demonstrated that systematic manipulations of aspects of the described situation lead to different patterns of language processing, even when the descriptions are equivalent at the textbase level (for a review, see Zwaan & Radvansky, 1998). To give a recent example, Zwaan (1996) presented participants with different versions of 10-sentence narratives in which the temporal relatedness between pairs of target events was manipulated. In the "close" condition, the target events were temporally contiguous, for example, "Maurice was shaking hands and beaming. A moment later, he turned pale." In the "intermediate" and "distant" conditions, "moment" was replaced with "hour" and "day," respectively. Thus, in these conditions, there was a time shift from the event of shaking hands and beaming to the event of turning pale. It is important to note that the conditions were equivalent at the textbase level, as defined by Kintsch and van Dijk (1978). That is, target events were described in consecutive sentences that were linked by the temporal marker *later,* which referred back to a previously mentioned event. Thus, textbase representations for the different versions of Zwaan's texts are indistinguishable. Nonetheless, effects of temporal contiguity were obtained on reading times, working memory activation, and long-term memory associations. Similar effects of temporal contiguity have also been recently reported by Carreiras, Carriedo, Alonso, and Fernandez (1997) and by Radvansky, Zwaan, Federico, and Franklin (in press). Many experiments have demonstrated analogous effects for causal, goal-related, and spatial relations (for recent reviews, see Graesser, Millis, & Zwaan, 1997; Lorch & van den Broek, 1997; Zwaan & Radvansky, 1998).

Both theoretical and empirical considerations have led researchers to assume that situation models are multidimensional, including at least the following five dimensions: time, space, causation, motivation, and protagonist. Readers are assumed to keep track of WHen, WHere, and WHy (causation and motivation) events occur and WHo was the principal agent in them. According to the event-indexing model (Zwaan, Langston, et al., 1995; Zwaan & Radvansky, 1998), readers index each event denoted in a story, typically by a verb, on each of the five dimensions and connect events in a memory representation based on their relatedness on each of the dimensions. The event-indexing model makes two global predictions about the comprehension process: the *memory-organization hypothesis* and the *processing-load hypothesis.*

According to the memory-organization hypothesis, the more indexes that two events share, the more strongly they will be connected in long-term memory. Zwaan, Langston, et al. (1995) have provided evidence for this hypothesis. The likelihood that readers cluster events together from the story based on their memory for that story was reliably predicted by the number of indexes shared by those events, over and above the effects of surface and textbase features of the text.

In this study, we were concerned with the processing-load hypothesis. According to this hypothesis, the fewer indexes that are shared between the current event being processed and other events in the situation model, the more difficult it should be to incorporate that event into the situation model. Consequently, there should be increases in processing load when there is little overlap between the indexes of the event being processed and the current mental representation relative to when there is a great deal of overlap. These increases in processing load occur because the reader has to update one or more event indexes, for example, when the story events move from one time frame to another or from one protagonist to a new one or when an action is described that is unrelated to any active goal in the situation model. Thus, the assumption is that a reader is keeping track of the evolving situation by constantly checking on each of the five dimensions whether new information is consistent with the situation model constructed thus far. Our current assumption (see Zwaan & Radvansky, 1998) is that readers keep retrieval cues to relevant parts of the already constructed situation model, the "integrated model" in long-term working memory (Ericsson & Kintsch, 1995), such that incoming information can be efficiently integrated, even when incoming information has to be integrated with information that was stated or inferred several clauses earlier.

Increases in processing load should manifest themselves in increased reading times under the general assumption that there is limited processing capacity and that more complex processes require more time to complete than less complex processes. We discuss later the conditions under which overlap between event indexes is present versus absent according to the event-indexing model.

Zwaan, Magliano, and Graesser (1995) provided partial evidence for the processing-load hypothesis. They found that breaks in temporal and causal continuity but not breaks in spatial continuity led to significant increases in sentence-reading times for short stories. As is commonly assumed in research on reading comprehension, these increases reflect the reader's relative difficulty in integrating upcoming information into the evolving mental representation. The purpose of this study is to extend the findings of Zwaan, Magliano, et al. (1995) by examining all five dimensions of the event-indexing model. An additional purpose is to examine the spatial dimension more closely, which has proven to be rather elusive in its effects on reading times. As in Zwaan, Magliano, et al. (1995), we employed multiple-regression analyses of reading times as a way to measure on-line processing load. Multiple-regression analysis of reading times is a frequently used method in comprehension research (e.g., Bloom, Fletcher, van den Broek, Reitz, & Shapiro, 1990; Graesser & Riha, 1984; Just & Carpenter, 1980; Millis & Simon, 1994).

We followed a general procedure in analyzing reading times. First, we conducted principled analyses of our stimulus materials to determine the relatedness of story events on each of the five situational dimensions. The criteria for these analyses are detailed in Appendix A. Subsequently, we collected clause (Experiment 1) or sentence (Experiments 2 and 3) reading times. Next, we conducted multiple-

regression analyses on each person's data. All variables were forcibly entered simultaneously so that the effect of each predictor variable was assessed after the effects of the other variables had been statistically partialled out. We then extracted the standardized regression coefficients (beta weights) for our predictor variables. In a final step, we determined whether each beta weight was significantly different from zero using (two-tailed) single-sample *t* tests. When its beta weight is significantly different from zero, the corresponding variable is considered a reliable predictor of reading times (Lorch & Myers, 1990).

EXPERIMENT 1

Zwaan, Magliano, et al. (1995) provided initial evidence that readers simultaneously monitor multiple situational dimensions during comprehension. Specifically, sentence-reading times increased with the number of situational dimensions on which a story event could not be linked to the previous event(s). We attempted to extend these findings in Experiment 1 by examining the effects of continuity breaks on reading times on all five situational dimensions. Unlike Zwaan, Magliano, et al. (1995), we employed a clause-by-clause rather than a sentence-by-sentence presentation of the texts to allow for more fine-grained analyses.

Our analyses for the temporal, spatial, and causal dimensions were the same as those used by Zwaan, Magliano, et al. (1995). Temporal continuity is preserved as long as an event is temporally contiguous (i.e., directly follows or overlaps) with the previous event. Zwaan (1996) and Carreiras et al. (1997) provided recent experimentally based, rather than correlational, evidence for this assumption. Spatial continuity is preserved as long as events take place within the same spatial region (e.g., a room or a clearing in the forest). We discuss spatial continuity in greater detail in the remainder of this article.

Causation includes both physical and psychological causation but not enablements because these are considered weak causal relations (see Trabasso, van den Broek, & Suh, 1989, for a discussion of types of causal relationships). Thus, causal continuity is preserved as long as there is a causal antecedent for an event in the current memory representation. The motivational, or goal, dimension involves intentionality. As readers read narratives, they keep track of the goals of protagonists (e.g., Lutz & Radvansky, 1997; Suh & Trabasso, 1993). Motivational continuity is preserved as long as an event or action is motivated by a goal that was stated or implied in the prior text.

Finally, the protagonist dimension reflects the introduction of a new agent into the situation model. The assumption is that it takes time to create a new token in the situation model representing a protagonist (e.g., Gernsbacher, 1990. Thus, protagonist-related continuity is preserved as long as the events involve a protagonist that is already part of the situation model.

All analyses of the situational dimensions were conducted using the coding scheme shown in Appendix A. In addition, the texts were analyzed on a number of auxiliary variables that are known to predict reading times, such as number of syllables and serial position. This allowed us to assess the effects of the situational dimensions apart from the effects of the auxiliary variables.

Method

Participants. Twenty-seven undergraduate psychology students at Florida State University participated in the experiment for course credit. All participants in this and the other experiments were native English speakers.

Materials and procedure. Four stories were adapted from Aesop's fables (Hague, 1985). "The Farmer and the Eagle" is shown in Appendix B. The adaptations consisted of replacing some of the more archaic words and expanding the texts somewhat. The adapted stories were each about 300 words.

These stories were analyzed using a set of five variables to represent the five situational dimensions, as well as a set of five auxiliary variables known to be reliable predictors of reading times. The auxiliary variables were in part the same ones as those used by Zwaan, Magliano, et al. (1995): number of syllables per clause, the serial position of each clause in the text, the number of new argument nouns, argument overlap, three dummy variables coding for text, and argument overlap. In addition, we included variables indicating the serial position of each clause within its sentence and the number of infrequent words per clause. The variable coding for clause position was included because we used a clause-by-clause presentation, and reading times are known to increase toward the end of a sentence (e.g., Just, Carpenter, & Woolley, 1982). The word-frequency variable was included because the fables contained several low-frequency words. Words were considered low frequency if their frequency was below 250 in the Kucera and Francis (1967) corpus. The analysis for the situational variables was conducted by a trained analyst who used the coding scheme shown in Appendix A. A second trained analyst provided an independent analysis of two of the stories. Reliability was generally very high: time (96%), space (89%), causation (91%), goal (93%), and protagonist (99%). Discrepancies were resolved through discussion.

Procedure Each participant was seated in a separate booth in front of a personal computer. After the experimenter had explained the procedure, the instruction was repeated on the computer screen. All text was in black letters against a white background. After the instruction, the participants read a short practice text to

familiarize themselves with the procedure. The stories were presented one clause at a time. Participants advanced through the text by clicking on the mouse button. The computer registered the reading times. Stimulus presentation and data collection were controlled by a program that was developed using Psyscope (Cohen, MacWhinney, Flatt, & Provost, 1993). Macintosh Quadra 630 personal computers were used to collect the reading times.

Results

Predictor variables. Table 1 shows the means and standard deviations for the predictor variables (except the dummy variables coding for text), as well as their bivariate correlations. The means and standard deviations indicate that there is sufficient variability in each of our predictor variables to predict reading times. The correlations were used to detect potential problems of collinearity among our predictor variables. Because there were many correlations to examine, a conservative alpha level of .001 was used. For all other analyses in this and subsequent experiments, however, an alpha level of .05 was assumed. The correlations were generally low or nonsignificant. The only substantial correlations were between causation and protagonist ($r = .50$) and number of syllables and new argument nouns ($r = .47$). The latter correlation is lower than the ones ($rs > .65$) reported by Zwaan, Magliano, et al. (1995). Given that these authors found significant effects for both

TABLE 1
Descriptive Statistics of and Bivariate Correlations Between Predictor Variables in Experiment 1

Variable	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
Syllables	—										
Sentence position	−.06	—									
Clause position	−.22	.05	—								
New nouns	.47	−.14	−.09	—							
Argument overlap	.24	−.11	−.10	.11	—						
Frequency	.36	−.12	−.04	.34	.03	—					
Time	.33	−.07	−.15	.13	.20	.14	—				
Space	.14	−.01	−.18	.03	.12	.05	.35	—			
Causation	.23	−.08	−.09	.09	.15	.18	.36	.21	—		
Goal	.15	−.14	−.16	.02	−.06	.04	.03	.00	.12	—	
Protagonist	.11	−.29	−.06	.05	.09	.24	.22	.28	.50	.21	—
M	9.96	17.97	1.58	.72	.22	.72	.21	.21	.16	.28	.09
SD	3.69	10.24	.77	.72	.41	.79	.41	.41	.37	.45	.28

Note. $N = 139$. For correlations $> .32$, $p < .001$.

number of syllables and new argument nouns, there was no reason to expect a serious collinearity problem here. The correlation between causation and protagonist was potentially more worrisome because it involved two variables of theoretical interest. The correlation reflects the fact that in the story an action by one protagonist (rather than, for instance, a natural event or a state) often caused a reaction in another protagonist. We decided to include both variables and closely monitor their performance.

We also conducted tests to assess multicollinearity among our predictor variables. Separate multiple-regression analyses were performed on each predictor variable with the remaining predictor variables in the equation. The multiple correlations ranged between .31 (for sentence position) and .63 (for syllables). Because the multiple correlations were not extremely high (e.g., > .8), we concluded that there were no serious multiple collinearity problems in our set of predictor variables.

Reading times. With the auxiliary variables and situation-model variables all forcibly entered into the multiple-regression equation, we predicted clause reading times. The results of these analyses are shown in Table 2. The standardized regression coefficients (beta weights) indicate the relative importance of the variables in explaining variance in the reading times. Thus, the results indicate that syllables were the strongest predictor in this analysis.

TABLE 2
Standardized Regression Coefficients (Beta Weights) From the Regression Analyses of Reading Times in Experiment 1

Variable	*Beta Weight*	*t*	*SE*
Theoretical			
Time	.057*	3.90	.015
Space	−.005	.49	.011
Causation	.043*	2.64	.015
Goal	.030**	1.93	.016
Protagonist	.026*	2.54	.010
Auxiliary			
Syllables	.348*	14.49	.024
Sentence position	−.142*	7.19	.020
Clause position	.046*	3.36	.014
New arguments	.136*	8.40	.016
Word frequency	.136*	7.32	.019
Argument overlap	−.002	−.16	.013

*$p < .05$, two-tailed. **$p < .07$, two-tailed.

Consistent with Zwaan, Magliano, et al. (1995), temporal and causal discontinuities led to significant increases in reading times, whereas spatial discontinuities did not. Furthermore, goal- and protagonist-related discontinuities led to significant increases in reading times, with goal-related continuity being significant on a one-tailed test only.

The auxiliary variables show a familiar pattern, with the number of syllables being the strongest predictor and the other variables being significant predictors in the predicted direction. The only auxiliary variable that was not reliable was argument overlap. This mirrors the results from the two experiments in Zwaan, Magliano, et al. (1995).

Discussion

These findings replicate and extend the findings of Zwaan, Magliano, et al. (1995) that coherence breaks on several situational dimensions affect reading times. Whereas Zwaan, Magliano, et al. found effects for temporal and causal breaks only, we found effects for two additional dimensions not studied by Zwaan, Magliano, et al.: goal and protagonist. These findings thus provide further support for the processing-load hypothesis of the event-indexing model. The only problematic finding for the event-indexing model is that, as in Zwaan, Magliano, et al., the spatial variable was not a significant predictor. We addressed this issue in Experiment 2.

EXPERIMENT 2

Previous studies have shown that readers do not spontaneously construct detailed spatial representations when reading narratives. For example, Zwaan and van Oostendorp (1993) found that participants who were instructed to read a description of the scene of a murder "normally" could correctly verify only 71% of inference statements about spatial relationships between objects in a room. Readers who were specifically instructed to form a cognitive map during reading, however, verified 92% of the statements correctly, but their reading times were much longer than those of the normal group. Zwaan and van Oostendorp concluded that readers do not normally construct detailed spatial representations, a conclusion that is consistent with other research (Langston, Kramer, & Glenberg, 1998; Wilson, Rinck, McNamara, Bower, & Morrow, 1993). It should be noted, however, that chance performance in the Zwaan and van Oostendorp experiment was 50% and that people in the normal condition did score significantly higher than that. This suggests that readers only construct rudimentary spatial models during normal reading but

are able to construct more detailed models under more conducive conditions (see also Zwaan & van Oostendorp, 1994).

In this experiment, we used a paradigm introduced by Morrow, Greenspan, and Bower (1987) and further developed by Rinck and Bower (1995). We thought that the tasks and materials used in this paradigm would maximize the likelihood readers monitored spatial continuity. In this paradigm, people first memorized the layout of a building before they read a set of narratives about events taking place in that building. Importantly, each text explicitly described the movements of a protagonist from one room to another. The central measure in these studies was the availability of objects in the building as a function of the protagonists' current location, which was assessed with either probe recognition latencies (Morrow et al.) or reading times for anaphoric sentences (Rinck & Bower). The basic finding with both methodologies was that the greater the spatial distance between the two, the longer the access time. Thus, this shows that situation models can be organized spatially and that this spatial structure can have an influence on comprehension. Thus, although we know that the availability of information may be mediated by spatial characteristics, it is unclear whether a shift from one location to another otherwise affects comprehension.

The general logic of this paradigm is to first ensure that readers possess a detailed spatial model, by having them learn a spatial layout of a building to criterion before reading the narratives about people moving about in that building. The question of interest studied by Morrow, Rinck, and their colleagues is not so much whether readers construct spatially based situation models during comprehension. Rather, the question is whether readers use previously constructed mental maps during comprehension. In contrast, we were interested in whether spatial information has an influence on comprehension when it is not needed to respond to a memory probe or resolve an anaphoric reference. If our reading-time analysis is sensitive to changes in spatial location, then we should find reliable increases in reading times.

Method

Participants. Sixteen participants were recruited from the University of Notre Dame community and paid $10 for their participation. An additional four participants were replaced, three for having more than 33% errors on the comprehension questions, one for going through some of the stories at the pace of around 100 ms per sentence, which is implausibly fast for a comprehension task.

Materials and procedure. The stimulus map, narratives, and comprehension questions were the same as those used by Rinck and Bower (1995). Appendix

C shows one of the narratives that was used. The map was of a research center that contained 10 rooms, with four objects in each room. The map was 18 × 13.5 cm in size and was displayed on an IBM-PC compatible computer.

People first memorized the map of the research center knowing that they would later read stories that were based on the map. Memorization involved a study–test procedure. During study, the entire map was displayed for 20 sec. An outline of the entire building was presented on the computer screen in black on a white background. The name of each room was presented in blue near the center of each room. In addition, each object was represented by an icon that stood for that object along with the name of that object somewhere near the icon. The name of each object was presented in red near the object.

After the opportunity to study the map, participants were given a recall test. For this test, an outline of the map was presented along with markers for the room names and the objects. For the room names, a row of 3 blue *X*s was presented in each room. For the objects, a black dot was placed at each object location. Participants responded by first selecting either a row of *X*s or a dot using the computer mouse. If a row of *X*s was selected, a question appeared below the map asking this: "What is the name of this room?" After the person typed in a response, the question was replaced with a line for 3 sec that read either "correct" or "incorrect-*room*," with room being the room name. The correct name of the room was then printed in the center of that room. If a dot was selected, that dot would turn red, and a question appeared below the map that read, "What is the name of this object?" The participants then entered their response on the computer. After this, the question was replaced with a line for 3 sec that read either "correct" or "incorrect-*object*" in which object was replaced with the object name. This was then erased along with the dot that was selected. Because the computer was evaluating the response, misspellings were counted as errors. This procedure continued until all of the room names and objects had been selected. This study–test procedure continued until a person could correctly answer all of the test questions twice in a row. For the narrative comprehension task, the stories were 22 to 27 sentences in length ($M = 23.4$). The stories were those versions used by Rinck and Bower (1995) that included both movement and motivating sentences.

The stories were analyzed using the same procedure and set of variables as Experiment 1 (except clause position, given that the unit of presentation was the sentence in this experiment). Reliability for the situational variables was extremely high: time (99%), space (100%), causation (96%), goal (98%), and protagonist (100%). Discrepancies were resolved through discussion.

Participants read each story one sentence at a time, pressing a space bar to proceed to the next sentence. Reading times were recorded to a file. At the end of each story, participants were presented with a set of three comprehension questions. These questions asked about general information with regard to what happened in the story. Participants responded to these questions by pressing one of two buttons

on the computer mouse. The entire experimental session typically lasted from 1 to 1½ hr.

Results

Predictor variables. Table 3 shows the means and standard deviations for the predictor variables (except the dummy variables coding for text), as well as their bivariate correlations. The means and standard deviations indicate that there is sufficient variability in most of our predictor variables to predict reading times. The two notable exceptions are time and causation. The means for these (dichotomous) variables are close to zero, indicating that there were few breaks in temporal and causal continuity. We decided to include these variables in the equation, in order to make the analysis equivalent to that of Experiment 1. We will not, however, draw strong conclusions about the effects of these variables per se. The correlations between the predictor variables were generally low or nonsignificant. The only substantial correlations were between number of syllables and new argument nouns (r = .46) and between time and causation (r = .55). The former correlation is comparable to that found in Experiment 1. The correlation between time and causation is rather high. Given that the variability within these variables was low, however, we do not draw strong conclusions about these variables.

Multicollinearity test yielded multiple correlations ranging between .20 (space, protagonist) and .45 (time). Because the multiple correlations were rather modest, there was no reason to expect serious multiple collinearity problems in our set of predictor variables.

TABLE 3
Descriptive Statistics of and Bivariate Correlations Between Predictor Variables in Experiments 2 and 3

Variable	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Syllables	—									
Sentence position	.11	—								
New nouns	.46	−.23	—							
Argument overlap	.22	.34	−.26	—						
Frequency	.31	−.16	.30	−.12	—					
Time	−.02	−.38	.24	−.23	.20	—				
Space	−.12	−.24	.12	−.09	−.14	.32	—			
Causation	−.05	−.35	.24	−.25	.16	.55	.14	—		
Goal	.12	−.18	.09	−.16	.04	.28	.00	.21	—	
Protagonist	.20	−.13	.31	−.16	.18	.30	−.03	.32	.10	—
M	22.78	12.32	1.69	.81	.69	.07	.35	.09	.26	.24
SD	8.16	6.88	1.16	.76	.77	.25	.48	.29	.44	.43

Note. N = 375. For correlations > .2, $p < .001$.

Reading times. As Table 4 shows, all five situational variables reliably predicted reading times. The effects for time and causation were quite large but are to be interpreted with caution for reasons stated earlier. In comparison with Experiment 1, the effect of space was also quite substantial. Furthermore, there were reliable effects of the goal and protagonist variable, extending the findings of Experiment 1.

The auxiliary variables show a similar pattern as in previous experiments, with number of syllables being the strongest predictor, and reliable effects for serial position, new argument nouns, and word frequency. Unlike in previous experiments, argument overlap was also reliable. Given that there is no theoretical explanation for why this variable was reliable in this but not in any of the other experiments, we consider the effect spurious.

Discussion

The results show quite clearly that our analysis is sensitive enough to detect whether readers monitor changes in spatial location with a reliable effect of spatial discontinuities on reading times. Furthermore, there were reliable effects of all other situational dimensions as well, making this the first experiment in which effects of five situational dimensions on reading times are found. As noted earlier, however, the results for the temporal and causal dimension should be interpreted with caution, given their relatively low variability. A more prudent conclusion is that we did not find evidence against the monitoring of time and causation during reading. The effects for goal and protagonist extend those of Experiment 1. It is particularly important to note that these effects occurred with texts that were con-

TABLE 4
Standardized Regression Coefficients (Beta Weights) From the Regression Analyses of Reading Times in Experiment 2

Variable	*Beta Weight*	*t*	*SE*
Theoretical			
Time	.076*	3.64	.021
Space	.065*	3.80	.017
Causation	.081*	5.28	.015
Goal	.029*	3.24	.009
Protagonist	.062*	4.92	.013
Auxiliary			
Syllables	.459*	15.26	.030
Sentence position	−.094*	5.86	.016
New arguments	.060*	5.74	.011
Word frequency	.035*	3.77	.011
Argument overlap	.036*	3.21	.011

*$p < .05$, two-tailed.

structed to test for spatial representations. A logical next question would then be if evidence for spatial monitoring will be found in the more naturalistic situation where the reader does not have a detailed mental map prior to reading. This question was addressed in Experiment 3.

EXPERIMENT 3

The results of Experiment 2 provide strong evidence that readers do keep track of spatial continuity when (a) they have an appropriate spatial representation available prior to reading and (b) the text clearly indicates transitions from one spatial region to the next. The purpose of Experiment 3 was to assess the effect of clearly marked transitions in the absence of a previously created mental map. To this end, people in Experiment 3 read the same texts as those in Experiment 2 without having learned the layout first.

There are three possible patterns of results. First, it is possible that there is no effect for the spatial variable. This outcome might occur if people do not monitor spatial continuity when they do not possess a strong spatial map to begin with, even if spatial transitions are clearly indicated in the text. This would be because the construction of such spatial relational information is quite effort consuming, as evidenced by increased reading times for people who are instructed to construct such representations (Zwaan & van Oostendorp, 1993). In the second outcome, there would be an effect of the spatial variable, and it would be equally large as that in Experiment 2. This would suggest that readers monitor spatial continuity to the same extent whether or not they possess a mental map. In this case, the conclusion would be that clear demarcations of spatial transitions in a narrative are sufficient as cues for readers to make a spatial shift. Finally, a larger effect of the spatial variable (i.e., significantly larger than in Experiment 2) would suggest that readers do normally monitor spatial continuity when spatial transitions are clearly indicated but that this process is much more effortful when a detailed mental map is lacking. Thus, they must expend more effort to achieve the goal of shifting to a new spatial location.

Given that the presence or absence of the map-learning phase is inconsequential to the other situational dimensions, as well as the auxiliary variables, we expected to find the same pattern for them as in Experiment 2.

Method

Participants. Sixteen participants were recruited from the Florida State University (12) and University of Notre Dame (4) communities and paid $10 for their participation. Three additional participants were replaced: one because of several impossibly fast reading times (less than 1 sec per sentence), one for excessively

long reading times (reading time over 10 sec for several sentences per text), and the third one because later inquiry suggested that she might have been informed about the purpose of the experiment.

Materials and procedure. The same narratives were used as in Experiment 2, but the map was not used. The procedure was the same as in Experiment 2, with the exception that the map-learning phase was omitted.

Results

Reading times. The results are shown in Table 5. Unlike in Experiment 2, spatial discontinuities did not reliably predict sentence-reading times. As in Experiment 2, however, the other situational variables were reliable predictors. All of the auxiliary variables but one were reliable predictors. Unlike in Experiment 2, there was no reliable effect of argument overlap.

In a subsequent analysis, we focused on the effect of the availability of a spatial representation on spatial-continuity monitoring. To this end, we performed a between-experiments comparison to test whether the beta weight for the spatial variable was significantly lower than in Experiment 2. This analysis yielded a reliable effect of map presence, $t(30) = 2.09$, $SE = .027$. As expected, the absence of a map did not have a detrimental effect on the other situational dimensions. Independent-samples t tests showed that the beta weights for time, causation, goal,

TABLE 5
Standardized Regression Coefficients (Beta Weights) From the Regression Analyses of Reading Times in Experiment 3

Variable	*Beta Weight*	*t*	*SE*
Theoretical			
Time	.058*	2.48	.023
Space	.009	.43	.021
Causation	.059*	4.55	.013
Goal	.049*	5.75	.008
Protagonist	.041*	3.81	.011
Auxiliary			
Syllables	.543*	12.68	.043
Sentence position	−.072*	2.71	.026
New arguments	.036*	2.39	.015
Word frequency	.043*	4.39	.010
Argument overlap	.012	.87	.013

*$p < .05$, two-tailed.

and protagonist in this experiment were not reliably different from those in Experiment 2 (all $ps > .14$).

Additivity. The processing-load hypothesis holds that processing load increases as a function of the number of situational coherence breaks. To test this hypothesis directly, we computed standardized residuals from multiple-regression analyses that included only the auxiliary variables. We then examined the standardized residuals as a function of the number of coherence breaks. In a series of initial analyses, we correlated, for each experiment separately, the residuals with the number of discontinuities (from 0 to 5) per sentence. These correlations (.17, .39, and .34, respectively, in Experiments 1, 2, and 3) were all significant.

To provide a more stringent test of the additivity hypothesis, we combined the data sets from the three experiments and conducted a one-way analysis of variance. Because the instances in which there were three or more coherence breaks were relatively infrequent—not surprising, given that our materials consisted of short narratives—we distinguished three levels of situational discontinuities: zero, one, and two or more. The average for the residuals were as follows: –170 ms (zero discontinuities), –38 ms (one discontinuity), and 394 ms (two or more discontinuities). The residuals clearly increase as a function of the number of coherence breaks; this pattern is highly reliable, $F(2,886) = 25.15$, $MSE = .89$. A Student Newman–Keuls post hoc test showed that all three groups were significantly different from each other.

Discussion

This experiment yielded several informative findings. In stark contrast to Experiment 2, there was no effect of spatial continuity on reading times. As in Experiment 2, however, there were reliable effects of the other four situational dimensions. Consistent with our expectations, the monitoring of these dimensions during reading did not critically depend on the availability of a spatial model. Apparently, the lack of a detailed mental map led readers to not monitor spatial continuity. The fact that spatial transitions were clearly indicated in the materials was apparently not sufficient as a cue for readers to monitor spatial continuity. An alternative possibility is that the participants in Experiment 3 constructed spatial models of a larger granularity than did the participants in Experiment 2, such that a change in rooms was not necessarily interpreted as a shift in location (the person was still in the research center). Our current experiments do not allow us to evaluate this hypothesis. This is an important topic for further research, however.

Finally, the analysis of the residuals provided some support for the hypothesis that situational discontinuities have additive effects on reading times. In all three experiments, a positive and significant correlation was observed between the

number of situational discontinuities and the standardized residuals of the reading times. An analysis of the data from the three experiments combined showed that reading times increased significantly from zero to one to two or more discontinuities. An experimental manipulation of the number of dimensions on which sentences are connected would provide more direct information on joint effects of the situational dimensions. This is a topic for further research.

GENERAL DISCUSSION

The purpose of this study was to test the processing-load hypothesis of the event-indexing model. In the first experiment, we replicated and extended the narrative comprehension findings of Zwaan, Magliano, et al. (1995). We replicated their results by showing that temporal and causal discontinuities led to reliable increases in sentence- and clause-reading times. We extended their results by showing that discontinuities with respect to goal and protagonist information also lead to elevations of reading times. As with Zwaan, Magliano, et al. (1995), we failed to find an effect of spatial discontinuities.

In the second experiment, we attempted to maximize the likelihood that participants would monitor spatial continuity by ensuring that (a) they had extensive prior knowledge of the spatial layout used as the setting described in the narratives and (b) the narratives, unlike the ones used in previous experiments, contained clearly demarcated transitions from one spatial region to the next in the described situation. Contrary to Experiment 1 and to Zwaan, Magliano, et al. (1995), we now found a reliable increase in reading times for spatial discontinuities. We also found reliable increases for the four other situational dimensions. The results for goal and protagonist replicate the effects of Experiment 1 with different materials. The results for time and causation were also reliable. As noted previously, however, these findings should be interpreted with caution given the low variability in the predictor variables.

Experiment 3 used the same narratives as in Experiment 2, but the participants did not learn a map prior to reading. Without a previously constructed mental map, they did not closely monitor spatial continuity during reading. This finding mirrors that of Experiment 1 and Zwaan, Magliano, et al. (1995). Given that an effect was obtained in Experiment 2, this rules out an explanation based on the idea that an effect of spatial continuity in these experiments is attributable to a deficiency in the regression method that was employed.

Our findings provide new support for the processing-load hypothesis of the event-indexing model: People monitor continuity on multiple situational dimensions when reading narratives. Although this was already established for time and causation by Zwaan, Magliano, et al. (1995), this study shows additional effects for motivation and protagonist. Thus, there now is strong evidence that readers simul-

taneously monitor temporal, causal, goal-related, and protagonist-related dimensions during narrative comprehension. We furthermore found that situational discontinuities have additive effects. Sentence-reading times, with the effects of the auxiliary variables partialled out statistically, increased with the number of situational discontinuities.

As with Zwaan, Magliano, et al. (1995), we did not find evidence that readers monitored spatial continuity unless they had a detailed mental map of the spatial layout prior to reading. The latter finding is consistent with findings that readers do not normally keep track of the relative positions of objects unless specifically instructed to do so (Zwaan & van Oostendorp, 1993). Together, these findings lead us to conclude that readers do not normally construct detailed spatial representations unless this is easy for them or relevant to their goals. This is not to say that people cannot use spatial information when processing information in situation models. The research by Morrow, Greenspan, & Bower (1987) described earlier demonstrates that spatial knowledge can have an influence when people need to refer to entities that are spatially removed from the protagonist. Also, research by Radvansky and Zacks (1991; Radvansky, in press; Radvansky, Spieler, & Zacks, 1993; Radvansky, Zacks, & Hasher, 1996) clearly showed that people can use spatial information to decide whether information should be integrated into a common situation model or stored in separate situation models.

A comparison between Experiments 2 and 3 suggests a theoretically important dissociation between the spatial dimension and the other situational dimensions. Under some conditions, readers are able to monitor all five situational dimensions simultaneously. Under other conditions, however, they monitor all dimensions but space when reading the same texts. This provides empirical support for the theoretical notion of a separate spatial dimension of situation models. It would be important for future research to examine whether similar dissociations can be found with respect to the other dimensions. Thus far, we have made the deliberately simplistic assumption that the situational dimensions operate independently and have equal status. Now that we have established that it is possible for readers to monitor all five dimensions simultaneously, however, the next step is to examine the independence or interdependence of the dimensions and differences with respect to their status in on-line comprehension and memory. In the wake of such research, we believe we have demonstrated that the event-indexing model holds promise as a conceptual tool for investigating the construction of meaning during reading.

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REFERENCES

Bloom, C. P., Fletcher, C. R., van den Broek, P., Reitz, L., & Shapiro, B. P. (1990). An on-line assessment of causal reasoning during comprehension. *Memory & Cognition, 18,* 65–71.

Carreiras, M., Carriedo, N., Alonso, M. A., & Fernandez, A. (1997). The role of verbal tense and verbal aspect in the foregrounding of information in reading. *Memory & Cognition, 23,* 438–446.

Cohen, J. D., MacWhinney, B., Flatt, M., & Provost, J. (1993). Psyscope: A new graphic interactive environment for designing psychology experiments. *Behavioral Research Methods, Instruments & Computers, 25,* 257–271.

Ericsson, K. A., & Kintsch, W. (1995). Long-term working memory. *Psychological Review, 102,* 211–245.

Gernsbacher, M. A. (1990). *Language comprehension as structure building.* Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Graesser, A. C., Millis, K. K., & Zwaan, R. A. (1997). Discourse comprehension. *Annual Review of Psychology, 48,* 163–190.

Graesser, A. C., & Riha, J. R. (1984). An application of multiple regression techniques to sentence reading times. In D. E. Kierras & M. A. Just (Eds.), *New methods in reading comprehension research* (pp. 183–218). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Graesser, A. C., Singer, M., & Trabasso, T. (1994). Constructing inferences during narrative text comprehension. *Psychological Review, 101,* 1–25.

Hague, M. (1985). *Aesop's fables.* New York: Holt, Rinehart & Winston.

Johnson-Laird, P. N. (1983). *Mental models.* Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Just, M. A., & Carpenter, P. A. (1980). A theory of reading: From eye fixations to comprehension. *Psychological Review, 87,* 329–354.

Just, M. A., Carpenter, P. A., & Woolley, J. D. (1982). Paradigms and processes in reading comprehension. *Journal of Experimental Psychology: General, 111,* 228–238.

Kintsch, W., & van Dijk, T. A. (1978). Toward a model of text comprehension and production. *Psychological Review, 85,* 363–394.

Kucera, H., & Francis, W. N. (1967). *Computational analysis of present-day American English.* Providence, RI: Brown University Press.

Langston, W., Kramer, D. C., & Glenberg, A. M. (1998). The representation of space in mental models derived from text. *Memory & Cognition, 26,* 247–262.

Lorch, R. F., & Myers, J. L. (1990). Regression analyses of repeated measures data in cognitive research. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16,* 149–157.

Lorch, R. F., & van den Broek, P. (1997). Understanding reading comprehension: Current and future contributions of cognitive science. *Contemporary Educational Psychology, 22,* 213–246.

Lutz, M. F., & Radvansky, G. A. (1997). The fate of completed goal information in narrative comprehension. *Journal of Memory and Language, 36,* 293–310.

Millis, K. K., & Simon, S. (1994). Rereading scientific texts: Changes in resource allocation. In H. van Oostendorp & R. A. Zwaan (Eds.), *Naturalistic text comprehension* (pp. 115–133). Norwood, NJ: Ablex.

Morrow, D. G., Greenspan, S. L., & Bower, G. H. (1987). Accessibility and situation models in narrative comprehension. *Journal of Memory and Language, 26,* 165–187.

Radvansky, G. A. (in press). The organization of information retrieved from situation models. *Psychonomic Bulletin & Review.*

Radvansky, G. A., Spieler, D. H., & Zacks, R. T. (1993). Mental model organization. *Journal of Experimental Psychology: Learning, Memory and Cognition, 19,* 95–115.

Radvansky, G. A., & Zacks, R. T. (1991). Mental models and the fan effect. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17,* 940–953.

Radvansky, G. A., Zacks, R. T., & Hasher, L. (1996). Fact retrieval in younger and older adults: The role of mental models. *Psychology and Aging, 11,* 258–271.

Radvansky, G. A., Zwaan, R. A., Federico, T., & Franklin, N. (in press). Retrieval of time based situation models. *Journal of Experimental Psychology: Learning, Memory, and Cognition.*

Rinck, M., & Bower, G. (1995). Anaphora resolution and the focus of attention in situation models. *Journal of Memory and Language, 34,* 110–131.

Suh, S., & Trabasso, T. (1993). Inferences during reading: Converging evidence from discourse analysis, talk-aloud protocols, and recognition priming. *Journal of Memory and Language, 32,* 279–300.

Trabasso, T., van den Broek, P., & Suh, S. Y. (1989). Logical necessity and transitivity of causal relations in stories. *Discourse Processes, 12,* 1–25.

van Dijk, T. A., & Kintsch, W. (1983). *Strategies of discourse comprehension.* New York: Academic.

Wilson, S. G., Rinck, M., McNamara, T. P., Bower, G. H., & Morrow, D. G. (1993). Mental models and narrative comprehension: Some qualifications. *Journal of Memory and Language, 32,* 141–154.

Zwaan, R. A. (1996). Processing narrative time shifts. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 22,* 1196–1207.

Zwaan, R. A., Langston, M. C., & Graesser, A. C. (1995). The construction of situation models in narrative comprehension: An event-indexing model. *Psychological Science, 6,* 292–297.

Zwaan, R. A., Magliano, J. P., & Graesser, A. C. (1995). Dimensions of situation model construction in narrative comprehension. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21,* 386–397.

Zwaan, R. A., & Radvansky, G. A. (1998). Situation models in language comprehension and memory. *Psychological Bulletin, 123,* 162–185.

Zwaan, R. A., & van Oostendorp, H. (1993). Do readers construct spatial representations in naturalistic story comprehension? *Discourse Processes, 16,* 125–143.

Zwaan, R. A., & van Oostendorp, H. (1994). *Spatial information and naturalistic story comprehension.* In H. van Oostendorp & R. A. Zwaan (Eds.), *Naturalistic text comprehension* (pp. 97–114). Norwood, NJ: Ablex.

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APPENDIX A
Criteria for Determining Situational Continuity in Analyses of Reading Times (1 = Discontinuity, 0 = No Discontinuity)

Time: Assign event $E(n)$ a 0 when it (a) directly follows or (b) temporally overlaps with $E(n-1)$ in the described situation. Temporal continuity is indicated by the absence of a temporal adverb(ial) in the corresponding clause or by an adverb(ial) expressing temporal continuity, such as "then," "a moment later," or "finally." Assign $E(n)$ a 1 when there is an adverb(ial) denoting a time shift ("much later," "after a while") or when a time shift can be inferred, such as between the following two sentences: "He left for the store. When he returned ..."

Space: Assign $E(n)$ a 0 when it takes place in the same spatial region as $E(n-1)$ and a 1 when it takes place in a different region. A region is a segment of space with (a) clearly defined boundaries, for example, a room or (b) with proximity to a landmark, for example, "in front of the church."

Goal: Assign $E(n)$ a 0 when it is part of a currently active goal structure (multiple goals may be active at the same time). An active goal is a goal that was either stated explicitly in or is infererable from the previous events, $E(n-m)$, whereby $0 < m < n$, and that has not been fulfilled yet. Assign $E(n)$ a 1 if it (a) establishes a new goal or (b) violates a currently active goal. New goals are typically indicated by verbs such as "decided" or "wanted" or by prepositions or prepositional phrases such as "in order to."

Causation: Assign $E(n)$ a 0 if it has a causal antecedent that is not a goal in $E(n-m)$, whereby $0 < m < n$, and a 1 otherwise. The presence of a causal antecedent can be determined by locating an answer to "why $E(n)$" in $E(n-m)$. If the search comes up empty, a 1 has to be assigned to $E(n)$.

Protagonist: Assign $E(n)$ a 1 when it introduces a new agent in the story world and 0 otherwise.

APPENDIX B
One of the Stories Used in Experiment 1

The Farmer and the Eagle
One day a farm laborer happened upon an eagle
that was struggling to free its wings
which were caught in a barbed wire fence.
The farm laborer was struck with the beauty of the bird.
So he decided to let it go free.
The farm laborer regretted this decision somewhat
because he knew
that the creature would yield a very high price at the market place.
However
and therefore he felt
that it was the right thing to do.
The eagle was touched by this generosity
and showed the farm laborer
that it was grateful for its deliverance.
The next day
who was resting in the shade of an old wall
that was crumbling
The eagle remembered the kindness of the man
and flew swiftly up to him
and snatched in its talons the cotton headband
that the farm laborer was wearing.
The man rapidly jumped to his feet
and chased after the eagle.
He was blindly enraged by the eagle's behavior.
After a couple of minutes, the eagle droppped the headband on the ground
The farm laborer picked up the headband
and then proceeded to walk back to the old wall.
He was trying to explain to himself
why the eagle wanted to grab his headband.
When he returned to the wall,
the farm laborer realized
how wonderfully the eagle had repaid his kindness.
The old wall had collapsed
just where he had been sitting.

APPENDIX C
One of the Stories Used in Experiments 2 and 3

Wilbur wasn't so sure he wanted to be head of the center anymore.
He had just been informed that the board of directors would be making a surprise inspection tomorrow.
He immediately called all the center's employees together in the library and told them they had less than 24 hours to clean up the center.
He explained about the visit and said that all of their jobs were at stake.
He told everyone to spread out and clean and organize every room.
He went into the laboratory and made sure it was being cleaned, and then headed off to supervise the rest of the workers.
He walked from the laboratory into the wash room.
In order to devise a list of necessary tasks, he tried to think of everything that looked dirty or messy in the building.
He thought that the toilet in the wash room still looked like an awful mess.
However, he was pleased to see the wash room's sparkling tile floor since he knew the directors were more impressed by cleanliness than good research.
He hurried into the repair shop and yelled at the foreman for not getting those greasy machine parts out of sight.
Next he thought he'd better check to see that the researchers were getting things organized.
He walked from the repair shop into the experiment room.
He re-checked his list of tasks to see what else needed to be done to make the research center decent-looking.
He remembered that the television in the lounge should not be turned on tomorrow.
Looking around the experiment room, he reminded himself to make sure the experimenters would be busy conducting studies tomorrow so the directors would see how industrious they were.
As he went into the reception room, he thought about the presentation he was planning to make to the directors.
Next he walked from the reception room into the conference room.
He didn't want to let any uncleanliness distract the directors from his presentation, so he checked his list for things that needed to be cleaned.
He decided that the rug in the reception room needed thorough cleaning as soon as possible.
Sitting down at the table in the conference room, he started to write down notes for his presentation.
He imagined himself giving a high-powered talk, and began to feel the visit might go well after all.