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Situation Models in Language Comprehension and Memory

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This article reviews research on the use of situation models in language comprehension and memory retrieval over the past 15 years. Situation models are integrated mental representations of a described state of affairs. Significant progress has been made in the scientific understanding of how situation models are involved in language comprehension and memory retrieval. Much of this research focuses on establishing the existence of situation models, often by using tasks that assess one dimension of a situation model. However, the authors argue that the time has now come for researchers to begin to take the multidimensionality of situation models seriously. The authors offer a theoretical framework and some methodological observations that may help researchers to tackle this issue.

Language comprehension necessarily involves the construction of a representation of the state of affairs described in a text. Furthermore, successful memory of what is comprehended would necessarily involve the retrieval of such representations. These claims may seem rather self-evident and therefore not worthy of scrutiny to many people. However, up until the early 1980s, many, if not most, cognitive psychologists viewed text comprehension as the construction and retrieval of a mental representation of the text itself rather than of the situation described by the text. As Garnham and Oakhill (1996) have recently argued, these researchers had failed to do a task analysis of what it means to comprehend a text. This perspective was changed by two books published in 1983 (Johnson-Laird, 1983; van Dijk & Kintsch, 1983). Both books were independently inspired by insights from linguistics and philosophy in which the representational aspect of language had been widely studied. They focus cognitive psychologists' attention on the mental representations of verbally described situations, which have become known as *mental* models (Johnson-Laird, 1983) or *situation* models (van Dijk & Kintsch, 1983). It is important to note that these authors did not abandon the notion of a mental representation of the text itself (e.g., Schmalhofer & Glavanov, 1986). Rather, they assumed that readers construct situational representations in conjunction with such text-based representations. This shift in thinking was significant in that it redefined the role of language. Rather than treating language as information to analyze syntactically and semantically and then store in memory, language is now seen as a set of processing instructions on how to construct a mental representation of the described situation (see also Gernsbacher, 1990).

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In a discussion of situation models, it is important to distinguish them from the better-known concept of *schema* (e.g., Alba & Hasher, 1983). Schemata are mental representations of stereotypical situations. A well-known example is Schank and Abelson's (1977) restaurant script. A script for a restaurant visit represents the actors, props, entry and exit conditions, and action sequence typically encountered during restaurant visits. In contrast, a situation model of a restaurant visit would be a mental representation of a specific restaurant visit (e.g., "Thursday, October 14, 1997, at Chez Pierre, lunch with K."). In this view, the distinction between schemata and situation models can be conceptualized as one between types (schemata) and tokens (situation models). Furthermore, we would like to reinforce the point made by van Dijk and Kintsch (1983) that schemata can be used as building blocks for the construction of situation models. Several studies have examined the role of scripts in language comprehension (e.g., Bower, Black, & Turner, 1979; Graesser, Woll, Kowalski, & Smith, 1980). The focus here is on those studies aimed at understanding the representation of the described situation, the situation model, rather than the representations used to create the situation model.

A decade prior to the coining of the terms mental model and situation model, Bransford, Barclay, and Franks (1972) had demonstrated empirically that the nature of the described situation can have a powerful effect on the reader's memory. Bransford et al. had participants listen to sentences, such as 1a and 2a. Afterwards, the participants were presented with sentences, such as 1b and 2b, in a recognition test.

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*.

People who had heard 1a frequently "false alarmed" to 1b, whereas people who had heard 2a rarely false alarmed to 2b. This discrepancy cannot be explained by differential changes at the surface structure level of the test items. The only surface structure difference between 1a and 1b is that the pronoun *them* has been replaced with *it*. This is also the only surface structure difference between 2a and 2b (see also Garnham, 1982; and Radvansky, Gerard, Zacks, & Hasher, 1990). As Glenberg, Meyer, and Lindem (1987) have demonstrated, the differences between 1a and 1b and between 2a and 2b are also equivalent at the level of the propositional text base.

So what accounts for the Bransford et al. (1972) findings? It is the spatial layout described by the sentences. Sentences 1a and 1b describe essentially the same situation: The turtles are on top of the log, and the log is above the fish. Sentences 2a and 2b, however, describe decidedly different situations: According to 2a, the fish are beneath the turtles but not the log; whereas according to 2b, the fish are beneath the log but not beneath the turtles. Thus, 1a and 1b are being confused because they describe the same situation. In contrast, 2a and 2b are less likely to be confused because they describe different situations. In other words, the Bransford et al. findings can be explained if we assume that their participants created situation models of the state of affairs described in the study sentences, that these situation models were stored in long-term memory, and that people used them to make their later recognition decisions. It is not surprising then that Bransford et al. (1972) drew the conclusion that "sentences are information which [people] can use to construct semantic descriptions of situations" (p. 194).

Over the past 15 years, many researchers have argued that the construction of a coherent situation model is tantamount to the successful comprehension of a text (e.g., Glenberg, Kruley, & Langston, 1994; Graesser, Millis, & Zwaan, 1997; Graesser, Singer, & Trabasso, 1994; Johnson-Laird, 1983, 1989; Perfetti, 1989; van Dijk & Kintsch, 1983; Zwaan, Magliano, & Graesser, 1995). This change in the definition of the notion of comprehension shifts the research problem from the general, "How do readers comprehend a text?," to the more specific, "How do readers construct a coherent situation model?" One objective of this article is to review how this question has been addressed empirically since 1983. If one assumes that people can construct situation models, it becomes important to know what the memorial effects are of storing that information in the form of an integrated situation model rather than some other format (Radvansky & Zacks, 1997). Presumably, the storage of information in situation models has some beneficial influence on memory performance. This leads us to ask, "How does the storage of information in situation models influence later memory retrieval?" Thus, a second objective is to review the research investigating the influence of situation models on later memory retrieval. The third objective is to propose some new avenues of research that may allow us to come closer to answering these questions.

Several reviews of text comprehension processes have appeared in recent years (e.g., Graesser et al., 1994, 1997; McKoon & Ratcliff, 1992). However, none of these articles focuses explicitly on situation models. Graesser et al. (1994) and McKoon and Ratcliff focused specifically on inference generation and have thereby adopted a narrower focus than we do. Inferences can be made in the process of constructing a situation model, and situation models can influence the nature of the inferences that will be made. However, situation models are more than collections of inferences. They are amalgamations from information stated explicitly in the text and inferences. Graesser et al. (1997) provided a general overview of research in discourse comprehension and have thereby adopted a broader perspective than we do.

The question "How do readers construct a coherent situation model?" presupposes that we know what a coherent situation model is. But do we? Early definitions of the concept view situation models as multidimensional mental representations:

> A dynamic model of, say, a football game calls for a temporal sequence of events at various locations, for causal relations between the events, and for the interaction of individuals, interacting physically and socially, governed by physical laws and constrained by the "laws" of the game and social conventions and motivated by various intentions. (Johnson-Laird, 1983, p. 414)

Thus, according to Johnson-Laird, a situation model incorporates at least temporal, spatial, causal, motivational, and person- and object-related information. Gernsbacher (1990) has proposed a general framework for comprehension, which could, in principle, operate on each of the situational dimensions and provides many examples of how this might be envisioned. However, these theoretical efforts notwithstanding, situation models have been treated as one-dimensional mental representations in virtually all of the empirical research of the past decade and a half. The bulk of studies have focused on either spatial or causal–motivational representations. Some studies have focused on protagonists, and very few have focused on temporal information. To be sure, many studies have produced important insights about language comprehension, and something can be said for reductionism. Nonetheless, there appears to be a discrepancy between the multidimensionality of situation models on the theoretical plane and their one dimensionality in empirical research. We think that it is time to (a) take stock of the knowledge that has been gathered on situation models in various lines of research, (b) integrate these lines into a framework of multidimensional situation models, and (c) consider some ideas as to how to investigate multidimensional situation models and thus gain a better scientific understanding of language comprehension.

Why Do We Need Situation Models?

van Dijk and Kintsch (1983) have listed several reasons why situation models are needed to explain language processing. Several of these reasons are worth reiterating here.

Models Are Needed to Integrate Information Across Sentences

This follows from the straightforward observation that understanding connected discourse is more than understanding a set of individual sentences. Consider the following:

> 1. Lamar Alexander was behind in the polls. However, the former Tennessee governor remained optimistic. He considered it likely that a moderate candidate with new ideas would win the Republican nomination.

This snippet of discourse makes sense only when the reader is aware that "Lamar Alexander," "the former governor of

Tennessee," "he," and "a moderate candidate with new ideas" all refer to the same individual. According to situation model theory, the reader would set up a token for Lamar Alexander. Incoming information would be linked to this token based on grammatical and world knowledge. For example, grammatical knowledge suggests that the definite article in the second sentence indicates that the sentence refers to the same individual as the previous sentence. In contrast, had the second sentence contained the indefinite article, *a*, the reader would be cued to create a token for a new individual. World knowledge provides converging evidence about the identity of the denoted individual, that Lamar Alexander is the former governor of Tennessee. The pronoun *he* also refers to the former governor Lamar Alexander, which the reader can conclude on the basis of grammatical knowledge. Finally, picking out a referent for "a moderate candidate with new ideas" relies on domain knowledge. This is how Alexander used to market himself.

Also note that, as many researchers have observed, merely connecting adjacent sentences does not produce a coherent understanding. Consider the following example from Samet and Schank (1984):

> In a little Danish town, two fishmongers exchanged blows. Anders, by far the stronger, had a cousin in prison. Anders was twice the age of the cousin. When he first was convicted, Anders was living in Italy. Anders has a wife who lost her bathing cap. Her car is at this moment double-parked. (p. 64)

This text is odd precisely because it does not describe a unique situation. Despite that there is an explicit connection between each sentence and the previous one, the complete set does not lead to an integrated situation model. Thus, to understand comprehension, we have to know how readers construct and use integrated situation models.

Recently, Hess, Foss, and Carroll (1995) provided a powerful demonstration of the role of situation models in language processing. In a series of experiments, they found that the speed with which the last word of a sentence is named depends on how well it can be integrated with the current situation model rather than merely on its lexical associations to words prior to it in the sentence. These findings suggest that situation models have a strong and rather immediate effect on on-line comprehension.

Models Are Needed to Explain Similarities in Comprehension Performance Across Modalities

When we read a newspaper article about a particular event, we may come away with a similar understanding of that event as when we had seen it in a news report on television. Given the very different nature of these modalities, this is impossible to explain if we do not assume that readers construct a mental representation of the event itself rather than of the medium that described the event. There is empirical evidence that supports this intuition. Baggett (1979) found that students who saw a short film produced structurally similar recall protocols as students who heard a spoken version of the study that matched the movie in episodic structure. To be sure, there were differences in the recall protocols between the two groups, but these differences were due to content aspects. For example, the text version explicitly stated that a boy was on his way to school; but in the movie, this had to be inferred. It seems that a comparison of situation model construction across different modalities would be a fruitful area for further research.

If we do indeed construct situation models during reading, listening, or viewing, then we might assume that we use modality-independent cognitive procedures to construct these models. Consequently, people who are good at constructing situation models should demonstrate this ability across different modalities. This is exactly what Gernsbacher, Varner, and Faust (1990) found. They had college students comprehend stories in three modalities: written, auditory, and visual. The students' performance on these three tasks correlated substantially. The correlation between comprehending written and auditory stories was .92, the correlation between comprehending written and picture stories was .82, and the correlation between comprehending picture and auditory stories was .72. These findings are difficult to explain if one assumes that readers only create a mental representation of the discourse itself. However, they make sense if one assumes that the people in these experiments constructed higher level mental representations that transcend the specific modality from which they were constructed. It also suggests that there is a general comprehension skill that transcends modality-specific processing deficiencies (e.g., visual word recognition). In all probability, this skill is the ability to construct a coherent situation model.

Models are needed to explain the integration of verbal and visual information. Various text genres, such as scientific articles, textbooks, brochures, and newspaper articles, are often accompanied by graphs and pictures intended to enhance comprehension. Situation-model theorists argued that graphs and pictures aid comprehension by being jointly incorporated with information derived from the text into an integrated situation model. Glenberg and Langston (1992) found support for this hypothesis. They had their participants read texts that described four-step procedures, in which the middle two steps were to be executed at the same time. However, given the linear nature of language, these steps were described sequentially in the texts. When the texts were presented with appropriate pictures, that is, pictures in which the two middle steps were depicted as occurring simultaneously, people tended to construct mental representations of the procedure (i.e., both middle steps were connected equally strongly, as indicated by priming effects, to the first step and to the last step). However, when the texts were accompanied by pictures in which the middle steps were depicted as occurring sequentially, as in the texts, people tended to construct a mental representation of the text structure (i.e., one of the middle steps was connected more strongly to the first step and the other to the last step).

Models Are Needed to Account for Effects of Domain Expertise on Comprehension

There are differences in comprehension performance that cannot be explained by differences in verbal ability. More strongly, comprehenders with relatively low verbal skills can outperform more skilled comprehenders when they have more knowledge of the topic domain. In an interesting study, Schneider and Körkel (1989) compared the recall of soccer "experts" with novices of a text about a soccer match. Soccer expertise was crossed with grade level (3rd, 5th, and 7th). The most salient finding was that the 3rd grade soccer experts recalled more idea units from the text (54%) than did the 7th grade novices (42%). In other words, domain expertise more than offset the inherent difference in verbal skills between 3rd and 7th graders. This finding can be accounted for by asserting that the high-knowledge students had fewer problems constructing a situation model because they could assemble the model by retrieving relevant knowledge structures from their long-term memory (Ericsson & Kintsch, 1995), whereas low-knowledge readers had to construct the model essentially from scratch. There have been several other studies demonstrating how domain expertise may counteract verbal ability (e.g., Fincher-Kiefer, Post, Greene, & Voss, 1988; Yekovich, Walker, Ogle, & Thompson, 1990).

Situation Models Are Needed to Explain Translation

Translation of a text from one language into another involves much more than merely translating each of its individual words, as the failure of attempts at mechanical translation in the 1960s have taught us. For example, a literal English translation of the Dutch saying, "*Verkoop de huid niet voordat je de beer geschoten hebt,*" would yield, "Don't sell the skin before you've shot the bear." While this is certainly an understandable sentence, the correct translation would be "Don't count your chickens before they're hatched." Thus, the equivalency between the Dutch and English sayings is not at the lexical-semantic level, it is at the situational level: Do not execute an action before the preconditions for that actions have been met.

Zwaan, Ericsson, Lally, and Hill (1998) recently investigated whether people form situation models while they are translating texts from French into English. Zwaan et al. capitalized on the fact that French does not have a neuter pronoun, whereas English does, *it.* All of the texts used by Zwaan et al. contained a sentence with a pronoun referring back to an object or abstract concept in the previous sentence. The following is an example:

> *La France était un pays de tradition Catholique.*
>
> (France is a country with a Catholic tradition.)
>
> Elle est à la base de la plupart des cérémonies qui ont une origine religieuse.
>
> (It is at the foundation of most ceremonies that have a religious origin.)

If translators integrate information across sentences, then *elle* should be, correctly, translated as *it. Elle* in this example refers back to an abstract concept (the Catholic tradition) in the previous sentence. If translators operate on a sentence-by-sentence basis, then the translation of *elle* would be *she.* Zwaan et al. found that more fluent speakers of French (American graduate students in a French department) did indeed use the proper pronoun (*it*) in 90% of the cases, suggesting that they were using and integrating information across sentences during translation, whereas less fluent speakers of French (3rd semester undergraduates) used the incorrect pronoun (i.e., he or she) in 63% of the cases. Furthermore, the more fluent speakers also initiated their translations more quickly after having read the sentence than did the less fluent speakers, indicating that they were not merely sacrificing speed for accuracy. These findings suggest that the ability to form situation models during translation is an important part of translation skill.

Situation Models Are Needed to Explain How People Learn About a Domain From Multiple Documents

Much learning involves the integration of information from different documents. Perfetti, Britt, and Georgi (1995) provided a compelling example of how situation models are needed to account for text-based learning and reasoning about historical events, such as the events related to the construction of the Panama Canal. Multiple sources of information on the same topic overlap to varying degrees in terms of their referents and the relations among those referents. An efficient means of organizing this information is to integrate knowledge from different sources into a common situation model. As Perfetti and colleagues argued, people can construct a text base for each document they read, for example, a report on the ongoing problems between Panama and the United States by the Center for Strategic Studies and a persuasive text against treaties between the United States and Panama written by a congressperson. However, actual learning and reasoning (e.g., about whether the congressperson has a particular bias) takes place when people integrate the information from the documents into a situation model.

Not All Language Processing Tasks Involve Situation Models

There are cases of language processing that do not necessarily involve situation model construction. An example is proofreading. One might even argue that situation models are detrimental to proofreading. The task of a proofreader is to check the spelling of individual words, and it would seem that integrative processes would unnecessarily take up working memory resources. Singer and Halldorson (1996, Experiment 4) did indeed find that a proofreading instruction eliminated motivational inferencing. That is, participants did not respond faster to the question, "Do dentists require appointments?," after the sequence, "Terry was unhappy with his dental health; he phoned the dentist," than after the sequence, "Terry was unhappy with his dental bill; he phoned the dentist"; whereas this difference did occur under a "normal" reading instruction. Thus, our claim is not that situation models are needed in all language-processing tasks. However, we do claim that they are an integral part of all language comprehension tasks.

A General Processing Framework

In analyzing the process of situation model construction and the retrieval of situational information, we distinguish between (a) the *current* model, the model currently under construction, that is, the model at Time t_n; (b) the *integrated* model of the situations at Times t_1 through t_{n-1}; and (c) the *complete* model of the situations at Times t_1 through t_x. The current model is constructed at Time t_n while a person reads a particular clause or sentence, called c_n. The integrated model is the global model that was constructed by integrating, one at a time, the models that were constructed at Times t_1 to t_{n-1} while the person reads clauses c_1 to c_{n-1}. Finally, the complete model is the model that is stored in long-term memory after all the textual input has been processed. It should be noted that the complete model is not necessarily the final model. Comprehenders may ruminate over a story and generate additional inferences or develop entirely novel models. In fact, this is a quite common practice, as centuries of literary and religious hermeneutics demonstrate. However, this topic is beyond the scope of this article. To our knowledge, there exists no empirical research on it. We call the process of incorporating the current model into the integrated model *updating*.

We feel that this model provides a useful way to analyze the extant research on situation models. The model is admittedly sketchy, but this is by design, given that its main function here is organizational. It provides a prism through which we can systematically analyze the relevant research without overly constraining our perspective. For a more detailed theoretical account, we refer the reader to Radvansky and Zwaan (1998). A very simple example suffices to illustrate how we assume the model operates during comprehension. Suppose someone reads the following narrative:

> Peter took the elevator to the fifth floor. He went to talk to his professor. He was anxious to find out how the professor liked his draft. He walked up to the professor's office and knocked on the door. The professor looked up from his work.

We leave the reader in eternal suspense while we explain the model. When reading the first sentence, the reader creates a situation model involving a token that represents a male individual named Peter who rides an elevator for as yet unknown reasons. We assume that the reader infers that Peter is in a building and that the event took place before the moment of utterance of the sentence (given the past tense; see Reichenbach, 1947). Thus, a spatio–temporal framework is created about which we have more to say in The Event-Indexing Model section. This is the content of the current model, which becomes the integrated model when the reader moves on to the second sentence.

This sentence is integrated with the first one on several dimensions. First, the pronoun is a cue to the comprehender to look backward (Gordon, Grosz, & Gilliom, 1993) in the integrated model for an appropriate referent. This referent is found in Peter, who is the only available referent and shares the feature "male." Second, a goal is constructed ("went to" suggests intentionality; Trabasso & Suh, 1993). Third, the absence of a shift in tense or any other explicit temporal marker indicates that we are still in the same temporal interval (Zwaan, 1996; Zwaan, Magliano, & Graesser, 1995). Fourth, the absence of a spatial marker indicates we are still in the same spatial region (Zwaan, Magliano, & Graesser, 1995). Fifth, a second token is created representing the professor. The reader probably also infers that Peter is a student. This is the content of the current model at Time t_2. Although we describe the establishment sequentially, these processes most likely occur in parallel as soon as the relevant information is available.

As a next step, the integrated model is updated by incorporating the model (t_2) in it. Specifically, the referent is identified as Peter, so the goal is attributed to him (i.e., a link between Peter and the goal node is established), as may be the property of being a student. Furthermore, temporal and spatial links between the second and the first event are established. This amalgam constitutes the integrated model at Time t_2. The same process then continues for the subsequent sentences. Of special note is the fact that a causal relationship is established between Peter's knocking on the door and the professor's looking up. The complete model exists when all the sentences are integrated in this fashion.

We use three recent theoretical proposals as the framework for the concepts of current, integrated, and final model and the processes of constructing, updating, and retrieving a situation model. First, there is Ericsson and Kintsch's (1995) distinction between short-term and long-term working memory. In Ericsson and Kintsch's conceptualization, it is possible in highly practiced and skilled activities, such as language comprehension, to extend the fixed capacity of the general short-term working memory (STWM) system by efficiently storing information in long-term memory and keeping this information accessible for further processing. This expansion of STWM is called long-term working memory (LTWM) and corresponds to the accessible parts of a previously constructed mental representation in long-term memory. Because STWM contains retrieval cues to LTWM, people are able to efficiently retrieve previously encoded information without engaging in extensive long-term memory searches. In the case of text comprehension, people achieve this by keeping relevant portions of the previously processed text accessible in LTWM and by maintaining retrieval cues to this information in STWM. This allows for the efficient integration of information across sentences. In line with this, we propose that readers keep the integrated situation model in LTWM while the current model is constructed in STWM. During the *construction* process, there is transient activation in STWM to retrieval cues for parts of the integrated model. *Updating* occurs by forming links between the current model and the retrieved elements of the integrated model. At this point, the current model has been integrated and the integrated model has been updated, so that a new current model can be constructed in STWM. This process continues until the complete model is stored in long-term memory.

A second proposal is Garrod and Sanford's (1990) distinction between implicit and explicit focus. As Garrod and Sanford noted, implicit and explicit focus together are conceived of as representing the reader's "current working model of the discourse world" (p. 479). This is what we call the integrated situation model. According to Garrod and Sanford, explicit focus contains tokens corresponding to protagonists currently introduced to the discourse world, whereas implicit focus contains a representation of the currently relevant aspects of the scenes portrayed. In our terms, the currently relevant aspects of the integrated model would be in implicit focus, whereas the current model would be in explicit focus. However, as explained below, we go one step further than Garrod and Sanford by proposing that comprehenders keep more in implicit focus than just tokens for protagonists. Garrod and Sanford proposed that a locally coherent representation is constructed by mapping the contents of explicit focus with those in implicit focus. This is what we call updating.

A third proposal is the event-indexing model (Zwaan, Langston, & Graesser, 1995). According to this model, events are the building blocks of integrated situation models. When people read a clause, they construct a model of the situation denoted by that clause. Each event can be indexed on each of five dimensions: time, space, causation, motivation, and protagonist. The ease with which an event can be integrated depends on how many indexes it shares with the integrated model. We are now in a position to specify this by replacing the last phrase with "relevant parts" of the integrated model. There may be different criteria for each dimension as to what constitutes a relevant part of the integrated model. For example, for the temporal dimension, it would be the most recent event. Suppose that in the story about Peter the student, there was a paragraph describing Peter's thoughts about how he struggled with his paper last week, which was inserted after Peter knocked on the door. In that case, knocking would be the most recent event in the story, so it would be held as a retrieval cue in STWM until a later event could be connected to it. We provide an in-depth discussion of temporal information below. Alternatively, for the motivational dimension, the relevant part of the integrated model may be an unsatisfied goal, which does not have to be the most recent event in the event chronology. For example, suppose that in the story about Peter, it is described how he runs into a fellow student after stepping out of the elevator and has a brief discussion with her. In that case, the comprehender would hold Peter's goal of visiting the professor as a retrieval cue in STWM until it is satisfied (or replaced with another goal). We believe that this account is consistent with current work on goal information in narrative comprehension (e.g., Trabasso & Suh, 1993). Thus, if a clause denotes an event or action that is relevant to a currently unsatisfied goal, it is relatively easy to integrate the event on the motivational dimensions because it shares a goal index with a relevant part of the integrated model. If the event is not relevant to any goal currently in implicit focus, it is more difficult to integrate. We provide a more in-depth discussion of motivational information and of the event-indexing model below.

In our conceptualization of situation model construction, relevance is a crucial notion. Situation models are updated by forming connections between the current model and relevant aspects of the integrated model in LTWM on five different situational dimensions. We pointed out that there may be different relevance criteria for each dimension. Consequently, an incoming event can be connected to multiple elements of the integrated model. But what constitutes relevance? Here we make use of the concept *foregrounding*. In our framework and in line with Ericsson and Kintsch's (1995) work, information is foregrounded by creating and maintaining a retrieval cue to this information in STWM. Sometimes, the reader foregrounds information on the basis of world knowledge because of what he or she knows about human goals and actions or about the narrative genre (see Zwaan, 1994, for a demonstration of the effects of genre knowledge on comprehension and retrieval processes). For example, if we read "Betty wanted to buy her mother a present," we foreground this information until the goal is satisfied (e.g., Trabasso & Suh, 1993; also see our discussion of goal-related information below in the *Retrieval* section) because we know that humans carry out actions to achieve their goals and that narratives are typically about this.

Foregrounding may also be prompted by linguistic cues. Here we adopt Gernsbacher's (1990) and Givón's (1992) view of language as processing instructions. For example, compare "And then a man entered the lab" with "And then this man entered the lab." In the second sentence, the indefinite article *this* is serving as a cataphoric device to prompt readers to create a retrieval cue for the man in STWM, whereas the indefinite article *a* in the first sentence is less likely to do so. Consequently, information about the man is more accessible to the reader after the "this" sentence than after the "a" sentence (Gernsbacher & Shroyer, 1989). Similarly, when a protagonist is introduced by a proper name, for example, "Peter," a retrieval cue for that protagonist is created in STWM (explicit focus), whereas this is most likely not done when the protagonist is introduced by a role name, such as "the professor" (Garrod & Sanford, 1990). Consequently, information about Peter is more accessible further downstream in the text than information about the waiter. Both Peter and the professor are part of the integrated model, but only Peter has a retrieval cue in STWM where the current model is being constructed and the integrated model is being updated. Note that the situation would be reversed if Peter had been introduced as "a student" and the professor as "Ellen." Furthermore, there is evidence that when a protagonist is already in explicit focus and there are no competing referents, comprehension is impeded when the protagonist is referred to by a full noun specification rather than by a pronoun; this is called the *repeated name penalty* (Gordon et al., 1993). One explanation for this is that a full noun specification is a cue to the comprehender to introduce a new protagonist into the current model whereas a pronoun is a cue to attach the current model to the token representing the protagonist in STWM. Thus, the full noun specification clashes with the presence of a token representing the same referent in STWM.

Our discussion of the research on situation models is organized in part in terms of whether they address (a) the foregrounding of situational information, (b) the updating of the integrated model, or (c) the retrieval of the integrated model. The other dimension along which the discussion is organized is orthogonal to this. We group studies according to whether they investigated the spatial, temporal, causal, motivational, or protagonist-related dimensions of situations. The rationale for this is described below.

Five Situational Dimensions

As noted earlier, text comprehension researchers typically identify at least five dimensions of situations: time, space, causation, intentionality, and protagonist (Chafe, 1979; Gernsbacher, 1990; Givón, 1992; Johnson-Laird, 1983; Nakhimovsky, 1988; van Dijk, 1987; Zwaan, Langston, & Graesser, 1995). The dimensions of time, space, and protagonist are also featured in accounts of autobiographical memory of directly experienced events (e.g., Wagenaar, 1986). Future research may reveal that there are others that have to be taken into consideration. However, in this article, we focus on these five dimensions. We should also note beforehand that text comprehension and memory researchers have typically investigated each of these five situational dimensions separately from the others (without necessarily controlling for the effects of other dimensions).

We begin with spatial information because it is the dimension that has received the most attention and that has been the most closely associated with situation models. We then concentrate on causation and motivation, two dimensions which have also received a great deal of attention in the literature. Next, we focus on protagonists and objects, which have enjoyed a considerable amount of attention in research on anaphoric reference and instrumental inferences. Finally, we focus on the temporal dimension, which has received the least amount of attention but which, as we argue later, is a crucial dimension.

Space

Spatial information has received a relatively large amount of attention in the text-comprehension literature (see Clark, 1972; Huttenlocher, Eisenberg, & Strauss, 1968; and Huttenlocher & Strauss, 1968, for early discussions). There are good methodological reasons for this. The nonlinear nature of space provides an interesting mismatch with the linear nature of language. For example, two objects can be close in space and yet be described far apart in the text. When the objects in a room are described in a circular fashion, the first mentioned and last mentioned object may be next to each other spatially. By making use of the mismatch between spatial organization and linguistic structure, researchers can assess whether a reader has created a mental representation of the text or of the described situation. As we see later, there currently is no strong evidence that readers spontaneously track spatial information during comprehension. However, they are able to do so when asked.

It is intuitively obvious that speakers face a problem when they are called on to describe a spatial layout in language, which Levelt (1989) has dubbed *the linearization problem.* Speakers appear to have specific ways to deal with this problem. For example, in a now classic study, Linde and Labov (1975) asked people to describe their apartments. People typically described their apartment by taking the listener by the hand along an imaginary path through the apartment. A path description is an effective way of linearizing spatial information. In fact, the spatial information is forced into a temporal format, for example, "and then you get to the living room." This tension between the three dimensionality of space and the two dimensionality of language has made the construction of spatial situation models a fruitful area of research. Broadly speaking, the research has focused on three questions: (a) Are spatial models used during comprehension? (b) How are they modified during comprehension?, and (c) Are they used during memory retrieval?

Foregrounding

Once an integrated spatial situation model has been created, people may be able to scan through different parts of it, making information from those sections more available. This occurs as a part of information foregrounding in language comprehension. For example, if a target entity is a couch, it is more likely that it would be included in the foreground of the situation model when the protagonist is in the living room with the couch than if she or he is in the kitchen. If the situation model successfully models spatial relations, then items that are farther away from the current focus should be less available than near items.

The spatial foregrounding of information was demonstrated in a study by Glenberg et al. (1987; see also Singer, Graesser, & Trabasso, 1994). In two experiments (Experiments 1 and 2), people read stories containing a critical object. In half the stories, this object was spatially associated with the protagonist ("John *put on* his sweatshirt before going jogging"), whereas in the other half, this object was spatially dissociated ("John *took off* his sweatshirt before going jogging"). Two sentences after the critical sentence, the name of the critical object (e.g., sweatshirt) was presented, and people made recognition responses. Response latencies were longer in the dissociated than in the associated condition, even though the distance in the text was the same. In a third experiment, Glenberg et al. used a reading time paradigm with similar results. At a later point during the story, a sentence appeared that anaphorically referred back to the critical object (the sweatshirt). Reading times for that sentence were recorded. Glenberg et al. found that information spatially close to the protagonist, and hence more likely to be foregrounded in the situation model, led to faster reading times than information that was spatially separated.

This study of spatial foregrounding was extended in a set of experiments by Morrow, Bower, and colleagues (Morrow, Bower, & Greenspan, 1989; Morrow, Greenspan, & Bower, 1987; Morrow, Leirer, Altieri, & Fitzsimmons, 1994; Rinck & Bower, 1995; Rinck, Hähnel, Bower, & Glowalla, 1997; Rinck, Williams, Bower, & Becker, 1996; Wilson, Rinck, McNamara, Bower, & Morrow, 1993; see also Haenggi, Kintsch, & Gernsbacher, 1995; and Millis & Cohen, 1994). According to these researchers, the distance between the story protagonist and probed-for items should affect how available these items are. Furthermore, as the foreground portion of a situation model changes, those parts of the model that the protagonist was in, as well as those locations that the protagonist passed through en route, should have some residual activation. So information from these parts of a situation model should be more accessible than other parts that had not recently been foregrounded, although to a lesser degree than those parts that are currently foregrounded.

In these experiments, people memorized a map of a building, such as a laboratory or a warehouse, along with the locations of several objects within that building. Afterward, they read narratives about a protagonist who is moving around the building. Periodically during the course of reading the narrative, people were probed with pairs of object names (including the protagonist, such as lamp and Mary) and had to indicate whether the objects were in the same room of the building. The results showed that response time was mediated by the distance between the protagonist and the room where the objects were located. Probe identification was fastest when the objects were in the same room as the story protagonist. Responses were slower when the room the objects were located in was either the one the protagonist had just come from or an unmentioned room along the protagonist's path of travel (see O'Brien & Albrecht, 1992; and Wilson et al., 1993, on the importance of having a focus on the protagonist). Similar effects have been shown on the reading time of sentences that anaphorically refer to objects in the building (Rinck et al., 1996, 1997). These results suggest that information gradually falls away from the foreground of the model as the situation focus shifts and that situation models can capture complex aspects of situations, such as room divisions.

Another study (Morrow et al., 1989) showed that this effect is not tied to a protagonist's spatial location. In one experiment, observations were based on the room that the story protagonist was thinking about rather than the room that he or she was in. For example, in one passage while the protagonist was in the reception room, the probe objects were presented immediately after the sentence, "He thought the library should be rearranged to make room for a display of current research." People responded faster to objects in the room that was being thought about than to objects in other rooms. Therefore, the foreground of a situation model can be shifted to locations other than the protagonist's spatial location.

If spatial situation models are constructed during comprehension, then readers should have problems processing information that is inconsistent with the model. Several researchers have indeed found that when the information included in a text is spatially inconsistent with what has gone before, it takes people longer to read that information (de Vega, 1995). For example, when a story protagonist's location is different from the objects or people being described by a text, then people find this difficult to reconcile with their situation model, so comprehension processes take longer.

Updating

Ehrlich and Johnson-Laird (1982) found, consistent with the idea that readers construct and update spatial situation models, that people spent less time reading spatial descriptions when they were referentially continuous than referentially discontinuous. In this study, people were presented with three sentence descriptions of the arrangement of four objects (e.g., a knife, pot, glass, and dish) in space. For continuous descriptions, the subsequent sentences always referred to entities in the previous sentences, such as (a) "The knife is in front of the pot," (b) "The pot is behind the dish," and (c) "The dish is on the left of the glass." For discontinuous descriptions, the subsequent sentences did not always refer to previous mentioned objects, such as (a) "The knife is in front of the pot," (b) "The glass is behind the dish," and (c) "The pot is on the left of the glass." The participants' task was to create a diagram that correctly illustrated the spatial relations among the objects.

In the continuous descriptions, each subsequent sentence described an object that was spatially adjacent to the previously described object. Thus, each current model could be readily incorporated within the integrated spatial model, thereby updating the integrated model. The faster reading times in this condition presumably reflect the readers' ability to rely on the previously existing representation to help them comprehend the new information.

In contrast, for the discontinuous descriptions each sentence described an object that was nonadjacent to the previously described object. If readers did not construct a spatial representation on the basis of the sentences, then the speed of comprehending information in this condition should not differ from the continuous description condition. This of course did not occur; people spent more time comprehending sentences in the discontinuous condition. The slower reading times are interpreted to reflect the fact that people cannot update a previous situation model because the new information does not clearly correspond to the situation described by the previous information. As such, an entirely new representation must be created.

Thus, the Ehrlich and Johnson-Laird (1982) finding is consistent with the idea that people use spatial situation relations among entities to help form a coherent situation model. When the information can be interpreted as being consistent with a previous situation model, that situation model need only be updated. However, when there is no clear connection between new information and the previously described situation, updating cannot occur.

Retrieval

If situation models can be spatially structured, then this structure should influence the availability of the stored information. Therefore, during the retrieval of information from an integrated situation model, evidence of this spatial structure should be observed. In this section, we consider how memory retrieval can be affected by (a) spatial frameworks, (b) knowledge integration, and (c) retrieval set size.

Spatial frameworks. Information about the spatial relations between an observer and the objects in the environment is interpreted with a spatial framework (Bryant, Tversky, & Franklin, 1992; Franklin & Tversky, 1990; Logan, 1995). A spatial framework consists of a set of three ordered axes, such that above–below is more prominent that front–back, which in turn is more prominent than left–right (Clark, 1973). Above–below is especially salient due to the ever present effects of gravity. Front–back is salient because (a) human perceptors are oriented in this direction, (b) it is the direction of movement, and (c) humans preferentially interact with the world through what is in front of them. In contrast, left–right does not have any marked differences; hence the difficulty typically associated with its use.

Support for the use of spatial frameworks in situation models was obtained by Franklin and Tversky (1990). They had people read a passage that described a spatial environment. Readers were to imagine themselves in that environment. The passage described the locations of various objects in relation to the person, such as "Straight ahead of you, mounted on a nearby wall beyond the balcony, you see a large bronze plaque dedicated to the architect who designed the theater" (p. 65). During the reading, people were interrupted with probes that asked them to identify objects located at various directions. The results showed that responses were fastest to items located along the above–below dimension, slower to items located along the front–back dimension, and slowest to items located along the right–left dimension.

The pattern of information availability from memorized situation models can also be influenced by the perspective a person adopts when creating the situation model (Bryant et al., 1992). Specifically, people who adopt a perspective of an individual within the context of the situation find that information described as being in front is more available than information that is described as being behind. In contrast, people who adopt a perspective of an external viewer find that both of these types of information are equally available.

Spatial frameworks are not limited to being defined by the environment or an observer's orientation. There is some evidence that the functional relation among objects can influence the orientation of a reference frame (Carlson-Radvansky & Radvansky, 1996). For example, a hammer is typically considered to be above a nail if it is being used to pound it, no matter what the orientation of the nail may be. This evidence seems to indicate that the functional relations among entities are encoded into representations of a situation.

Spatial integration. A single situation model is able to represent several pieces of information about a situation. However, for information to be integrated, it must be clear that all of the pieces refer to the same situation. Integration does not occur when it is unclear how the facts might refer to the same situation, in which case people rely on separate models. This property of integration has an effect on the retrieval of information. Specifically, memory performance is better when information can be easily integrated into a situation model than when it is stored across a number of representations.

In a study by Mani and Johnson-Laird (1982), people were presented with descriptions of four or five objects and given the task of remembering them. These descriptions were about the placement of objects in a two-dimensional plane. The arrangement objects formed patterns such as the following:

ABC
D

A description that referred to a unique arrangement can be represented by a single situation model. For example, the following three sentences are a *determinate description* in that they uniquely describe the situation of the arrangement above: (a) A is behind D, (b) A is to the left of B, and (c) C is to the right of B. However, descriptions that are consistent with a variety of situations do not result in the integration of information into a situation model. For example, for the arrangement above, the following sentences would provide an *indeterminate description* of the above arrangement of objects: (a) A is behind D, (b) A is to the left of B, and (c) C is to the right of A. While this description can refer to the objects in the diagram, it can also refer to other arrangements. Thus, it is unlikely that people will interpret these sentences as referring to the same situation.

Mani and Johnson-Laird (1982) found that on a later recognition test, determinate descriptions showed more evidence of gist memory (i.e., memory for the meaning rather than the form of the description) than did indeterminate descriptions whereas indeterminate descriptions yielded better memory for verbatim information than did determinate descriptions. That is, people were more likely to identify inference statements as having been seen before for determinate rather than indeterminate descriptions. This suggests that the integration of situation-specific information can occur only when a set of facts clearly refers to a single situation and that situation models are used to make the long-term memory retrieval decision.

Retrieval set size. Here, retrieval set size refers to the number of situation models included in a retrieval set. Memory retrieval is influenced by whether a set of facts, having overlapping concepts, refers to a single situation and thus a single situation model or to multiple situations and thus several situation models. A series of experiments (Radvansky, 1992; Radvansky, Spieler, & Zacks, 1993; Radvansky, Wyer, Curiel, & Lutz, 1997; Radvansky & Zacks, 1991; Radvansky, Zacks, & Hasher, 1996) has used a fan effect paradigm to assess the impact of the number of situation models in the retrieval set on memory retrieval. A *fan effect* is an increase in response time accompanying an increase in the number of associations with a concept in a memory probe (J. R. Anderson, 1974). In these experiments, people memorized sentences about objects in locations, such as "The potted palm is in the hotel," "The potted palm is in the museum," and "The pay phone is in the museum." *Fan* is defined as the number of associations off of the object and location concepts. The design of the experiments allowed a person to organize around either the object or location concepts.

A fan effect is observed when a set of related facts refers to several situations, so that these facts are stored across several situation models. During memory retrieval, all of those models containing the concepts in the memory probe are activated. Provided a person engages in more than just a plausibility judgment (J. R. Anderson & Reder, 1987; Reder & Anderson, 1980; Reder & Ross, 1983; Reder & Wible, 1984), one model is selected to be retrieved into working memory. The activation of multiple situation models produces competition and retrieval interference, leading to a fan effect. So when presented with "The potted palm is in the hotel" as a memory probe, not only is the "hotel" model activated but so is the "museum" model because it also contains a potted palm. The more irrelevant situation models that are activated, the longer the response time. In contrast, a fan effect is not observed when a set of related facts refers to a single situation and thus is stored in a single situation model. So when presented with "The pay phone is in the museum" as a memory probe, although there may be other objects in the museum (e.g., the potted palm), the pay phone is not in any other models, so no retrieval interference occurs. Thus, during memory retrieval, (a) there are no additional related but irrelevant models activated, (b) response time is unaffected, and (c) no fan effect is observed.

This pattern of response times holds across a variety of circumstances. It does not change as a function (a) when the study sentences contain definite (i.e., *the*) or indefinite (i.e., *a* or *an*) articles (Radvansky et al., 1993), (b) of the order of the concepts in the sentences (Radvansky et al., 1993, 1996; Radvansky & Zacks, 1991), (c) of instructions to explicitly try to organize a set of facts in one way or another (e.g., in terms of either the object or the location concept; Radvansky & Zacks, 1991), (d) of the transportability of the objects (Radvansky et al., 1993), and (e) of cognitive age (Radvansky et al., 1996).

It is important to note that in these studies, the information is not presented in a structured context during learning, such as in the form of a narrative. Instead, the organization of the information into situation models is spontaneously initiated by the people themselves. So even in the absence of cues to organization and structure, people actively evaluate what situations are described by the facts and organize the information around those situations.

Types of spatial representations. Some of the research on situation models has focused on people's ability to construct spatial representations and how these representations are affected by the manner in which that information was presented. For instance, it has been shown that people can create a fairly accurate mental representation of a space on the basis of a description of that location from a text. A study by Ferguson and Hegarty (1994) demonstrated that mental maps created from a description provided by a text retained many characteristics observed when people study a location presented in a map form. Specifically, their mental representations appear to often represent many of the important spatial interrelations among different map locations. Furthermore, the map as a whole appeared to be organized around landmarks, with these types of locations being most accessible, and other nonlandmark locations being organized around them.

The manner in which a space is described to a person can vary depending on the perspective that is provided. The two most common perspectives provided in a text are route and survey. Route perspectives describe movement as though a person were actually traveling within the space. Such descriptions often contain spatial terms such as *to the right, up ahead,* and so forth. In contrast, survey perspectives provide a bird's eye view of the location, as if one were viewing a map. Such descriptions often contain spatial terms such as *to the east or near the border.* When asked to verify inferences about spatial relations not explicitly stated, people are as fast and as accurate for either type of description, independent of how they originally learned the space (Ferguson & Hegarty, 1994; Perrig & Kintsch, 1985; Taylor & Tversky, 1992). This suggests that people were using viewpoint independent situation models to verify these inferences.

Causation

A large number of studies have addressed whether and how readers keep track of causal information during the comprehension of narratives and expository texts. There is a great deal of converging evidence that readers routinely keep track of causal information. These causal relationships can either be indicated explicitly in text, for example, by causal connectives such as *because* or *therefore,* or are inferred by readers using their knowledge of events. For example in "Cathy poured water on the bonfire; the fire went out," readers generate the inference that the water caused the bonfire to go out. This inference is based on the knowledge that water extinguishes fire (Singer & Halldorson, 1996).

Foregrounding

The causal relation between events described in a text can be foregrounded by the use of causal connectives, such as *because, so, therefore,* and *consequently.* A number of studies have investigated the role of causal connectives in comprehension (e.g., Caron, Micko, & Thuring, 1988; Deaton & Gernsbacher, in press; Millis & Just, 1994; Traxler, Bybee, & Pickering, 1998). Caron et al. were among the first to show that the causal connective *because* increases the coherence of the final representation of the events described in a sentence. Millis and Just extended these findings by showing that the first mentioned event in a pair of statements is more accessible to the reader when the statements are conjoined by *because* compared with when they are in two different sentences. However, a problem with this finding is that the presence or absence of the connective is confounded with whether the events are reported in one or two sentences. Millis and Just also found that the causal connective affected the accessibility of the first event only if the two events were moderately causally related. If the events were unrelated, no facilitative effect was observed.

Deaton and Gernsbacher's (in press) findings are largely consistent with earlier findings. Their results show that the presence of a causal connective facilitates on-line comprehension and increases cued recall for the clause following the connective, compared with noncausal connectives such as *and* or *then.* The inclusion of noncausal connectives removed the confound that was present in Millis and Just's (1994) study. Deaton and Gernsbacher also found that *because* is an effective cue only when the events denoted by the two clauses conjoined by the causal connective are causally related. There was no beneficial effect of *because* for events that had no (obvious) causal relation, such as "Susan called the doctor because the baby played in his playpen." Traxler et al. (1998) used an eye tracking paradigm that allowed them to conclude that causal connectives influence processing in an incremental fashion. That is, as soon as the reader encounters *because,* he or she attempts to construct a causal connection between the previous event and the incoming event. This suggests that readers are highly sensitive to causal connectives as cues to construct a causal links between events.

Updating and Retrieval

In most cases, readers can update the integrated model by forming causal connections between the integrated model and the current model, without being prompted by connectives. In such cases, world knowledge plays a crucial role. Singer and his colleagues have conducted extensive research into the role of causation in language comprehension (e.g., Singer, Halldorson, Lear, & Andrusiak, 1992). In particular, Singer et al. were interested in how readers use their world knowledge to validate causal connections between events described in sentences, such as the following:

1a Mark poured the bucket of water on the bonfire.

1a′ Mark placed the bucket of water by the bonfire.

1b The bonfire went out.

1c Does water extinguish fire? (p. 507)

In Singer et al.'s paradigm, readers typically read sentence pairs such as 1a–b or 1a′–b. They are subsequently presented with a question like 1c. Singer et al. found that readers were faster in responding to 1c after the sequence 1a–b than after 1a′–b. According to their validation model, the reason for this is that the knowledge that water extinguishes fire is activated to validate the events described in 1a–b. However, because this knowledge cannot be used to validate 1a′–b, it is not activated. In our terminology, the event described in 1b is integrated with the event described in 1a by way of a causal connection, whereas 1a′ and 1b remain unintegrated on the causal dimension (although they would be integrated on the temporal and spatial dimensions according to the event-indexing model).

In a related line of research, readers were asked to study sentence pairs, presented one sentence at a time on a computer screen, that varied in degree of causal relatedness. They were subsequently presented with the first member of each pair as a recall cue for the second member (Duffy, Shinjo, & Myers, 1990; Keenan, Baillet, & Brown, 1984; Myers, Shinjo, & Duffy, 1987). In this paradigm, researchers analyzed reading times for the second sentence of each pair—a measure of ease of updating the integrated model—and recall of the second sentence when people are cued with the first sentence—a measure of retrieval of the integrated model. The most intriguing finding in this research is that causal relatedness has a curvilinear relationship with cued recall, such that events that are moderately causally related are recalled better than either events than are causally unrelated or events that have a strong causal relationship.

Myers et al. (1987) argued that the moderate pairs lead to the best recall because readers are both enabled and necessitated to form a causal inference to connect the two events. Causally unrelated pairs do not enable readers to generate a connecting inference, whereas strongly related pairs do not necessitate readers to generate a connecting inference. This interpretation can also account for the pattern in the reading times. Reading times are fastest for high related pairs because the reader does not have to form an integrative inference to incorporate the current model into the integrated model. Reading times are longer in the intermediate condition because readers have to form an integrative inference, which takes up extra processing time. Finally, reading times are longest in the noncausal condition because readers attempt to form an integrative inference but fail to do so.

Duffy et al. (1990) obtained more direct support for the assumption that the intermediate pairs were more likely to prompt the generation of elaborations than the high and low related pairs. They instructed their participants to write an elaboration sentence that could be inserted between the two sentences. As predicted, people spent the least amount of time generating sentences for the intermediate pairs. Furthermore, because now an elaborative inference was generated for each pair, the recall advantage of the intermediate pairs vanished.

Single events can have multiple causes (e.g., for a brush fire to occur, there has to have been a period of drought and a carelessly discarded cigarette), and multiple events can have a single cause (e.g., the same tornado can destroy homes, uproot trees, and turn over cars). Trabasso, van den Broek, and their colleagues have proposed a causal network model of comprehension to capture this myriad of connections (Trabasso & Magliano, 1996; Trabasso & Sperry, 1985; Trabasso & Suh, 1993; Trabasso & van den Broek, 1985; van den Broek, 1994; van den Broek & Lorch, 1993). According to the causal network model, text comprehension shares features with problem solving. When a person reads about an event, he or she attempts to explain that event by using information from the previous sentence, from the mental representation of previously reported events—now in long-term memory—or from world knowledge.

By linking events through explanatory inferences, the reader creates a causal network of the narrated events. One of the basic premises of the causal network model is that readers form causal connections between events in nonadjacent sentences in a text. This is an interesting claim because it suggests that readers look beyond the current contents of working memory (typically assumed to be one or two sentences) or to make causal connections. Various studies suggest that readers do indeed make global causal inferences during on-line comprehension, even when it is also possible to form a connection between the current event and the information in working memory (Albrecht & Myers, 1995; Dopkins, 1996; Trabasso & Suh, 1993; van den Broek & Lorch, 1993). Theoretical arguments have also been advanced as to why readers monitor global causal coherence. Specifically, it is argued that readers form global causal connections in an "effort after meaning" (Graesser et al., 1994).

Consistent with the causal network model, various studies have demonstrated that explaining events, actions, and processes is an effective comprehension strategy (Chi, de Leeuw, Chiu, & LaVancher, 1994; Trabasso & Magliano, 1996; Zwaan & Brown, 1996). Chi et al. had two groups of high school students read an expository text about the blood circulation system. One group received no special instruction. However, the other group received the instruction to try to explain every process and event described in the text. The participants who received the explanation instruction increased their performance on a comprehension task by 10% over the control group. In addition, the better comprehenders, that is, students with higher college aptitude test scores, benefited as much from the instruction as less skilled comprehenders, that is, students with lower college aptitude test scores. There is also evidence that skilled comprehenders spontaneously generate more explanatory inferences than do less skilled comprehenders (Trabasso & Magliano, 1996; Zwaan & Brown, 1996).

In addition to generating backward causal inferences, readers may generate predictions about the causal consequences of events. For example, when reading "The business man didn't notice the banana peel," we might predict that he will step on it and slip. Early research on predictive inferences generally suggests that they are not made during on-line comprehension (e.g., Duffy, 1986; Potts, Keenan, & Golding, 1988; Singer & Ferreira, 1983). However, more recent studies have demonstrated that predictive inferences are being made during on-line comprehension when the stimulus materials (a) constrain the number of potential predictions, (b) provide sufficient context, and (c) foreground the to-be-predicted event (Keefe & McDaniel, 1993; Murray, Klin, & Myers, 1993; Whitney, Ritchie, & Crane, 1992). For example, Keefe and McDaniel found support for predictive inferencing using a naming task. When words thought to reflect a particular (forward) inference were presented immediately after a predictive sentence, a significant decrease in naming time was found relative to a control condition, suggesting that readers had made the predictive inference. However, when the probe word was presented after an intervening sentence (as had been the case in earlier studies of predictive inferencing) or after an interval filled with nonreading activity, the priming effect was not observed. Keefe and McDaniel speculated that forward inferencing occurs during reading but that predictive inferences are quickly deactivated when there is no further information to support them. To summarize, the current research on predictive inferences suggests that readers are selective in drawing predictive inferences but can draw them when prompted by foregrounding devices and can maintain them when there is sufficient context to sustain them.

Intentionality

Many researchers have argued that the comprehension of narratives revolves around keeping track of the goals and plans of protagonists (e.g., Graesser, 1981; Lichtenstein & Brewer, 1980; Schank & Abelson, 1977). According to Schank and Abelson, who also provided a representational format for goal information, people have life themes that generate goals to be attained, which, in turn, generate plans of action. For example, if someone trains hard for a marathon (a plan), it may be to win the marathon (a goal that generated the plan), to become a famous athlete (a theme that generated the goal). As we see later, there is a considerable body of evidence suggesting that readers keep track of motivational information during comprehension.

Human behavior is goal directed, and because narratives describe human behavior, readers can use general cognitive procedures to explain human behavior. Many researchers assume that goal structures have a special status in the comprehension of narratives. One reason for this is that many actions, states, and events described in narratives are related to goals: They are either part of a goal plan structure (e.g., asking a professor to write a letter of recommendation for you when you apply to graduate school) or form an obstacle to the realization of a goal (e.g., the professor tells you he can't write a letter because he doesn't know enough about you). Thus, a goal plan hierarchy is a highly important organizational mechanism for structuring narrated events. Much of the research on causal inferences discussed in the previous section includes motivational inferences. Here we focus on the research that deals exclusively with motivational inferences.

Foregrounding and Updating

There is extensive evidence that the statement of a goal carries considerable weight during text comprehension. For example, a statement such as "Betty decided to knit a sweater" introduces a goal on the part of Betty. This goal is maintained at a high level of availability in the reader's mental representation as long as the focus remains on Betty and until the goal has been satisfied (Lutz & Radvansky, 1997; Trabasso & Suh, 1993). In other words, a goal statement is an effective foregrounding device. When a goal of a character is unsatisfied, the information relating to that goal should be in a high state of availability. In our terms, there should be a retrieval cue in STWM to the goal in the integrated model in LTWM. In contrast, information about goals that are already completed should be less available (in our terms, there should be no retrieval cue in STWM), thereby updating the current model. This is the pattern that empirical evidence yields. When people are probed for information from a story, failed goal information is more available than completed goal information (Lutz & Radvansky, 1997; Radvansky & Curiel, in press; Suh & Trabasso, 1993; Trabasso & Suh, 1993). Furthermore, for the completed goal information, although that goal has been achieved, that information is still at a higher level of availability than neutral information (Lutz & Radvansky, 1997; Radvansky & Curiel, in press). This presumably occurs because completed goal information is part of the causal chain of the story that links several ideas together, providing coherence to the story. In contrast, neutral information does not serve such a role.

Goal information is often not stated explicitly in a text and has to be inferred. Graesser and his colleagues have systematically investigated the types of motivational inferences that readers generate during text comprehension (Graesser & Clark, 1985; Graesser et al., 1994; Long & Golding, 1993; Long, Golding, & Graesser, 1992). One conclusion of this research is that readers are more likely to construct superordinate than subordinate motivational inferences. That is, when reading about an action, readers attempt to infer the goal that motivated the action if that goal is not mentioned explicitly in the text. However, readers do not infer more subordinate actions. Thus, when reading "Roger went to the grocery store," readers infer that Roger wanted to buy groceries but not that he drove to the store. Thus, Graesser and colleagues' research demonstrates that readers update situation models on the motivational dimension by linking actions to a higher level goal as opposed to lower level actions. This finding is consistent with the view that superordinate goal inferences contribute to the reader's effort to construct a coherent situation model, whereas subordinate goal inferences do not. As a result, information related to the goal can now be maintained in a working memory buffer as retrieval cues to facilitate the incorporation of future events into the integrated model.

Retrieval

As mentioned earlier, a basic assumption underlying research on intentionality is that goal structures provide the backbone for a person's understanding of the events described in a narrative. Consequently, this information should be better encoded in memory and should be easier to remember later on. Consistent with this assumption, a number of studies have found that when people were asked to recall a narrative they had read earlier, the goal-related information was recalled better than other information that was not related to the protagonists' intentions (Black & Bower, 1980; Fletcher & Bloom, 1988; Myers & Duffy, 1990; Myers et al., 1987; Trabasso, Secco, & van den Broek, 1984; Trabasso & van den Broek, 1985). In general, an increased number of such connections increases the probability of recall, except, as discussed in the *Causation* section, at very high levels of interconnectivity when recall may suffer because information is so interconnected that readers perform fewer elaborations on it and, therefore, remember it less well (Myers & Duffy, 1990; Myers et al., 1987).

Protagonists and Objects

Protagonists and objects form the "meat" of situation models. Many studies have investigated protagonists and objects. One line of research focuses on anaphoric resolution. In other words, do readers connect incoming information to tokens for protagonists or objects? Of special interest to our perspective is the research on whether and to what extent readers keep track of protagonists. Another line of research focuses on whether readers instantiate objects when they are not mentioned explicitly in the text. The general conclusion from this research is that readers appear to be intensively engaged in keeping track of protagonists during comprehension whereas the amount of focus on objects appears to be more dependent on contextual cues.

Foregrounding and Updating

Much of the research on pronoun resolution has focused on the linguistic cues that readers use to resolve pronouns. Some of the grammatical and lexical factors that have been found to affect pronoun resolution are (a) whether a character was the subject in the previous sentence (Gordon et al., 1993), (b) whether a character was first mentioned in the previous sentence (Gernsbacher & Hargreaves, 1988; Gordon et al., 1993), (c) whether the character was mentioned by name in a previous sentence (Sanford, Moar, & Garrod, 1988), and (d) the semantic relatedness between the antecedent description and the anaphor (Garrod & Sanford, 1977). There is evidence that several of these cues have rather immediate effects on anaphoric resolution and may operate simultaneously (e.g., Garrod, Freudenthal, & Boyle, 1993). In other words, comprehenders are very sensitive to a variety of linguistic cues about anaphoric resolution.

Sanford and Garrod (1981) proposed that readers interpret texts against the background of a constantly changing model of what the text is about, that is, what we call the integrated situation model. This model incorporates both the currently active entities, protagonists, objects, events, and the relevant background knowledge. Sanford and Garrod's focus model makes predictions about the level of activation of tokens representing protagonists in working memory. Main protagonists, typically introduced by name, are part of explicit focus, whereas less important protagonists become part of implicit focus. For example, in the narrative "Paige went to the restaurant and ordered a steak; after her meal, Paige chatted a bit with the waiter and then she left," Paige is the main protagonist; the reader expects to hear more about her. The waiter, however, is part of the background, the restaurant scenario. We do not expect to hear more about him after Paige has left the restaurant. When a new scenario is introduced, say, a movie theater, then the integrated model should be updated by (a) maintaining the main character in the buffer and (b) removing the character that is bound to the previous scenario (e.g., the waiter) from the buffer. Sanford et al. (1988) have shown that the use of a proper name increases the likelihood of mention in a continuation task (in which people are asked to complete a sentence or text) and the ease of referential resolution. Also consistent with these findings, Morrow (1985) found that readers tend to resolve ambiguous pronouns with the main protagonist.

Readers have been demonstrated to use their domain knowledge in resolving pronouns. For example, Morrow, Leirer, and Altieri (1992) showed that pilots were more likely to correctly resolve pronouns in narratives about aviation than were nonpilots whereas the two groups were equally accurate on general narratives. This result is consistent with the notion that readers use their background knowledge to integrate information from different sentences and that this knowledge involves properties of protagonists.

There is more direct evidence that readers keep track not only of protagonists themselves but also of information associated with them. Albrecht and O'Brien (1995; see also Myers, O'Brien, Albrecht, & Mason, 1994) had people read narrative texts about a protagonist with a particular trait, for example, being a vegetarian. Several sentences further into the story, an action (ordering a hamburger) was described that was inconsistent with the trait. Reading times for sentences describing a trait inconsistency were elevated compared with a control condition, suggesting that readers had incorporated the trait in their situation models and had detected the inconsistency.

In a related study, Carreiras, Garnham, Oakhill, and Cain (1996) observed that readers routinely and immediately incorporate stereotypical gender information in situation models. When a sentence introduced a stereotypically male or female protagonist by a descriptor noun such as *nurse* or *doctor*, reading times on a subsequent sentence were slowed when it contained a pronoun that was inconsistent with the stereotypical gender. For example, when reading "The baby-sitter settled down to watch a video," readers were slowed when the next sentence was "Then he heard the baby crying" compared with when it was "Then she heard the baby crying."

While there has been some research on the processing of protagonists and objects in a situation model, we are not aware of any research that has looked at the updating of protagonist or object characteristics. For example, an issue that would be addressed by such research would be to investigate what would happen to the activation level of protagonists' mood states when they change.

Objects, especially instruments for actions, are often left implicit in texts. For example, when we read "Norm pounded a nail into the plywood wall," no mention is being made of a hammer. The question of interest is whether readers infer that Norm used a hammer when reading a sentence such as this one. Initial research suggested that readers do indeed instantiate instruments (Paris & Lindauer, 1976). However, these conclusions were based on the fact that instruments often occurred as intrusions in recall protocols. These findings were discredited in a study by Corbett and Dosher (1978), who showed that the instruments were not encoded during comprehension but rather inserted during recall. Thus, the conclusion from this research is that readers do not obligatorily instantiate instruments during comprehension (see also Graesser et al., 1994). However, readers may do so under certain circumstances and these circumstances are as yet not very well understood. Some potential factors are (a) the accessibility of the instrument (McKoon & Ratcliff, 1992), (b) the causal importance of the object, and (c) the reader's goal. For example, McKoon and Ratcliff (1986) showed that readers may infer instruments when the instrument had been mentioned explicitly in the previous sentence. Of course, explicitly mentioning an instrument is a very direct way of foregrounding it. Therefore, an instrument inference is more likely to be made when the instrument has been foregrounded. Truitt and Zwaan (1998) recently showed that the generation of instrument inferences is influenced by more subtle cues. Specifically, they found that activation of the instrument word varied as a function of the internal temporal structure of the event, as indicated by the verb aspect. Recognition latencies for instrument words that had been mentioned in a previous sentences (e.g., "hammer") were reliably shorter when the action was described as ongoing ("Jason began pounding the nails into the board") compared with when it was described as punctual ("Jason pounded the nails into the board"). Conversely, correct rejection latencies for the instrument word were reliably longer in ongoing actions compared with punctual actions when the instrument word had not been mentioned. Truitt and Zwaan argued that it is more relevant for readers to infer the instrument when it is still being used than when it is part of a completed action. More research is needed to gain a better understanding of the conditions under which instruments are inferred and incorporated into a situation model.

Retrieval

Some of the strongest evidence for person-based situation models has been obtained using the fan effect paradigm described above. It has been demonstrated that people can integrate information into situation models on the basis of person concepts rather than spatial locations. Radvansky et al. (1993) had participants memorize lists of facts about people in locations, such as "The banker is in the phone booth." It is important to note that the locations used in these facts were small ones that typically contain only a single person at one time, such as a phone booth, a witness stand, or the bathroom on a Greyhound bus. Because it is unlikely that more than one person will occupy one of these locations at one time, a location-based organization is implausible. However, it is possible for a person to travel from place to place. As a result, participants create situation models that are organized around a person concept. On a recognition test, a fan effect is observed for multiple person–single location conditions but not for single person–multiple location conditions.

Using small locations is not the only way a person-based organization may be observed. In another study (Radvansky et al., 1997), a person-based organization was observed using the abstract relation of ownership rather than the spatial relation of containment. Participants memorized facts about people buying objects, such as "The lawyer is buying the greeting cards." The objects were all ones that can be purchased in a drugstore, such as toothpaste, a magazine, or candy. A person-based organization was then observed on the subsequent recognition test with a fan effect for conditions with a single object being bought by several people but not for conditions with a single person buying several objects.

However, the ownership relation is not adequate in and of itself for the creation of situation models organized around a person concept. The information is integrated only when it potentially refers to a single situation, such as buying a collection of items at a drugstore. No such organization is observed when the objects are typically purchased at different times and in different locations, such as a house, computer, or car. In that case, the person cannot become the basis for organization because people tend not to buy these sorts of objects in the same situation.

Time

The role of temporal information in narrative comprehension has received relatively little attention in cognitive psychology. This lack of research stands in stark contrast with the importance and ubiquity of temporal information in language. Every sentence obligatorily contains information on the absolute or relative time at which the event described in the sentence occurred (Miller & Johnson-Laird, 1976; Quine, 1960). To achieve a proper understanding of the situation described by a text, the reader needs to know when the described events took place both relative to each other and relative to the time at which they were narrated. Thus, to develop sophisticated models of text comprehension, one needs to explain how readers make use of temporal information to construct situation models. The evidence to date strongly suggests that readers spontaneously keep track of temporal information during on-line comprehension.

We know very little about the cognitive processing of temporal information in language. However, we know much more about the semantics of temporal information in language. Various linguists have proposed complex theories on how temporal information is conveyed in language. As Ter Meulen (1995) recently noted, linguistic theories specify the interpretive options and the consequences thereof afforded by a particular linguistic structure. Which options are selected by the reader under which conditions is the domain of cognitive psychology.

Foregrounding

As noted earlier, languages have extensive systems for specifying temporal relationships among events and between the events and the time of utterance. A number of studies have looked at the effects of temporal connectives on comprehension. Temporal markers are a way of making temporal relations explicit and thereby foregrounding them. Bestgen and Vonk (1995) recently found that temporal markers differentially affect the availability of preceding information. Specifically, *and* and the absence of a temporal marker (e.g., "He opened the door, went inside, . . .") made previous information more available than a sequential marker such as *then*. This is consistent with the idea that situation models are based around some spatial–temporal framework. When information could be interpreted as being consistent with a timeframe, it could be incorporated into a single representation more easily than when the text signaled a change to a different timeframe and a different situation model would be involved.

Updating

As with spatial information, the temporal structure of sets of events does not straightforwardly map onto a linguistic structure, although people's conceptualization of time is linear as opposed to their conceptualization of space (see Ter Meulen, 1995, for a representational system for temporal information). One reason why there is not a perfect match between the chronological and narrated order of events is that some events may overlap in time and yet have to be narrated in a nonoverlapping fashion. Linguists have argued that readers–hearers use a default assumption when comprehending narrated events, which is called the *iconicity assumption* (e.g., Hopper, 1979). This assumption holds that the narrated order of events is expected to match their chronological order. In other words, the comprehender's default assumption is that each current model will be attached to the most recent event in the integrated model. A psychological explanation for this assumption could be that real-life events enter one's consciousness in chronological order so that the default mode of constructing temporal representations is a chronological one. For example, when we read "He patted the dog and jumped the gate," we assume that the patting took place before the jumping. We can deviate from the chronological order by using temporal markers, such as adverbs, as in "Before he jumped the gate, he patted the dog." In this case, there is a mismatch between the narrated and chronological order of events. Ohtsuka and Brewer (1992) and Zwaan and Whitten (1998) have demonstrated that mismatches such as these lead to decrements in text comprehension performance, as indicated by the proportion of correct responses to comprehension questions (Ohtsuka & Brewer, 1992), chronological order recall, and processing speed (Zwaan & Whitten, 1998). Moreover, Mandler (1986) has demonstrated that minor violations of the iconicity assumption lead to momentary increases in processing load during on-line sentence comprehension. For example, reading times are longer for "He patted the dog before he jumped the gate" than for "Before he jumped the gate, he patted the dog." These findings are analogous to the findings of Ehrlich and Johnson-Laird (1982) in the spatial domain. If the structure of the text does not match the structure of the situation, comprehension is impeded.

Other studies have focused on the effects of temporal discontinuities on comprehension. For example, some researchers have argued that in addition to an iconicity assumption, comprehenders also use a strong iconicity assumption (Zwaan, 1996; see also Dowty, 1986). According to the strong iconicity assumption, the default assumption in comprehension is that events that are narrated in adjacent clauses are contiguous in time. For example, in "He entered the room, looked around, and opened the window," we assume that these three actions were carried out in close succession and that there were no other significant events between them. There is some linguistic evidence for a strong iconicity assumption. Grimes (1975) noted that in *Kâte,* a language of Papua New Guinea, events that are contiguous in time are grammatically distinguished from events "that are separated by a lapse in which nothing of significance for the story happens" (p. 36). Although languages such as English have not grammaticalized this distinction, it is plausible that time lapses in stories have psychological significance in English as well.

One of the characteristics of situations in the world is that they often bound within a limited temporal range. As such, if events move beyond the boundaries of either of these types of locations, then people should interpret the information as referring to a new situation and, as such, should create a separate situation model. A study by A. Anderson, Garrod, and Sanford (1983) reports effects of this type. In particular, people were asked to read a passage in which there was a time shift. There were two story versions, one in which the time shift was short enough to be considered part of the same situation (e.g., 10 min later in a movie watching story) or to be part of a new situation (e.g., 6 hr later in a movie watching story). This idea of how time switches can affect the structure of the situation model was tested in a number of ways: by having people give story continuations, recording time to answer questions, or recording reading times. A. Anderson et al. found that references to scenario-dependent characters (e.g., a projectionist) were more likely to occur in short time shifts than in long time shifts. Furthermore, question answering times and reading times of sentences that referred to such scenario-dependent characters were longer for the long time shift story versions than the short time shift story versions. This seems to indicate that when there is a large enough jump in time, people are likely to create a new situation model and carry over only those aspects of the previous model that are relevant to this new situation (e.g., the story protagonist).

One difficulty with the A. Anderson et al. (1983) study is that large shifts in time are often accompanied by a large shift in location. For example, 6 hr after a movie has begun, it is not only likely that the story has moved out of the timeframe of a movie watching scenario, but it is also likely that the story protagonist is no longer in the movie theater but in a different location. Furthermore, A. Anderson et al. distinguished between only two type of time shifts, short and long. Each of these points was addressed in a study by Zwaan (1996).

In Zwaan's (1996) study, people read narratives similar to the ones used by A. Anderson et al. (1983), except that there were three time shifts: (a) short, marked by phrases such as *a moment later*; (b) intermediate, marked by phrases such as *an hour later*; and (c) long, marked by phrases such as *a day later.* Appendix A shows one of these narratives. The temporal markers were structured such that both short and intermediate markers were consistent with the same scenario, but the long marker was outside of the described scenario, much like the A. Anderson et al. study. In the example, both the "moment" and the "hour" intervals are consistent with the scenario of a reception (as was established in a norming study), whereas the "day" interval is not. This allowed for a test among four theories: (a) a text-based model, an extreme version of Kintsch and van Dijk's (1978) theory, where all processing is guided by the overlap of arguments in the sentences comprising the text; (b) a scenario model in which processing is affected more by a shift out of the scenario than within a scenario; (c) a strong iconicity assumption, where processing is affected by whether a time shift indicates actions that occur either immediately after an event or action or are further removed in time; and (d) a hybrid model of the scenario and strong iconicity assumption, where processing is affected by any shift in time, with longer shifts in time producing greater disruptions in processing. The results of several experiments using sentence reading, probe recognition, and priming measures all support the strong iconicity assumption. For example, recognition responses to probe words denoting events that took place before the time shift, such as *beaming* in Appendix A, were faster for the short condition, suggesting that they were still highly accessible in working memory during comprehension compared with the intermediate and long conditions that did not reliably differ from one another. The probe words were always presented after the critical sentence (boldfaced in Appendix A). Furthermore, in a primed recognition task that was administered after participants had read all the stories, there was reliably more priming between events from the story directly preceding and directly following the temporal marker ("a moment/hour/day later") in the short condition compared with the intermediate and long conditions. This suggests that the events were more strongly connected in long-term memory when they were temporally contiguous than when they were not.

These results suggest that the event in the current model will be attached to events in the integrated model that are within the same general timeframe. However, when there are no events within the same timeframe in the integrated model, a new timeframe is created in the integrated model and the current event is a retrieval cue to that timeframe in LTWM. This construction takes up cognitive resources and slows processing time accordingly.

Carreiras, Carriedo, Alonso, and Fernandez (1997) have obtained further evidence that temporal proximity in the described situation affects the accessibility of information. Carreiras et al. had their participants read short narratives such as the following:

> 4. Marta is a 45-year -old woman, and she is unmarried.
>
> She lives in a downtown apartment in La Coruña.
>
> *Now she works/Some time in the past she worked* as an economist for an international company.
>
> She visits her parents on weekends.
>
> She loves underwater photography, and she likes to practice water sports.
>
> However, he is afraid that his marriage will fail again. (p. 441)

There were two versions of each text. Verb tense was manipulated in the critical sentence (in italics), such that the sentence referred to either a past or the present occupation of the protagonist. People were probed with the word denoting the occupation of the protagonist (e.g., "economist") one, two, or three sentences after the critical sentence. Recognition responses to the probe words denoting the protagonist's present occupation were significantly faster than those to probe words denoting the protagonist's past occupation. These results are consistent with Zwaan's (1996) suggestion that readers construct temporal intervals and that information from within the current interval is more accessible to the comprehender than information from earlier intervals. These results also demonstrate that it is not so much distance in the surface structure of the text that determines accessibility of information but distance in the situation model.

Retrieval

The use of time as a basis for organizing information into a situation model has been explored in a recent study by Radvansky, Zwaan, Federico, and Franklin (1998). In one experiment, people memorized a list of sentences, such as "The banker was adjusting his tie when the camera flashed." Participants were told that all of the information in the sentences took place at a party. So while there was a common spatial location, it could not be used to segregate the facts into separate situation models. In sentences such as these, activities such as a banker adjusting his tie are placed in a temporal framework, which in this case is identified by the phrase "when the camera flashed." This was done instead of using direct references to time periods, such as "at 7:43," to avoid the possibility that people would use a preexisting temporal structure to organize the information. Instead, people must rely on their understanding of what makes up a situation in the world and decide whether the information can be integrated into a common situation model. The results of a recognition test showed that people experienced interference (a fan effect) when retrieving facts in which an activity was described as occurring across several time periods whereas there was no retrieval interference (no fan effect) when retrieving facts in which there were several activities occurring in a common time period. So people can integrate facts about a common time period into a single situation model and reduce the amount of retrieval interference experienced later.

This basic finding was replicated and extended in a second experiment in which time was marked by the verb tense used in the study sentences. People memorized a list of facts in which a person was described as doing either one or three activities. For those cases where there were three activities, they were either all described in the same verb tense (e.g., all in the past tense) or were each in a different verb tense (i.e., one in the past, one in the present, and one in the future tense). It should be noted that the materials were designed so that it was plausible for one person to be performing three activities at once. Specifically, one activity was always mental (e.g., "thinking"), one was facial (e.g., "whistling"), and one manual (e.g., "polishing"). The results of a later recognition test showed that people were slower at responding to different time probes relative to same time probes. Furthermore, there was no difference between the same-time and single-time probes. This again suggests that people can integrate a set of facts referring to a single time period into a common situation model and that this has consequences for later memory retrieval.

The Nature of Situation Models

There are two general theoretical issues facing researchers interested in the role of situation models in (language) comprehension and memory. The first issue is the relationship between linguistic cues and world knowledge. The second issue is the multidimensionality of situation models.

Linguistic Cues Versus World Knowledge

We agree with the view espoused by Gernsbacher (1990), Givón (1992), Kintsch (1992), and others that language can be regarded as a set of processing instructions on how to construct a mental representation of the described situation. As we have discussed, readers make use of lexical cues, such as causal and temporal connectives, to construct situation models. Similarly, they make use of grammatical cues such as word order to identify the referent of a pronoun or to identify the chronological order of the described events. In conjunction with linguistic cues, readers make use of their knowledge about experienced situations to construct situation models, in particular to accomplish such tasks as identifying causal and motivational relationships between actions and events, to place events in time and space, and to associate traits with protagonists.

In the introduction as well as in the subsequent discussions, we have pointed out the essential role of knowledge in situation model construction. However, we also need to learn more about how linguistic cues influence the construction of situation models and how they interact with prior knowledge. For example, several researchers have noted that not all the information that is explicitly stated in a text (let alone the unstated information that can be inferred from the explicit statements) is included in a situation model. But what do the cues writers and speakers use to tell readers and hearers what and what not to incorporate in a situation model? Several researchers have pointed to the effects of foregrounding (e.g., Albrecht & O'Brien, 1995; Glenberg et al., 1987; Kintsch, 1992; Magliano, Dijkstra, &

Zwaan, 1996; Whitney et al., 1992). For example, movie directors use a repertoire of very specific (and well-known) devices to place information in the foreground (e.g., with camera angles and editing seemingly unrelated shots together). Magliano et al. found that the presence of a foregrounding device increases the likelihood that viewers will form explanations about the foregrounded character, object, state, or event. For example, when two seemingly unrelated shots are shown successively, such as a man without a parachute falling from a plane and a circus tent, viewers infer that the man will land on the tent, even though the man and the tent are not shown in the same shot and the tent is unrelated to anything that went on before in the movie. Similarly, there is a variety of linguistic devices that can be used to foreground information, from the lowly cleft sentence (e.g., "It was John who leaked the information to the press") to complex literary devices such as an unusual perspective.

Furthermore, we need to learn more about the level of resolution at which situations can be represented. Some have argued that it is unrealistic to assume that readers construct "lifelike" mental representations (e.g., "movies in the head") of situations during comprehension (McKoon & Ratcliff, 1992). Most situation model researchers would subscribe to this view. Situation models are likely to be rather abstract representations in which, for example, tokens may represent protagonists or objects (e.g., Johnson-Laird, 1983). It is known from the literature on mental imagery that people are capable of constructing rather detailed mental images from verbal descriptions. However, creating a detailed mental image requires extensive and effortful processing. For example, it takes several exposures to a text to construct a spatial image (Denis & Cocude, 1992), and it takes participants at least 3 s to construct an elaborate image of, for example, a canary. Below the 3-s threshold, only rudimentary images may be formed (Marschark & Cornoldi, 1991). Given that normal word reading times are at least 10 times faster, it seems unlikely that readers typically generate detailed visual images during comprehension.

Multidimensionality

The theoretical reasons for treating situation models as multidimensional mental representations have been outlined in the introduction. To gain a fuller understanding of text comprehension, we need to know how many and under what circumstances readers monitor these dimensions. Furthermore, we need to know whether these dimensions interact in particular ways. For example, is spatial coherence monitored when temporal and causal coherence are intact?

In linguistics, Chafe (1979) has made similar observations concerning the multidimensionality of text coherence:

> Rather than think of an experience as being stored in memory in terms of distinct episodes, it seems preferable to think of a more complex storage in terms of coherent spaces, coherent configurations of characters, coherent event sequences, and coherent worlds. At points where all of these change in a maximal way, an episode boundary is strongly present. But often one or another will change considerably while others will change less radically, and all kinds of varied interactions between these several factors are possible. (p. 180)

There are also methodological reasons for treating situation models as multidimensional mental representations. An important one is that situational dimensions may have been confounded in previous research (see also Zwaan, Magliano, & Graesser, 1995). For example, many studies have examined the effect of coherence on one situational dimension on reading times and comprehension without controlling for the other dimensions.

In all the studies reviewed so far, situational dimensions have been studied in isolation. However, if we take seriously the question of how readers understand texts, then we need to start thinking about the interrelatedness of the situational dimensions. A few studies have begun to address these issues. Taylor and Tversky (1997), for example, have investigated dimensional dyads, while Zwaan, Magliano, and Graesser (1995) have investigated temporal, causal, and spatial relatedness.

Zwaan, Langston, and Graesser (1995) made the relatively simplistic assumption that all five situational dimensions are equally weighted during text comprehension. However, the weight assigned to each dimension might depend on the nature of the task that a person is engaged in. Most researchers would claim, as do we, that the motivational and causal dimensions form the backbone of situations constructed during narrative comprehension. There are several reasons for this. At the level of task analysis, humans read texts to understand why events happened. Comprehension is an "effort after meaning" (Graesser et al., 1994). It is not enough to know that TWA Flight 800 crashed or when or where it crashed. We want to know why it crashed. The empirical evidence we have reviewed suggests that not only do readers consistently form causal connections during comprehension but that these connections have also been shown to facilitate the retrieval of information from long-term memory.

We would also argue that temporal information is crucial to the construction of situation models. There are three general reasons for this. First, as noted earlier, each sentence contains cues about temporal relations among described events and between the described events and the moment of writing. It seems unlikely that these cues would be so ubiquitous if they did not have an important role in comprehension. Second, temporal information is crucially important for identifying motivational and causal links between events. For example, an effect can never precede its cause; therefore, the reader needs to know the temporal order of events before generating a causal connection. Third, often the causes of events or the motivations for actions are unknown. In that case, temporal information is critical. An example is history (see Perfetti et al., 1995).

The jury is still out on spatial information. There is a great deal of evidence to suggest that readers are able to generate spatial inferences and construct relatively detailed spatial representations. However, there is also evidence suggesting that readers do not construct detailed spatial representations unless explicitly instructed to do so (Albrecht & O'Brien 1995; Wilson et al., 1993; Langston, Kramer, & Glenberg, in press; Zwaan, 1993; Zwaan & van Oostendorp, 1993, 1994), although at the expense of a large increase in processing time (Zwaan & van Oostendorp, 1993).

There are at least three factors conspiring against the spatial dimension. First, as noted earlier, there is a mismatch between the essentially nonlinear nature of space and the linear nature of language. Second, spatial information is not encoded as richly in the language as temporal information is. Consequently, there are relatively few cues as to how to construct a particular spatial representation. Third, spatial information is not as closely intertwined as temporal information with the motivational and causal dimensions. This suggests that readers are more likely to encode spatial information when it is related to the causal and motivational dimensions. Zwaan, van den Broek, Truitt, and Sundermeier (1996) have recently examined the hypothesis that readers are more likely to encode location information when that information is causally relevant (as suggested by Zwaan & van Oostendorp, 1993, 1994). Appendix B shows a sample story used in these experiments. As the appendix indicates, there were two versions of each story: a causal one and a control. In the causal version, the object is potentially causally relevant because the protagonist may step on it, which does, indeed, happen later on in the story. Participants' recognition responses to the word *pushpin* were probed at three different subsequent locations in the text (as indicated in Appendix B). In each case, that is, even before the outcome of the story was described, the responses were reliably faster in the causal version than in the control version, suggesting that the object was more available to the comprehender when it was potentially causally relevant than when it was not. Think aloud protocols furthermore showed that participants who read the causal version were indeed forecasting that Christine would step on the pushpin.

Finally, we would argue that the main protagonists are a crucial component of situation models. Most narratives, ranging from *The Odyssey* to the short passages used in psycholinguistic experiments, describe the goals and actions of a main protagonist. There is evidence to suggest that a person may encode more information about a protagonist than just his or her name. In addition, it should be noted that objects can also function as a central element of situation models, for example, in a textbook chapter about the heart or a printer manual. Finally, abstract concepts and processes can function as protagonist-like entities, such as freedom in a political treatise, iconic memory in a cognitive psychology textbook, or plate tectonics in a geology textbook. However, barring these special cases, the extent to which tokens for objects are encoded and stored in situation models presumably depends on their causal relevance.

The Event-Indexing Model

Zwaan, Langston, and Graesser (1995) have proposed an event-indexing model (*events* is taken generally and refers to both events and actions) of text comprehension. The event-indexing model makes general claims about both on-line comprehension and about the resulting representation on the reader's long-term memory. During comprehension, each incoming event (as denoted by a verb) is decomposed into five indexes: time, space, causality, intentionality, and agent. These dimensions correspond to the dimensions listed by Chafe (1979; see also Gernsbacher, 1990). There is empirical evidence that each of these variables individually plays a role in comprehension. However, we do not regard this set of indexes as exhaustive or fixed. Future research may demonstrate the importance of other situation model dimensions.

Incoming events can be more easily integrated into the evolving situation model to the extent that they share indexes with the current state of the model. For example, an event that is temporally and spatially contiguous with the previous event, and thus shares temporal and spatial indexes with the previous event, is relatively easy to integrate, whereas a temporally and spatially noncontiguous event is relatively difficult to process, all other things being equal. The reader now has to construct new temporal and spatial indexes. Thus, the event-indexing model makes the general prediction that the processing load during comprehension varies as a function of the number of situational indexes shared between the currently processed event and the current state of the situation model.

Zwaan, Magliano, and Graesser (1995) obtained partial support for this hypothesis. Specifically, they found that temporal and causal discontinuities have additive effects on the processing load during the comprehension of short stories. For example, if an incoming story event was (a) separated by a time shift (e.g., as denoted by a time adverbial like *an hour later*) from the previous event and (b) was causally unrelated to the previous event(s), then reading times would be elevated more than if there was only one discontinuity. These results were replicated in a recent study by Zwaan, Radvansky, Hilliard, and Curiel (in press). Additional support was obtained in a task in which readers rated how well each sentence fit in with the previous sentences. Fit ratings increased with the number of situational dimensions on which the event described in the sentence under consideration overlapped with the previous events (Magliano, Zwaan, & Graesser, in press).

Another prediction from the event-indexing model concerns the representation of stories in long-term memory. The end result of successful story comprehension is a coherent mental representation in long-term memory. According to the event-indexing model, the long-term memory representation of the situation model is a network of nodes that code the events described in and inferred from the story. Two event nodes may be connected through a given number of situational links. For example, if two events share a temporal or an agent index, they are connected through a temporal or agent link. The event-indexing model predicts that the strengths of the interconnections between memory nodes coding for story events will vary with the number of shared event indexes between these events.

Zwaan, Langston, and Graesser (1995) obtained initial evidence for this claim. The likelihood that participants regarded a pair of story verbs as related increased almost linearly with the number of indexes shared between the two events denoted by the two verbs. Moreover, Zwaan et al. were able to establish that each of the five situational dimensions (time, space, causation, intentionality, and protagonist) made a unique contribution toward explaining variance in the relatedness scores for story events, "over and above" the contributions of text-level variables and links between verbs in the mental lexicon.

However, in its present state, the event-indexing model is not, and was not intended as, a complete model of situation model construction. It is able to predict the link strengths between event nodes in long-term memory with some accuracy. However, it does not clearly specify the nature of the links between event nodes. For example, the model currently does not encode the temporal ordering of events or the nature of a goal hierarchy, nor does it encode the direction of a causal relationship. Clearly, this information has to be incorporated to provide a fuller account of situation model construction.

Another limitation is that the event-indexing model treats the individual dimensions as independent entities. This makes sense from a methodological point of view in the first phase of model development. However, it is likely that the situational dimensions interact in specific ways. For example, sometimes the chronological order of events can be reconstructed in the absence of linguistic cues such as tense or adverbs. For instance, in "John fell; he stepped on the banana peel," the reader knows that the event that is narrated last must have occurred first on the basis of the causal information (Mandler, 1986). Conversely, sometimes temporal information may prohibit a particular causal inference, as in "Someone was making noise in the backyard; Mike had left hours ago" (this example prohibits the inference that Mike was responsible for the noise, although it does prompt the inference that Mike did not make the noise).

In the introduction, we presented an updated version of the event-indexing model that makes use of recent proposals in the memory and text comprehension literature (Ericsson & Kintsch, 1995; Garrod & Sanford, 1990). Specifically, we distinguished three types of situation model: the current model, the integrated model, and the complete model. We also distinguished four classes of processes that operate on these models. *Construction* refers to the construction of a model of the situation described in the clause that is currently being read. *Updating* refers to the process of incorporating the current model into the integrated model of the situations described in previous clauses. *Retrieval* refers to the process of bringing parts of the integrated or final model back from long-term memory into LTWM and STWM. Finally, *foregrounding* refers to the process of maintaining retrieval cues in STWM buffers to parts of the integrated model in LTWM. This process is different from, but often the result of, authors' and speakers' use of foregrounding devices in language.

We are currently developing a more sophisticated version of the event-indexing model (Radvansky & Zwaan, 1998). Briefly, the new model makes a distinction among (a) a situational framework, (b) situational relations, and (c) situational content. The situational framework is conceived of as a spatial–temporal framework, grounding situations in space and time. In this respect, we assume that the establishment of a spatio–temporal framework is obligatory during the construction of a situation model. If specific spatio–temporal information is given, then it will be used. However, a person may still be able to construct a situation model without it. For the spatial location, a person could either infer from the text what the appropriate location would be or would instantiate some "empty stage" to serve as the location. For the temporal information, if the timeframe is not defined explicitly or with respect to other events, then the person would probably be able to derive an appropriate length of time from knowledge of similar situations stored in long-term memory.

Situational relations are relations on the five situational dimensions as analyzed by the event-indexing model. However, we should point out that this more recent development makes important distinctions between spatial and temporal framework information and spatial and temporal relation information. Spatial framework information establishes the location in which a situation takes place (e.g., the park), whereas spatial relational information denotes the spatial interrelations among entities within that location (e.g., to the left). Similarly, temporal framework information establishes the timeframe of the situation, whereas temporal relation information may specify the temporal sequence of events in a course of events situation. Another distinction between relation and framework information is that we assume that framework information is obligatory whereas we assume that relation information is optional, especially if it is not directly mentioned. The latter assumption is consistent with research showing that people infrequently spontaneously compute relations among entities in a situation. In addition to the spatial, temporal, and causal relations outlined by the event-indexing model, the new theory considers other types of relations as well, including ownership and interpersonal relations. This is in keeping with our aim of trying to provide a more comprehensive account of situation models.

An important claim of the new theory concerning the role of relations in a situation model refers to what we consider to be the more important relations in the representation. By more important, we mean that these relations are (a) more likely to be needed to successfully "understand" the situation, (b) more likely to be inferred when left unmentioned, and (c) most likely to be remembered later. Specifically, the new theory makes a distinction between functional and nonfunctional relations (Carlson-Radvansky & Radvansky, 1996; Garrod & Sanford, 1989). Functional relations describe the interaction of two or more entities within a situation. As such, these are the more important type of relations in a situation model. Nonfunctional relations describe the interrelations among entities but do not provide information about how the entities interact in the situation.

Finally, situational content includes information such as entities (protagonists and objects) and their properties (e.g., physical and mental attributes). Entities correspond to the people, animals, objects, and ideas that stand in relation to one another in a situation. These entities are represented by tokens in a situation model. Associated with each of these tokens are the properties of that entity. Typically, these properties are most relevant for understanding the situation. Properties can include such things as the entity's physical appearance or state, the intentions or goals of the entity, and the emotions of the entity.

Like relations, entities and properties are included in a situation model only when they are central to a person's understanding of the situation. However, the entity central to the situation model, the protagonist, is an obligatory part of the representation. Furthermore, any properties of the entity that either produce functional interrelations with other entities or are needed to explain existing functional relations are represented directly with the token in the situation model.

To avoid having the situation model become overly complex, a token often contains a pointer that refers to more generalized information about an entity that can be used when necessary but is not currently needed in the situation model. It is in this generalized representation that more stable characteristics are stored. For example, if a reader is told that "Bill is very tall" and if this information is not relevant to a person's understanding of the subsequent situations Bill is involved in, this information is relegated to a generalized representation of Bill and is not included in the subsequent situation models. However, if the reader encounters information that makes this information important again, such as "Bill could see over everyone's head," it could be retrieved from the generalized representation and stored directly with the token in the model.

Various connectionist type models of language comprehension have been proposed, most notably Kintsch's (1988) construction–integration model and Just and Carpenter's (1992) capacity constrained READER model. Other examples are the landscape model (van den Broek, Risden, Fletcher, & Thurlow, 1996) and the capacity-constrained construction–integration model of Goldman, Varma, and Coté (1996). These models allow the researcher to model some specific aspects of situation models as well as other aspects of language comprehension. For example, the construction–integration model allows the researcher to manipulate the strength of the links between nodes in the situation model and those between different levels of representation (surface structure, text base, and situation model). We agree with Goldman et al. (1996) that "several capabilities must be added to 'smarten up' the current class" (p. 100) of models. One of their proposed additions is a situation model construction module. We would argue that such a module would have to have the capability to (a) represent connections among situational nodes on different dimensions, such as time, space, causation, intentionality, and agency; and (b) capture the construction, foregrounding, updating, integration, and retrieval of situational information in the current model, the integrated model, and the complete model. These are interesting and important challenges for future research.

Conclusion

The objectives of this article were to (a) provide an integrative overview of the extant research on situation models in text comprehension and memory retrieval and (b) propose some ideas for future research. The rationale for these objectives was our observation that situation models are a critical conceptual tool in explaining and predicting human language comprehension and memory performance but that an integrative overview of situation models was lacking.

The success of the situation model view has already directly lead to some important discoveries and theoretical developments about language comprehension and memory retrieval. In the future, we think that this view can be extended to other areas of research that involve the understanding of situations, such as autobiographical memory. With continued effort in developing more elaborate and precise theories, such as the event-indexing model and its progeny, cognitive researchers can hope to gain a better understanding of how situation-specific knowledge is used in mental processing.

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Appendix A

The Grand Opening

Example story from "Processing Narrative Time Shifts" by R. A. Zwaan, 1996, *Journal of Experimental Psychology: Learning, Memory, and Cognition,* copyright 1996 by the American Psychological Association. Number in parentheses indicates sentence after which probe words were presented in Experiments 1 and 2a.

Today was the grand opening of Maurice's new art gallery.
He had invited everybody in town,
who was important in the arts.
Everyone who had been invited had said that they would come.
It seemed like the opening would be a big success.
At seven o'clock, the first guests arrived.
Maurice was in an excellent mood.
He was shaking hands and beaming.
A moment/an hour/a day later, he turned very pale. (1)
He had completely forgotten to invite the local art critic.
And sure enough, the opening was very negatively reviewed
in the weekend edition of the local newspaper.
Maurice decided to take some Advil and stay in bed the whole day.

Recognition Probe (Experiments 1 and 2a)
beaming
Primed Recognition Items (Experiment 3)
Prime: Maurice was shaking hands and beaming.
Target: He turned very pale.

Appendix B

Redecorating

Example story used by Zwaan et al. (1996). Numbers in parentheses indicate sentences after which probe words were presented in three different experiments.

Christine decided to redecorate her room.
Her parents had lent her some money to buy a new carpet and new couch.
Christine had bought a beautiful dark blue carpet and a white couch.
The final touch was to decorate the walls.
Christine had bought some posters of some Vincent van Gogh paintings.
First, Christine had to remove her old posters from the walls.
She took her shoes off and stood on a chair to remove the posters.
As Christine was removing the pushpins from the wall,
she dropped one on the floor/put them in a box. (1)
After she was finished, she rolled up her old posters.
She had promised to give them to her younger sister.
Christine was very happy with her new room
and walked around to see all the posters. (2)
Suddenly she screamed, holding her right foot and limping around. (3)

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