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Mental Models Contribute to Foregrounding during Text Comprehension

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A primary property of mental models is that they represent what the text is about (the events, objects, and processes described in the text), rather than features of the text itself. We used this property to demonstrate that mental models are operative during text comprehension. Subjects read texts that were propositionally equivalent, but described events in which the main actor was either spatially associated with a target object or spatially dissociated from the object. Pronominal reference kept the actor foregrounded throughout the text, but the target object was never repeated. The question of interest was whether the target object remained foregrounded when the text described events in which the actor and the object were spatially associated. Data from experiments using item recognition and reading time measures provided an affirmative answer. Thus the mental model controlling foregrounding reflected the structure of the events described by the text, not just the structure of the text. © 1987 Academic Press, Inc.

Pleasure is gained from reading when the text engages us, when it involves us. The phenomenal experience is akin to the events described in the text unfolding before our eyes: We become excited, anxious, or bored almost to the same degree as when the events are experienced directly. Even when reading exposition, there is something special about texts that engage us compared to those we simply read.

Until recently, there was little in the cognitive psychology of discourse comprehension that suggested this sort of engagement. Comprehension was modeled as construction of static representations of text. The situation has a potential remedy with the introduction of mental models.

Mental models have an appealing theoretical flavor. They are the result of constructive activity: Constructing a mental model requires continual interaction between the text and the reader's linguistic, pragmatic, and world knowledge. Mental models are updatable: The representation is modified by the addition of new information, and that new information may require accommodation that produces a completely different interpretation of the events. Mental models are manipulable: Portions of the representation can be reorganized and moved into contiguity with other portions to create emergent relations. Mental models are perceptual-like: They integrate information from different senses so that the mental model of an event described by a text need not be different in kind from the mental model constructed upon witnessing the event. Finally, several theorists (Collins, Brown, & Larkin, 1980; Johnson-Laird, 1983; Sanford & Garrod, 1981; van Dijk & Kintsch, 1983) assert that mental models are important for discourse comprehension: When a mental model is used as the referent for linguistic constructions, it guides interpretation of the text, controls inference making, and influences the extent to which the text is judged coherent.

Given this agreement as to the theoretical importance of mental models, it is surprising that there is little agreement as to

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exactly what constitutes a mental model, and there is little research demonstrating the operation of a putative mental model while reading. In this article we begin to remedy the situation. Our specific goals are to extract from the different theories the most salient feature that characterizes mental models as mental representations, and to use this feature to determine if mental models are functional during the comprehension of text. The second goal is met by examining the role of mental models in foregrounding concepts during text comprehension.

Mental Models Represent What the Text is About, Not the Text Itself

A basic feature of any representation is that it represents something, and any proposal regarding representations is incomplete without a specification of what is represented (Palmer, 1978). The key intuition shared by mental modelers is that a mental model is a representation of the situation described by a text, what the text is about, rather than a representation of the text (a description of the text) itself. This feature is a component of mental models proposed by Johnson-Laird (1983), Sanford and Garrod (1981), and van Dijk and Kintsch (1983).

This key feature can be illustrated by materials used in Bransford, Barclay, and Franks (1972) (see also Garnham, 1981, for similar materials and analyses). In that experiment, subjects were asked to memorize one sentence from pairs of sentences such as 1a and b and 2a and b.

1a. Three turtles rested *on* a floating log, and a fish swam beneath *them*.
1b. Three turtles rested *on* a floating log, and a fish swam beneath *it*.
2a. Three turtles rested *beside* a floating log, and a fish swam beneath *them*.
2b. Three turtles rested *beside* a floating log, and a fish swam beneath *it*.

On a recognition test, subjects who had memorized one of the sentences from pair 1 had great difficulty remembering which member of the pair they had been asked to memorize. On the other hand, subjects who had memorized one of the sentences from pair 2 had little difficulty discriminating the old from the new sentence. As Bransford et al. (1972) observed, these results are puzzling if the product of comprehension is a propositional description of the sentences. However, the results are compatible with the assumption that the cognitive representation is a mental model of what the sentences are about.

[We use the phrase, "propositional description of the sentences," in preference to what others, notably Kintsch and his colleagues, have referred to as a "propositional representation of the text," or the "meaning of the text." The term "propositional representation" is too broad because, as we will argue, mental models can be propositional (in fact, The van Dijk and Kintsch situation model is composed of propositions). Also, we prefer not to equate "propositional description of a text" with "meaning of a text." This equation is begging the question. It is not at all clear how to conceptualize the meaning of a text, much less how a comprehender might represent that meaning (see, for example, The Garnham (1981) discussion of the meaning of a proposition).]

Table 1 presents a propositional description of sentence pairs 1 and 2. The sentences in pair 1 differ only in the sixth proposition. In sentence 1a, the location of the swimming fish is given as beneath the three turtles (beneath p1); in sentence 1b the location of the swimming fish is given as beneath the log (beneath p3). It is easy to understand why subjects would confuse the two sentences: They are very similar. Note, however, that the sentences in pair 2 also only differ in the sixth proposition, and the sentences in pair 2 differ to exactly the same degree as the sentences in pair 1. On this analysis, the sentences in pair 2 should be as confusable as the sentences in pair 1. The data disconfirm this prediction, however. Apparently, the cognitive representa-

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TABLE 1
PROPOSITIONAL DESCRIPTIONS OF SENTENCES 1a, 1b, 2a, AND 2b

Sentence 1a	Sentence 1b
p1: (three, turtles)	p1: (three, turtles)
p2: (rest, p1)	p2: (rest, p1)
p3: (floating, log)	p3: (floating, log)
p4: (location, p2 *on* p3)	p4: (location: p2 *on* p3)
p5: (swim, fish)	p5: (swim, fish)
p6: (location: p5 beneath *p1*)	p6: (location p5 beneath *p3*)
Sentence 2a	**Sentence 2b**
p1: (three, turtles)	p1: (three, turtles)
p2: (rest, p1)	p2: (rest, p1)
p3: (floating, log)	p3: (floating, log)
p4: (location: p2 *beside* p3)	p4: (location: p2 *beside* p3)
p5: (swim, fish)	p5: (swim, fish)
p6: (location: p5 beneath *p1*)	p6: (location: p5 beneath *p3*)

tion of the sentences is not just a propositional description of those sentences.

According to mental model theory, the cognitive representation of text is a representation of the things (objects, events, processes) described by the text, not a description of the text. The events described by the sentences in pair 1 are quite similar to one another. In fact, the two sentences may be used to describe the identical event, the only difference being in the choice of words used to describe the event. Suppose then that upon reading a sentence from pair 1 the subject mentally represents the event described by the sentence. That subject would be unable to determine if he had read sentence 1a or sentence 1b, because both sentences describe his mental representation.

The sentences in pair 2 describe events that are likely to be quite different from one another. When the three turtles are beside the log and the fish swims beneath them, the fish need not (and probably does not) swim beneath the log too. Similarly, when the three turtles are beside the log and the fish swims beneath the log, the fish need not (and probably does not) swim beneath the fish too. Thus if the subject is representing the event, he or she should have little difficulty determining which sentence was read originally; only one of them describes the event mentally represented.

A number of distinctions are correlated with the distinction between cognitive representation as representation of events (or whatever the text describes) and as descriptions of the sentences. For example, it is likely that representing the event requires the use of more world knowledge than describing the sentences (Sanford & Garrod, 1981; van Dijk & Kintsch, 1983); representing the event probably requires more constructive (Bransford et al., 1972) or elaborative (Anderson, 1983) or secondary processing (Sanford & Garrod, 1981). Importantly, however, the representation of the event may well be in the form of propositions. As long as the propositions describe the event, rather than the sentences, then the representation is, by this criterion, a mental model (Oden, 1987).

To summarize, mental modelers offer an intuition regarding the representation of text. Namely, the result of comprehension includes a representation of what the text describes, not just a description of the text itself. Although mental models are often presumed to have additional defining features (see for example, Johnson-Laird, 1983), our experiments focus on this one. Indeed, previous demonstrations that mental models are used to represent text have also traded on this feature (Bransford et al., 1972; Garnham, 1981; Mani & Johnson-Laird, 1982; Perrig & Kintsch, 1985). All of these demonstrations have used memory paradigms, however. Our experiments investigate whether mental models affect on-line comprehension, namely foregrounding. We turn to the description of these experiments after a brief discussion of the concept of foregrounding.

FOREGROUNDING IN TEXT COMPREHENSION

An important feature of text, the feature that gives it its text-like character (as opposed to a list of sentences), is that text is cohesive; successive sentences belong together. Halliday and Hasan (1976) suggest a variety of intersentential relations that give rise to cohesive ties. Of those they suggest, the most important may be coreference (Sanford & Garrod, 1981). Sentences that refer to the same entity, even when they are composed of different words, are coreferential.

A prototypical case of coreference is the use of pronouns. For example, the pronoun "them" in sentence 1a is coreferential with "three turtles." The problem for theories of comprehension is how readers determine that "them" refers to the same entity as "three turtles" (see Lockman and Klappholtz (1980) for a discussion of the difficulties brought about by the variety of ways of referring to the same entity).

One (partial) solution is that certain elements (tokens) of the text are kept foregrounded, that is, highly activated, or in a special buffer. Then, as each referring word or phrase is encountered, tokens in the foreground are preferentially searched to determine if the new word or phrase is coreferential with a previously encountered term. In fact, attempting to use a pronoun to refer to information that is not in the foreground may be so difficult as to make the utterance anomalous (Fletcher, 1984; Lesgold, Roth, & Curtis, 1979; Sanford & Garrod, 1981). Various theoretical realizations of foregrounding are The Carpenter and Just (1977) discourse pointer, The Kintsch and van Dijk (1978) buffer, The Sanford and Garrod explicit focus, and Sidner's (1983) focus.

There has been a good deal of research into the factors that control entry and maintenance of tokens in the foreground. For example, the probability that a token remains foregrounded after initial mention depends on recency of mention or reference (Carpenter & Just, 1977; Lesgold et al., 1979; Sanford & Garrod, 1981), whether the entity was introduced as a sentence topic or comment (Sanford & Garrod, 1981; Sidner, 1983, van Dijk & Kintsch, 1983), the character of the intervening sentences (Sanford & Garrod, 1981), and the propositional structure of the text (Fletcher, 1981). The question addressed by our experiments is whether the structure of the mental model influences the extent to which tokens are foregrounded.

General Plan

Subjects read paragraphs such as the one in Table 2. Each paragraph began with a setting sentence which introduced the main character. The main character was foregrounded throughout the paragraph by reference. The second sentence was a critical sentence which included a target noun (highlighted in the table, but not for the subjects). In the associated condition, the critical sentence described an event in which the main character and the target object were spatially associated. In the dissociated condition, the critical sentence described an event in which the main character and the target object were spatially dissociated. Note that the critical sentence has the same number of words (and almost identical wording) and the same propositional structure in the two conditions.

Following the critical sentence the sub-

TABLE 2
One Scenario Paragraph

Setting sentence	John was preparing for a marathon in August.
Critical (associated)	After doing a few warm-up exercises, he put on his *sweatshirt* and went jogging.
Critical (dissociated)	After doing a few warm-up exercises, he took off his *sweatshirt* and went jogging.
Filler	He jogged halfway around the lake without too much difficulty.
Filler	Further along his route, however, John's muscles began to ache.
Question	Was the marathon scheduled to be held in the summer?

ject read no, one, or two filler sentences. Filler sentences always kept the main character foregrounded by using a pronoun to refer to that character (see Sidner, 1983). The filler sentences never referred to the target object.

Consider whether the associated–dissociated variable should affect the probability that the token representing the target object (e.g., sweatshirt) is foregrounded. Kintsch and van Dijk (1978; Fletcher, 1981; Miller & Kintsch, 1980) propose that foregrounding is controlled by the propositional structure of the text (although Van Dijk and Kintsch (1983) claim that the situation model also plays a role in keeping information foregrounded). Briefly, readers are assumed to relate propositions that include the same arguments. Given two related propositions, the proposition encountered second is subordinate to the one encountered first. Propositions are maintained in the buffer according to the "leading edge strategy": The most superordinate and the most recent propositions are maintained.

On this account, the associated–dissociated variable is irrelevant, because the propositional description of the text is not affected by this variable. In fact, any theory of comprehension that proposes that foregrounding is determined solely by the propositional structure of the *text* is forced to predict no effect of the associated–dissociated variable.

Now consider predictions derived from a mental model point of view. In the associated condition, the main character and the target object are spatially associated in the events described by the text. On the assumption that the mental model captures the spatial structure of the events, the token representing the main character and the token representing the target object should be "close" in the representation. Furthermore, keeping the main character in the foreground should tend to keep the target object in the foreground too. On the other hand, in the dissociated condition the text describes an event in which the main character and the target object are spatially distant. In the mental model, the token representing the main character and the token representing the target object should be unrelated. Therefore, in the dissociated condition, keeping the main character in the foreground does not imply that the target object will be foregrounded.

We have left the definition of "close" undefined, because the definition has no consequences for our predictions. For example, suppose that the mental model representation is image-like so that "close" means spatially close in the image. In this case, in the associated condition, keeping the main character foregrounded (in the mind's eye) is likely to keep the target object foregrounded. Alternatively, suppose that the mental model is propositional so that "close" means in the same proposition, or having many associations between the items. McKoon and Ratcliff (1980) have demonstrated that keeping one argument of a proposition activated (foregrounded) enhances the activation of propositionally related items.

Experiment 1

In this experiment we test the mental model prediction that the structure of the event (and thus the structure of the cognitive representation) will influence degree of foregrounding in text comprehension. The measure of degree of foregrounding comes from the item-recognition procedure developed by McKoon and Ratcliff (McKoon & Ratcliff, 1980; McNamara, McKoon, & Ratcliff, 1984). After reading a critical sentence, a subject is presented the target noun. The subject responds "yes" if the noun is recognized as occurring in the passage, and "no" otherwise.

The primary dependent variable is response time, which is interpreted with the aid of two assumptions. First, it is assumed that shorter response times reflect greater activation or availability of the token representing the target object. Second, it is assumed that tokens in the foreground are more available than tokens not in the foreground. These assumptions are noncontroversial (e.g., Fletcher, 1981). Thus the mental model position predicts faster response times in recognizing the target word in the associated condition than in the dissociated condition.

We included a second independent variable for pragmatic reasons. A token representing the target object is likely to be introduced into the representation and foregrounded upon initial mention (Sanford and Garrod, 1981), whether or not the target object and the main character are associated. Thus testing for item recognition immediately after the critical sentence is unlikely to reveal any differences in response time. Furthermore, even if the mental model position were substantially correct, the associated target object is unlikely to remain foregrounded throughout an extensive series of filler sentences that never refer to the target object. For these reasons, we manipulated the delay between the end of the critical sentence and presentation of the target noun for item recognition. The delay was either no, one, or two filler sentences. Only at an intermediate delay should the associated–dissociated variable substantially affect foregrounding and thus recognition time.

The third independent variable was related to the content of the paragraphs. In half the paragraphs (one scenario) all of the actions were part of a single scenario, such as the jogging scenario in Table 2. In the other paragraphs (two scenarios) the critical sentence moves the main actor from one scenario to another. An example is provided in Table 3. The initial scenario is arranging flowers; the second scenario is grocery shopping.

The intent of this manipulation was to enhance the dissociation between the main character and the target object. In the one-scenario paragraphs the character and the object are dissociated spatially; in the two-scenario paragraphs they are dissociated spatially and they are dissociated in that the target object is no longer relevant to the immediate goals and plans of the character in the new scenario. Sanford and Garrod (1981) and Sharkey and Mitchell (1985) have demonstrated effects of this second sort of dissociation.

TABLE 3
TWO SCENARIO PARAGRAPH

Setting sentence	John was arranging a bouquet for the table.
Critical (associated)	He put the last *flower* in his buttonhole, then left the house to go shopping for groceries.
Critical (dissociated)	He put the last *flower* in the vase, then left the house to go shopping for groceries.
Filler	When he got to the store, he went to the produce section to pick up some broccoli.
Filler	He then picked up cheese to make a sauce for the vegetable.
Question	Was John arranging the wine glasses?

Filler paragraphs were also included in the experiment. The filler paragraphs were similar in structure to the experimental paragraphs; however, a proportion of the targets were not nouns and a proportion of the targets had not occurred in the paragraph. These fillers were intended to discourage a strategy of concentrating on nouns, and to discourage subjects from always responding "yes" on the item recognition test.

Finally, questions requiring a "yes" or "no" answer were prepared for approximately one-fourth of the paragraphs. These questions were asked after reading the last sentence in the paragraph (and responding to the target if tested after the last sentence). The questions were intended to encourage meaningful reading of the paragraphs.

Method

Subjects. The 20 subjects were students enrolled in introductory psychology classes at the University of Wisconsin—Madison. These students participated to fulfill a course research requirement.

Materials and design. A total of 48 experimental paragraphs were composed along the lines of the examples in Tables 2 and 3. Also, 64 filler paragraphs (and 10 practice paragraphs) were based on the filler paragraphs used in Dell, McKoon, and Ratcliff (1983).[1] Considering the 64 filler paragraphs, 24 required a "yes" (it was in the paragraph) response to a nonnoun target, and 40 required a "no" response.

The three independent variables, associated–dissociated, delay, and number of scenarios, were manipulated within subjects. Excluding the 10 practice paragraphs, each subject read 112 paragraphs divided into four blocks of 28. Within each block were 12 experimental paragraphs (one in each of the 12 conditions formed by crossing the three independent variables), 6 filler paragraphs requiring a "yes" answer to the target, and 10 filler paragraphs requiring a "no" answer. For each subject we randomly determined (a) the assignment of specific paragraphs to block of 28, (b) the order of the paragraphs in each block, and (c) for each experimental paragraph whether the paragraph was in the associated or dissociated condition and the delay between the critical sentence and the item-recognition test.

The presentation and timing of all events was controlled by an Apple II computer. The paragraphs were presented using the upper and lower case orthography associated with the 40-column Turtlegraphics screen.

Procedure. Subjects were encouraged to read the materials carefully for comprehension. The paragraphs were presented one sentence at a time. After reading a sentence, subjects pressed either of two keys to erase the screen and present the next sentence. When the item-recognition test was scheduled (zero to two sentences after the critical sentence), pressing a key erased the screen and presented the target, underlined with asterisks, in the middle of the screen. Subjects responded "yes" by pressing the righthand key and "no" by pressing the lefthand key. Following the response, subjects were given feedback for two seconds and exhorted to be more careful if they had erred. Any remaining filler sentences were then presented. For approximately one-quarter of the paragraphs, a "yes"–"no" question was then presented. This question was answered by pressing one of the two keys. The next paragraph was initiated by pressing either of the keys. The experimental procedure required about 75 min. Subjects were given a short break halfway through the experiment.

Results and Discussion

For each subject in each condition we computed the median of the correct response times. The means of these medians are displayed in Figure 1. The bars on the bottom of the figure indicate the error rates in the various conditions.

The major result is clear. The associated–dissociated variable interacted with the delay, $F(2,38) = 3.79$, $MSE = 57851$.[2] The interaction is due primarily to the significant difference between the associated and the dissociated conditions at a delay of one sentence, $F(1,19) = 5.43$, $MSE = 80929$, whereas the difference is not significant at either of the other delays.

These results disconfirm the proposal that the only cognitive representation controlling the foregrounding of tokens is a description of the text. The results confirm the predictions based on a mental model approach to comprehension. Apparently, the representation of a text reflects the spa-

[1] We thank Gail McKoon for providing these materials.

[2] The probability of a Type I error was set at .05 for all analyses.

tial structure of the events described, and that structure plays a role in comprehension.

One objection to this conclusion is that the target noun, by virtue of being associated with the main character, is marked as special, and hence is given special attention by the subject. We have two counters to this objection. First, scrutiny of our passages indicates that it is just as likely that the noun would be considered special in the dissociated condition as in the associated condition. For exmple, in one paragraph a toddler either stays close to his brother (associated) or wanders away (dissociated). In this paragraph the dissociated condition generates a more important set of circumstances than the associated condition. Second, when the target noun in the associated condition was singled out for special attention, then the difference in response times should have revealed itself in the zero-sentence delay. Because there was actually a slight (though nonsignificant) reversal at the zero-sentence delay, this objection can be dismissed.

The remaining response time analyses revealed no surprises. The main effect of delay was significant, $F(2,38) = 25.4$, $MSE = 75068$, as was the main effect of number of scenarios, $F(1,19) = 11.26$, $MSE = 42188$. The number of scenarios variable did not interact with any other variable, all $Fs < 1$. This last result can be used as some indication of the generality of our main finding across language samples. That is, the interaction between the associated–dissociated variable and the delay variable was found for both types of paragraphs that are otherwise demonstrably different in overall response time (see Figure 1).

In an analysis of the error rates, the only significant effect was for delay, $F(2,38) = 10.93$, $MSE = .015$. Importantly, the response time effects cannot be attributed to a speed–accuracy tradeoff. For the filler paragraphs, the error rates were .10 and .06 for the "yes" and "no" responses, respectively.

Experiment 2

We have assumed that in the associated condition the speeded reaction to the target object reflects heightened activation of the token in the foreground. An alternative explanation is that the speedup in the as-

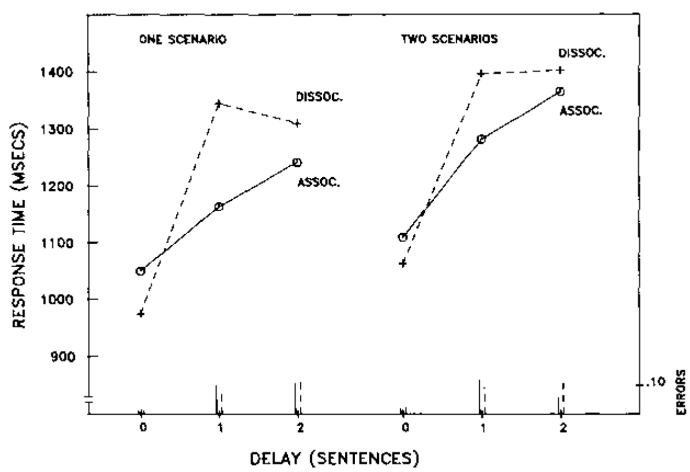

FIG. 1. Experiment 1: Average recognition time for critical nouns.

sociated condition reflects a decrease in the time needed for lexical access while reading the target on the item recognition test. In fact, Sharkey and Mitchell (1985) have demonstrated that some of the effects Sanford and Garrod (1981) attributed to foreground processing (reference resolution) may well have occurred at the stage of lexical access.

Experiment 2 was designed to test this alternative. The experiment was closely modeled after Experiment 1, the only significant change being to substitute a lexical decision task for the item recognition task. If faster processing in the associated condition reflects foreground processing, then the difference between the associated and dissociated conditions should be eliminated when the lexical decision task is used. If the difference remains, then at least some of the difference should be attributed to lexical access.

Whatever the outcome, our conclusion that a mental model of the text is formed during comprehension is secure. Experiment 2 only addresses the comprehension processes that are affected by this mental model.

Method

Subjects. The 20 subjects were volunteers from introductory psychology classes at the University of Wisconsin—Madison. The students participated to fulfill a course requirement.

Materials and design. The materials and design were identical to that used in Experiment 1, but for changes in the filler paragraphs. The test stimuli in 40 of the filler paragraphs were pronounceable nonwords. In 24 of the filler paragraphs the test stimuli were words; 12 were words from the paragraphs (but not nouns), and 12 were words that had not occurred in the paragraphs.

Procedure. The procedure was identical to that used in Experiment 1, except that subjects responded "yes" when the test stimulus was a word and "no" when it was a nonword.

Results and Discussion

The means of the median correct response times are displayed in Figure 2. For the experimental paragraphs, there were so few errors (four in the whole experiment) that they were not analyzed. For the filler paragraphs the error rates were .01 and .02 for the words and nonwords, respectively.

The only significant effect on the response times was for delay, $F(2,38) = 3.49$, $MSE = 24148$; the lexical decisions slowed with delay. Importantly, there was no significant effect of the associated-dissociated variable, $F(1,19) = 1.00$, $MSE = 16495$, nor was there an interaction between the associated variable and delay, $F(2,38) = .94$, $MSE = 20986$.

One might object that we have accepted the null hypothesis, and that this is particularly inappropriate because the pattern of results from Experiment 2 (Figure 2) closely mirrors the pattern obtained in Experiment 1. The objection may be dismissed upon consideration of two arguments. First, the power of Experiment 2 is at least as great as the power of Experiment 1. Experiment 2 actually has more observations (because there are fewer errors). Furthermore, the error terms are substantially smaller in Experiment 2. For the critical interaction between the associated–dissociated and the delay variable, MSE in Experiment 1 was 57851; in Experiment 2 it was 20986. Thus the effect is simply much smaller than in Experiment 1.

Second, it is reasonable that the data should have a pattern similar to that in Experiment 1. Some subjects, some of the time, may have been unable to prevent recognition of the target as a word from the text from influencing the lexical decision. Thus the pattern of data probably reflects a combination of a null effect in lexical decisions and the associated–dissociated effect

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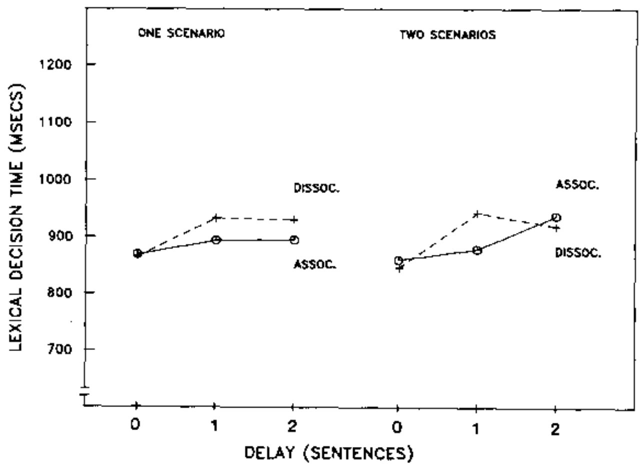

FIG. 2. Experiment 2: Average lexical decision time for critical nouns.

on recognition for a small proportion of the trials.

Apparently, then, lexical access is not strongly affected by the associated–dissociated variable, and by implication, lexical access is not strongly affected by the mental model of the text. Thus our conclusion is secure that the results from Experiment 1 demonstrate an affect of the mental model on foregrounding.

EXPERIMENT 3

An important function of the foreground is to provide tokens to which pronouns can refer (Fletcher, 1984; Sanford & Garrod, 1981; Sidner, 1983). In fact, if an appropriate token is not present in the foreground, the text may be perceived as inelegant, if not anomalous. In this experiment, we examined resolution of pronouns as a function of the object's role in the putative mental model.

Subjects read paragraphs such as the one in Table 4. As in the previous experiments, the paragraph began with a setting sentence that introduced the main character. The main character was foregrounded throughout the paragraph by reference.

TABLE 4
EXAMPLE PARAGRAPH FROM EXPERIMENT 3

Setting sentence	Warren spent the afternoon shopping at the store.
Critical (associated)	He picked up his (torn) *bag* and went over to look at some scarves.
Critical (dissociated)	He set down his (torn) *bag* and went over to look at some scarves.
Filler	He had been shopping all day.
Test sentence	He thought it was getting too heavy to carry.

The second sentence was a critical sentence that described an event in which the main character and the target object were spatially associated or spatially dissociated. After zero or one filler sentences (which never referred to the target object), a test sentence was presented. This test sentence used the pronoun "it" to refer to the target object.

Immediately after the critical sentence is read the target noun should be represented in the forground in both the associated and the dissociated conditions. Hence when the test sentence is read immediately after the critical sentence, resolution of the pronoun

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should be relatively effortless and the test sentence should be read relatively quickly in both conditions. Consider, however, the situation in which the test sentence is delayed by the reading of a filler sentence. If a mental model controls maintenance of information in the foreground, then the critical object is more likely to be represented in the foreground in the associated condition than in the dissociated condition. Therefore, resolution of the pronoun and reading of the test sentence should be faster in the associated condition than in the dissociated condition.

Because we are measuring the time to read a whole sentence, we cannot be absolutely certain that any effect is produced by the processing of a particular word (i.e., resolving the reference of the pronoun). Nonetheless, the task measures foreground processing on line, and hence, if we are correct, it should be more sensitive than the item recognition task to manipulations of the foreground.

We also manipulated whether the target noun was modified by an adjective (see Table 4). Sanford and Garrod (1981) proposed that modified nouns are more strongly foregrounded than unmodified nouns. Thus we expected faster pronoun resolution (and faster reading times) when the target noun was modified in the critical sentence than when it was not.

Finally, immediately after reading the test sentence, subjects read the question "In the previous sentence, what does the word 'it' refer to?" The subject was required to answer this query out loud. We supposed that in the dissociated condition subjects would have difficulty reinstating the token representing the target object so that answers to this question may be in error.

Method

Subjects. The 24 subjects were students enrolled in introductory psychology classes at the University of Wisconsin—Madison. These students participated to fulfill a course research requirement.

Materials and design. We constructed 48 paragraphs based on those used in Experiments 1 and 2. The initial sentence provided a setting. The second sentence, the critical sentence, described an event in which the target object (e.g., bag, in Table 4) and the main character were spatially associated or were spatially dissociated. In either case, the target noun could be modified by an adjective (e.g., torn) or left unmodified. Each paragraph also had a filler sentence that kept the main character foregrounded, but did not refer to the target nor did it introduce any new tokens into the foreground.

The test sentence always began with a pronominal reference to the main character and then used the pronoun "it" to refer to the target object. Following the word "it," the test sentence included additional descriptive information to aid resolution of the pronoun. This information was included so that resolution could proceed in the dissociated condition, in which, presumably, the token for the object is absent from the foreground and so further specification of the token is required.

Finally, each experimenal paragraph included the question, "In the previous sentence, what does the word 'it' refer to?" This question was displayed immediately after reading the test sentence.

A total of 48 filler paragraphs (and 10 practice paragraphs) were adapted from those used in Experiments 1 and 2. Many of these filler paragraphs used the word "it." However, the test question never referred to the word "it." Instead, these questions always required a "yes" or "no" verbal response (e.g., "Did the maid think that the hedges needed watering?"). These filler paragraphs were used to discourage the strategy of concentrating on the sentences containing the pronoun "it."

The three independent variables, associated–dissociated, number of adjective modifying the target noun (zero or one), and delay between the critical sentence and the test sentence (zero or one filler sentences), were factorially crossed, resulting in eight conditions presented to all subjects. The 48 experimental paragraphs were divided into eight sets with 6 paragraphs in each set. Each set was assigned to one of the eight conditions. The particular set assigned to any condition was counterbalanced over subjects.

Excluding the 10 practice paragraphs, each subject read a total of 96 paragraphs. These were divided into six blocks of 16 paragraphs. Within each block were 8 filler paragraphs and one exemplar of each of the eight conditions. Each subject received a unique random ordering of (a) the conditions within a block, (b) the filler paragraphs assigned to a block, and (c) the experimental paragraphs assigned to the block.

Procedure. Subjects were encouraged to read the materials carefully for comprehension. The paragraphs were presented one sentence at a time. After reading a sentence, the subject pressed either of two keys to erase the screen and present the next sentence. Timing of the test sentence was from the time the sentence was visible on the screen until the subject hit a key. Subjects did not know that reading was being timed. Following the test sentence the question appeared on the screen and the subject was allowed unlimited time to answer the question with a verbal response. The experimenter scored the response, and the computer provided visual feedback for two seconds. In answering questions about the antecedent of the pronoun "it," only verbatim reproductions of the target were scored as correct. The next paragraph was initiated by the subject pressing either of the keys.

The experimental procedure required about 1 h. Subjects were given a short break halfway through the experiment.

Results

The data are presented in Figure 3. These data are the means of the median correct reading times in each condition for each subject. That is, a reading time was only used when the subject was able to correctly answer the question "In the previous sentence, what does the word 'it' refer to?"

Three effects are obvious. First, there is a large effect of the associated–dissociated variable, reading the test sentence took about 253 ms less time in the associated consition. Second, the sentences were read about 276 ms faster with no delay between the test sentence and the critical sentence than when one filler sentence intervened. Finally, and most importantly, these two variables interacted. In the associated condition the effect of delay was to decrease reading time by a nonsignificant 38 ms, whereas in the dissociated condition the effect of the delay was to increase reading time by 590 ms. This interaction is, of course, just what is expected if maintenance of tokens in the foreground is controlled by a mental model of the situation, rather than a description of the text.

These observations are supported by statistical analyses using subjects as the random variable ($F1$) and using paragraphs as the random variable ($F2$). For both of these analyses, the data were the median reading time in each condition for each unit (subject or paragraph). Of the 48 paragraphs, 5 were excluded from the paragraph analysis because these paragraphs had one or more conditions in which there were no correct reading times. There were main effects for both the associated–dissociated variable, $F1(1,23) = 6.17$, $MSE = 498590$, $F2(1,42) = 6.71$, $MSE = 1680696$, and the delay variable, $F1(1,23) = 7.87$, $MSE = 464540$, $F2(1,42) = 9.01$, $MSE = 1828922$. The interaction of these variables was also statistically significant, $F1(1,23)$

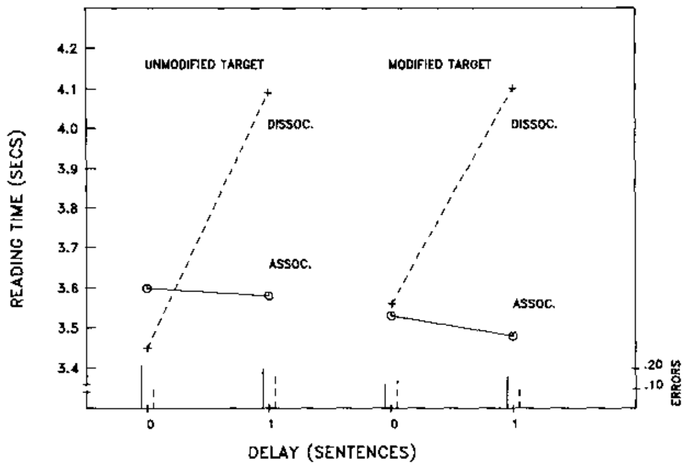

FIG. 3. Experiment 3: Average reading times for the test sentences.

= 13.43, MSE = 352554, $F2(1,42)$ = 10.54, MSE = 1348090.

Contrary to our expectations, the number of adjectives modifying the target noun (zero or one) was not significant, nor did it interact with any other variable, all $F1$s < 1, all $F2$s < 1.42.

There were no significant effects in analyses of the error rates (see error bars in Figure 3) either by subjects or by paragraphs.

General Discussion

The results may be summarized easily. The spatial structure of events described in narrative texts influences comprehension processes. The influence is not just at the level of lexical access, but appears to affect foreground processing, namely the tokens maintained in the foreground. These results are strong support for the claim that the representation of text is (at least in part) a mental model of the events described by the text.

Our primary claim regarding mental models as representation of text is that they represent what the text is about, not the text itself. The claim is illustrated most clearly by the data in Figure 3. The associated and dissociated paragraphs do not differ in the relations among the propositions describing the text. The difference is in the events the texts are about. In the dissociated condition, the main actor and the critical target are spatially dissociated. Keeping the main actor in the foreground does not keep the target in the foreground, as demonstrated by the long reading time after a delay of one filler sentence. In the associated condition, the actor and the target are spatially associated. In this case, keeping the actor foregrounded serves to keep the target foregrounded too, even though the target is not mentioned again. The equality in reading times over delay is all the more impressive given the standard finding that the probability that an item is foregrounded drops sharply over comparable delays (Carpenter & Just, 1977; Fletcher, 1981; Lesgold et al., 1979; Sanford & Garrod, 1983).

Fletcher (1986) has compared a number of strategies for maintaining information in the foreground. He found that a strategy based on the plans and goals of the main characters predicted which propositions were recalled more accurately than strategies based on story–grammar structure, the leading edge strategy, recency, frequency, and other strategies. The character's plans and goals are often not explicit in the text, but must be inferred from *what the text is about*. In this sense, then, Fletcher's (1986) results are consistent with the claim that mental models are used during comprehension.

The primary characteristic of mental models, that they represent what the text is about, is closely tied to other features attributed to mental models. For example, mental models are thought to be updatable. Because mental models represent what the text is about, rather than the text, when what the text is about changes (e.g., changes in the events portrayed in the text) the mental model will, perforce, also change. So, as Warren moves away from his shopping bag (see Table 4), the mental model is updated in that it no longer includes a representation of the bag.

As another example, mental models can be used to integrate information from different modalities (van Dijk & Kintsch, 1983). Thus when attending a play, information from the verbal discourse is easily combined with visual information. The mechanisms that do this sort of integration are not difficult to imagine once it is recognized that the representation of the discourse is, at least in part, a representation of what the discourse is about. Thus verbal reference to an object on the stage attaches to the *same element* in the mental model as visual information from the object itself.

Finally, van Dijk and Kintsch (1983) note that learning from a text (as opposed to memorizing the text) requires a mental model. If all we obtained from a text was a description of the text itself, it would be difficult to account for how texts can modify thinking about people, things, and ideas mentioned in the text. Instead, representations of those people, things, and ideas may be modified directly by participating in a mental model of the text.

Nonetheless, we make no claim that the representation of a text does not include a description of the sentences. In fact, there is good reason for supposing that it does (Johnson-Laird, 1983; van Dijk & Kintsch, 1983). For example, there is evidence from memory paradigms that under some circumstances memory for surface characteristics of the text is preserved (Anderson & Paulson, 1977; Keenan, MacWhinney, & Mayhew, 1977). There is also evidence that some forms of reference, ellipsis in particular, require a verbatim representation (Halliday & Hassan, 1976, Johnson-Laird, 1983).

Although our stimulus texts were all narratives, we believe that similar results are likely to be found for expositions that tap knowledge structures used to construct models (cf. Kieras & Bovair, 1984). To illustrate, we take advantage of our readers' sophisticated knowledge regarding experimental reports. While reading the report of an experiment designed to discriminate between two theories, the reader foregrounds tokens representing both theories. Upon reading that one theory has been disconfirmed by the results of the experiment, the token representing that theory may be removed from the foreground. That is, in the mental model of the world described by the report, the disconfirmed theory is no longer relevant. Thus reference to the disconfirmed theory should be more difficult to resolve than reference to the theory that was supported.

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