CHAPTER SEVEN

The retrieval of situation-specific information

Gabriel A. Radvansky & Rose T. Zacks

Imagine that you are reading a particularly engaging whodunnit where you are trying to solve the mystery before the author hands the solution to you at the end of the book. One of the basic elements of this task is to try to reconstruct the circumstances under which the murder took place. This may include the location of the important objects at the crime scene, the location of the other people at the time of the murder, the relation of the different characters to one another and the victim, and other pieces of information. To make the task more difficult, those aspects of the crime scene that you are allowed to learn about are revealed at different points in time and usually not in the order of their importance. To be successful, you must mentally retrieve and integrate this information to create a mental representation of the situation in which the murder took place. Furthermore, you must be able to successfully retrieve this representation when there are later references to the crime situation, including avoiding retrieving similar but different situations you have experienced or read about.

Mental representations of situations, such as a murder scene, are referred to as mental models or situation models (although they are typically discussed in reference to less dramatic circumstances). Although these two terms are used by different theorists in somewhat different ways, for the present we consider them to be synonymous and use only the term situation model. *Situation models* (Johnson-Laird 1983, 1989) are representations of specific situations, such as a situation described by a text[1] (e.g. Glenberg et al. 1987, Graesser et al. 1994). In general, the structure of a situation model is a functional analogue of a situation in a real or imaginary world. A situation model acts as a simulation of a unique set of circumstances in the world. In other words, a situation model is a second-order isomorph of the represented situation (Shepard & Chipman 1970), in much the same way that a wrist-watch is a functional representation of the daily rotation of the Earth. This chapter discusses issues and findings related to how memory retrieval is affected by the structure of situation models.

A substantial difficulty in dealing with the concept of situation models is that there is no single accepted view. As a step toward alleviating this confusion and as background for reviewing the literature in the area, we present here our own view of a situation model theory. Some of the ideas of this theory are shared with other researchers, whereas others are unique to our own perspective.

We will first outline some characteristics that compose our situation model view, along with some evidence to support these characteristics. These characteristics are divided into three classes: (a) descriptions of situation model structure; (b) descriptions of how situation models are constructed, and (c) descriptions of the processes involved in retrieving information from situation models. Following this exposition, we address some findings that relate to memory retrieval by considering how different aspects of situation models can influence retrieval. At the end of the chapter, we will discuss some aspects of our view that await further development, pending the outcomes of future research.

A SITUATION MODEL THEORY

The structure of situation models

This first section provides an outline of how we conceive of the structure of a situation model. Later we will show how our notions about situation model structure relates to our conception of how information is retrieved from these representations.

At the heart of the view presented here is the notion that situation models represent specific situations as they might occur in a real or possible world. That is, a situation model is not directly concerned with the representation and organization of general knowledge, such as categorical information. Instead, each model represents a unique situation or event. When aspects of a situation refer to general knowledge, the situation model may contain pointers to information stored in long-term memory. For example, a situation model of a potted palm in a hotel would contain pointers that refer to general information about potted palms and hotels, such as knowledge that potted foliage needs watering and that hotels can overcharge customers. This information would not be stored directly in the situation model.

Situation models contain tokens representing the entities in a situation. Associated with these tokens are the relevant properties of the entities, and the functional relations among those entities. All of this information is represented with a single spatial–temporal framework. In order to use the notion of situation-specificity effectively, we need to define what a situation is. We borrow from Barwise & Perry (1983, Barwise 1989) the idea that a situation is composed of a collection of entities. Each entity may have a set of properties associated with it. Furthermore, there is some specified relation of the entities to one another in the situation. Typically, these can be described as functional relations in the sense that they support a person's understanding of the situation in terms of how the entities interact with one another.

The *entities* of a situation can be any meaningful object, such as a person, inanimate object, or abstract idea (e.g. "George got the idea in the garage"). Each entity is represented by a token in the situation model. For abstract ideas, this tokenization would amount to a process of making the ideas concrete. The *properties* of an entity are its characteristics, such as its being blue, angry, heavy, the leader, or dead (Gernsbacher et al. 1992). The *relations* of a situation are the meaningful associations among objects that provide structure to the situation. These include, but are not limited to, spatial, temporal, or ownership relations. The *spatial temporal location* provides the framework for the situation. While some sort of spatial temporal location needs to be specified, a particular identity does not need to be assigned. In other words, it is not the case that each situation model has a tag that specifies a particular location and time, such as "in Grant Park at 12.30 pm on Thursday the 2nd". Instead, the model refers to a situation that would occur at a particular time in a particular place, although just where and when may be left unspecified.

Situation models may represent either novel or commonplace situations. Although a situation model is not a representation of general knowledge, if the situation is a common one, the model's construction may be heavily influenced by the structure of general knowledge representations, such as schemas (and their ilk, scripts (Schank & Abelson 1977) and frames (Minsky 1986)). In extreme cases, the situation model itself may be little more than an instantiated schema. Unlike a schema, however, a situation model can represent more novel sets of circumstances. For instance, our ability to understand a new narrative with little difficulty suggests that people form a representation of the situations described in the narrative rather than creating a representation based strictly on previous knowledge, as would be the case if only a schema were being instantiated.

In our view, situation models are *abstract* representations, meaning that a situation model need not rely on a perceptual code and need not be constrained by properties of perceptual codes. In support of this view is evidence that situation models are able to convey aspects of a situation, such as ownership (Radvansky et al., in press) or logical relations (Johnson-Laird 1992) that are not concrete or perceptual in nature. In contrast to a perceptual code, such as a visual mental image of a scene, a situation model of a scene would capture the relevant functional relations among the objects in the scene without being limited to a particular perspective or viewpoint. Another way to state this is that situation models represent the gist of a situation. Because a situation model is abstract, it can map onto a number of different possible actual situations. For example, a situation model for "the pay phone is in the city hall" may be able to map onto any number of city halls with any type of pay phone (connected or not), placed anywhere in the building.

It should be noted, however, that the availability of information from within a situation model may be mediated by the perspective of an observer from within that situation (Franklin & Tversky 1990). However, this only occurs when the person uses their imagination to place themselves within the situation as an observer or participant. In these cases, the relations among the entities in the situation (such as the entities a person is interacting with) guide the structure of the situation model. (A more detailed comparison of situation models and mental images will be presented later in the chapter.)

A situation model is also an *analogue* representation in the sense that its structure directly models the structure of the situation that it represents. This is in contrast to other types of memory representations, such as propositional or text-based codes, where the information is coded in a verbal-linguistic format. In this sense, situation models are more similar to mental images. For example, in a situation model of the spatial arrangement of objects, objects that are close in space are coded close to one another in the model (e.g. Glenberg et al. 1987). We would also like to make clear that, by claiming that a situation model directly models the situation it represents, we do not intend that the representation itself is a veridical copy of the situation in the world. Instead, it is a representation of the situation as it is comprehended by the individual. For example, a spatial situation model is not a direct copy of the actual Euclidean space. Instead, the situation model structure may be a mixture of a hierarchical and Euclidean structure in much the same way that people perceive spaces in the world (e.g. McNamara 1989).

Situation models can represent either dynamic or static situations. Following Barwise & Perry (1983), we make a distinction between at least two different types of situations: states-of-affairs and courses-of-events. A state-of-affairs is a static situation in which the major components of the situation do not change. It involves the same collection of entities, in the same relations to one another within a common, continuous spatial–temporal location. A course-of-events, in contrast, is a dynamic situation composed of a series of related event frames that are linked through some common entity or thematic relation.

To make this distinction clearer, consider the following. A mail carrier making a phone call is a state-of-affairs situation. There is only a single spatial–temporal location involved. The entities, their properties, and their interrelations remain the same throughout the situation. In contrast, the situation of the mail carrier delivering the mail on her route is a course-of-events situation. Unlike the other situation type, there are several spatial–temporal locations involved, with different entities at each (e.g. different houses, streets, and obstacles such as dogs). The mail carrier and her constant purpose across the locations serve to unify those separate scenes into a single situation. Static and dynamic situation models have been observed to have different effects on mental processing (e.g. Radvansky et al. 1993).

We consider situation models that involve some sort of causal goal structure, such as those that are constructed from reading a narrative (e.g. Graesser et al. 1994), to be course-of-event types of situations. This is because a causal structure is generated over a series of different time frames, and possibly different locations. In these cases, a causal structure can serve to unite the collection of event frames into a single situation model.

The creation of situation models

This section outlines those aspects of our view which relate to the initial creation and updating of situation models in memory. These notions are constrained to circumstances where a person is representing new information.

The notion of situation specificity that guides our model implies certain constraints on the information integrated into a single situation model. In particular, a model contains only information that can be interpreted as referring to a single situation in the world. For example, if you were told that "Jim bought some hot dogs from a vendor" and "Tom read about Randy in the programme", it is unlikely that these two pieces of information would be stored into a single situation model. Instead, the information would be stored in separate models. In contrast, several pieces of situation-specific information that refer to the same situation will be integrated into a common situation model. For example, if you knew that Jim and Tom went to a ball game together, you could integrate the two pieces of information mentioned above into a single model. Information will continue to be integrated into a previously existing situation model until it becomes clear that a new situation is present (e.g. Anderson et al. 1983).

Once a situation model has been created, it can be updated to include new information that is relevant to the situation. This updating includes the addition of new information not previously available, the removal of erroneous information, and the adjustment of components of the model for a more accurate understanding of the situation.

Another important point is that situation models are not created automatically, as some researchers have argued (McKoon & Ratcliff 1992). Instead, people create a situation model only when they have the goal of understanding a situation that is being presented to them (Graesser et al. 1994, Zwaan 1994). For example, in a study by Zwaan, subjects created a situation model of a text that they were reading only when it was described as an account from a newspaper (encouraging the development of a situation model) rather than when it was described as a literary text (where the emphasis is more on the language used than on the described situation). If a person does not have the goal of understanding a situation as a whole (such as when editing a manuscript for typos), they may store the information in a different form, such as a propositional code. Much of the research supporting this idea comes from the area of discourse comprehension.

Consistently with other situation model researchers, we think that when people encode situation-specific knowledge, the situation model is not the only representation that can be created. In addition to the situation model, people may also create propositional and mental image codes (e.g. Johnson-Laird 1983). Propositional codes capture verbal-linguistic aspects of a situation, such as the characteristics of language that was originally used to describe a situation or the verbal labels associated with the components of a situation. Mental images can be thought of as individual perspectives on a situation model. When a person takes the perspective of an observer within a situation, a mental image may be created. For example, a situation model of a house could be viewed from many different angles, thus producing many different mental images. This does not mean that the mental image will be the representational code used to extract information from that perspective. The situation model may still be used. We will discuss the relevance and influence of other representational codes later in the chapter.

A common assumption of theorists concerned with situation models is that they are created in working memory. We make the additional

assumption (which some dispute, e.g. Glenberg & Langston 1992, Payne 1993) that situation models can also be stored in long-term memory. In long-term memory, each situation model is stored as a separate memory trace. Although two or more situation models cannot be part of the same memory trace, connections between situation models, including hierarchical nesting, can be encoded through the use of pointers. With respect to hierarchical nesting, for example, a situation model of a house may contain a pointer referring to a situation model of the dining room. In this way a person can represent subcomponents of a situation without creating an overly complex situation model.

Memory retrieval

The previous sections outlined characteristics of situation models that were important for providing an understanding of what situation models are, and how and when these representations are initially created. In this section, we consider those points that are more important for this chapter, namely, those factors that influence the retrieval of information stored in situation models.

First, only one situation model can be active in working memory at one time. There is a limit on a person's working memory capacity. She is able to directly consider only one situation at a time. Any mental processing that requires the consideration of more than one model will be made more difficult by this constraint. This limitation is observed most prominently in research on logical reasoning (e.g. Johnson-Laird 1992). However, this does not mean that a person cannot keep track of multiple situations. In order to do this, she must keep pointers active in working memory that allow her to call up a particular situation model from long-term memory when she needs it. Nonetheless, it is important to keep in mind the point that the retrieval process is limited to bringing only a single situation model into working memory from long-term memory at one time.

Information pertaining to the entities, properties, relations, and locations that compose a situation is potentially available when the relevant situation model is active in working memory. The ease of accessing these different types of information is dependent on the organizational structure of the situation model itself. For example, in a spatial situation model, those aspects of the spatial framework that have been made more salient by a person's interactions with the situation will be more accessible (Franklin & Tversky 1990).

In addition to the actual structure of the situation model, the availability of information can also be mediated, being dependent on which portion of the model is currently foregrounded or at the focus of attention (e.g. Glenberg et al. 1987). Information is more accessible from foregrounded portions of a model than other portions of the structure. For example, when describing the layout of a room, if the current focus is on the bookcases, information stored at that portion of the situation model will be more accessible than other portions, such as information concerning the windows at the opposite end of the room.

People retrieve information from situation models only when motivated to do so. This idea is similar to the idea that situation models are only created when a person is motivated to do so. Likewise, people retrieve information from a situation model that they have stored only when the circumstances favours the use of these representations. This may occur when the encoding context involved an emphasis on the creation of situation models, and this emphasis is carried over to or reintroduced at the retrieval stage. It is possible for a person to create a situation model and store it in long-term memory, and then use an alternative representation code during later retrieval. For example, people may disregard a situation model when they suspect it may be faulty (Hasher & Griffin 1978).

Situation models are accessed from memory through a parallel, content-addressable search. During a search, the memory probe activates all of the situation models stored in long-term memory that contain features (i.e. entities, properties, relations, and/or locations) that are contained in the retrieval probe. The more features a probe and a model have in common, the greater the activation of that model. This is similar to several feature-matching models of memory retrieval (e.g. Hintzman 1986). In this way, a person can access the appropriate memory for a situation by knowing who or what was involved (e.g. the situation about the banker), what properties these entities had (e.g. it involved something that was green), what relations were involved (e.g. it was the situation where someone bought something), and/or where or when it occurred (e.g. in the hotel).

Following the parallel access of all of the situation models that contain features present in the retrieval probe, a single model is selected to be retrieved into working memory. The model that is first fully activated is the one that can be clearly discriminated from the others by the strength of its level of activation. We do not have the final word on how this selection of one situation model from among those that receive some activation takes place, but some speculations are presented later.

Although situation models are activated in parallel in long-term memory, and this activation is mediated by the feature resemblance of the probe to the model, the internal structure of the model is not available until it is brought into working memory. In other words, the retrieval process is able to access those models that contain certain

elements, but it is unable to determine how these elements are connected to one another. For example, a person may know that a situation model may contain a banker, a lawyer, a chair, a pen, and an ownership relation, but will not be able to know that it is the lawyer that owns the chair until a search of the situation model is made in working memory. This notion is supported by research showing that item information is available before relational information (Ratcliff & McKoon 1989).

Having provided an outline of our situation model view, we would now like to turn to the research that is relevant to it. In the next part of the chapter we hope to show how the retrieval of situation-specific information is influenced by: (a) the organizational structure of situation models; (b) foregrounding; (c) memory for the gist of a description, and (d) whether information is stored in a single model or is stored across multiple models.

EFFECTS OF SITUATION MODEL STRUCTURE ON RETRIEVAL

In this section we address how the structure of a situation model influences the retrieval of information. As stated above, our position claims that people do not have the ability to evaluate the internal structure of a situation model while it is in long-term memory. Therefore, any influence of the internal structure of a situation model should be observed only when the model is currently active in working memory. In most cases, this has been studied under conditions where a subject is initially creating and updating the situation model. For example, memory for information may be probed when the subject is currently reading a passage of text.

Model structure

A situation model should have a structure that is analogous to the situation in a real or imaginary world that it represents. This structure should influence the availability of stored information. One of the more common ways to test these claims has been to assess the retrieval of spatial information. This is because there seems to be general agreement about important dimensions of spatial representations. That is, it is expected that a spatial representation would encode relations such as above, below, near, far, etc. If spatial information is needed to understand a situation, then the situation model would contain those spatial relations as part of its structure. Therefore, during the retrieval of information from a situation model, evidence of this spatial structure should be observed in the data.

Spatial reference frames

When a person takes the perspective of a viewer within a situation, the availability of information is mediated by a spatial framework oriented around that observer. This spatial framework is defined by an interaction of the observer and the environment (Bryant et al. 1992, Carlson-Radvansky & Radvansky 1996, Franklin & Tversky 1990). For example, for an upright observer, the above–below dimension is the most salient, followed by the front–back, and left–right dimensions. This arrangement of information availability is presumably dictated by the functional relation of the observer with the world around her. The above–below dimension is the most prominent because of the ever-present effects of gravity. The front–back dimension is also prominent, particularly because humans preferentially interact with the world through what is in front of them.

These notions about effects of spatial frameworks on information ability were tested by Franklin & Tversky (1990). In their study, subjects read a passage that described a spatial environment. During their reading, subjects were encouraged to imagine themselves within that space. The passage provided a general description of the environment as well as the location of various objects within that space in relation to the person. An example of one such passage is provided in Box 7.1.

During the reading of the passage, subjects were interrupted with probes that asked them to identify objects located at various directions from themselves. For example, a subject would be given the probe RIGHT, and have to say which object was in that direction. Response times for these retrievals were recorded. As can be seen in Figure 7.1, the results were consistent with the hypothesis that the internal structure of a situation model reflects the functional relations among objects, in this case a spatial framework. Subjects responded fastest to items located along the above–below dimension, more slowly to items located along the ahead–behind dimension, and slowest to items located along the right–left dimension. This pattern parallels data on the availability of information when subjects are presented with location tasks for perceptually available stimuli (e.g. Bryant et al. 1993, Logan 1995).

BOX 7.1 Example passage used by Franklin & Tversky (1990).

You are hob-nobbing at the opera. You came tonight to meet and chat with interesting members of the upper class. At the moment, you are standing next to the railing of a wide, elegant balcony overlooking the first floor. Directly behind you, at your eye level, is an ornate lamp attached to the balcony wall. The base of the lamp, which is attached to the wall, is gilded in gold. 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 theatre. A simple likeness of the architect, as well as a few sentences about him, are raised slightly against the bronze background. Sitting on a shelf directly to your right is a beautiful bouquet of flowers. You see that the arrangement is largely composed of red roses and white carnations. Looking up, you see that a large loudspeaker is mounted on the theatre's ceiling about 20 feet directly above you. From its orientation, you suppose that it is a private speaker for the patrons who sit in this balcony. Leaning over the balcony's railing and looking down, you see that a marble sculpture stands on the first floor directly below you. As you peer down toward it, you see that it is a young man and wonder if it is a reproduction of Michelangelo's David.

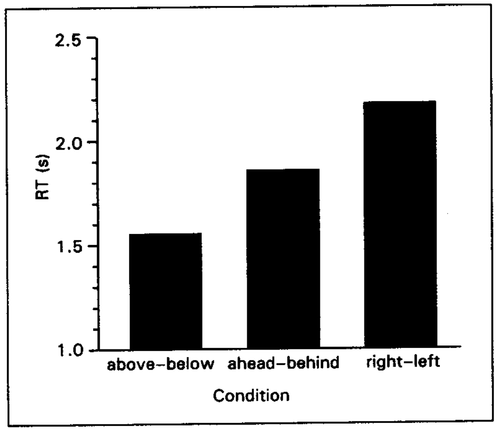


FIG. 7.1. Response Time (RT) for verifying that a target object is in a specified direction from an upright observer in a situation model. Derived from data presented in Franklin & Tversky (1990).

Furthermore, the spatial framework changes as the orientation of the viewer changes. In a second experiment, Franklin & Tversky (1990) had subjects imagine that they were reclined in the situation. Under such conditions, the relative accessibility of object identities changed. As can be seen in Figure 7.2, the objects located along the front–back dimension were as accessible as objects along the head–feet dimension, with objects along the right–left dimension being the least accessible. This change in availability is consistent with the notion that the functional relation of the observer within the described situation affects the relative salience of objects within the situation model.

Spatial frameworks are not limited to being defined by the environment or an observer's orientation. There is some evidence that the functional relation between 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 itself may be. This evidence would seem to indicate that it is the functional relations among entities that people are encoding into their representations of a situation.

Overall these findings support the notion that situation models reflect the functional relations among entities that interact in an

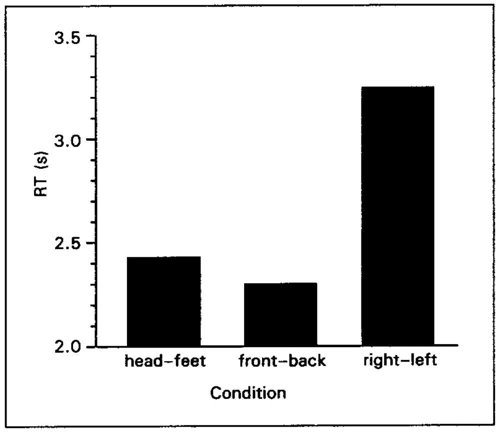


FIG. 7.2. Response Time (RT) for verifying that a target object is in a specified direction from a reclining observer in a situation model. Derived from data presented in Franklin & Tversky (1990).

environment. Furthermore, these functional relations mediate the availability of information from within the situation model.

Foregrounding

As stated earlier, foregrounded parts of situation models held in working memory show increased availability. One factor determining foregrounding is a strong association with a story protagonist. One means of manipulating whether entities are associated with a protagonist is by varying the relative spatial distance between the two. If the target entity is a lamp, 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 lamp than if she is in the garage. Simply put, if the situation model successfully models the functional relations of entities in the world, then items that are further away from the current focus should be less available than near items.

Such an effect was demonstrated by Glenberg et al. (1987; see also Singer et al. 1994). In the study of Glenberg et al. people read passages in which a critical object was embedded. The story presented in Box 7.2 is an example of one such passage. Subjects were asked to visualize the described scenes while reading, to encourage the creation of a situation model. In half the passages, the critical object was spatially associated with the protagonist ("Warren picked up his bag before going shopping"), whereas in the other half, the critical object was spatially dissociated from the protagonist ("Warren put down his bag before going shopping"). At a later point during the passage, a sentence appeared that anaphorically referred back to the critical object (the bag). Reading times for that sentence were recorded.

BOX 7.2. Example text from a study by Glenberg et al. (1987).

Warren spent the afternoon shopping at the store.
He picked up/set down his *bag* and went over to look at some scarves.
He had been shopping all day.
He thought it was getting too heavy to carry.

As can be seen in Figure 7.3, Glenberg et al. (1987) 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 suggests that situation models embody functional relations of the situation, in this case, spatial distance, and that this factor determines item accessibility. (For a related account, see Anderson et al. 1983, Garrod & Sanford 1983.)

This notion of spatial foregrounding was extended in an interesting set of experiments by Morrow et al. (1987, 1989). There were two ideas behind these studies. The first was that not only should items spatially close to a protagonist be more available than spatially far items, but that the absolute distance between the protagonist and the item should mediate the degree to which items were available. The second idea was that as the foreground of a situation model shifts, there should be residual activation in those portions of the model that had been just previously activated, as well as, those portions that the person was

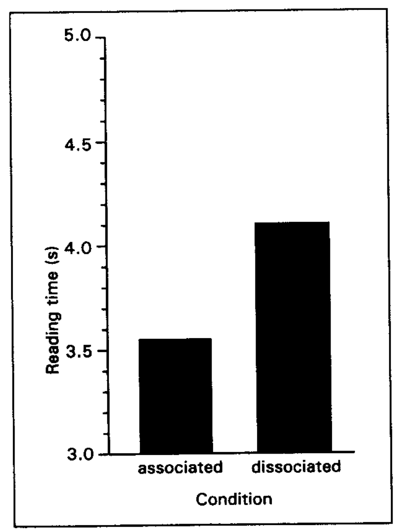


FIG. 7.3. Reading time for sentences containing a reference to an object mentioned earlier. Associated objects were spatially associated with a story protagonist and were therefore in the foreground of the situation model. In contrast, dissociated objects were spatially dissociated from the protagonist and therefore not in the foreground of the situation model. Derived from data presented in Glenberg et al. (1987).

required to pass through on their way in from one location to the next. As a result, information from these parts of a situation model should be more accessible than parts that had not recently been foregrounded, although to a lesser degree than those parts that were currently in the foreground.

In the experiments of Morrow et al. (1987, 1989), subjects memorized a layout of a building, such as a laboratory or a warehouse, along with the locations of several objects within that building. An example of one such building layout is presented in Figure 7.4. This memorization served to allow subjects to create a relatively complex spatial model of the environment that they could use for reference when later reading stories about events that took place in that location. Afterward, subjects read a narrative in which the protagonist moved about from room to room within the building. During the course of reading the narrative, subjects were probed with pairs of object names (including the name of the protagonist, such as: desk–Bill). The subjects' task was to indicate whether the objects were in the same room in the building.

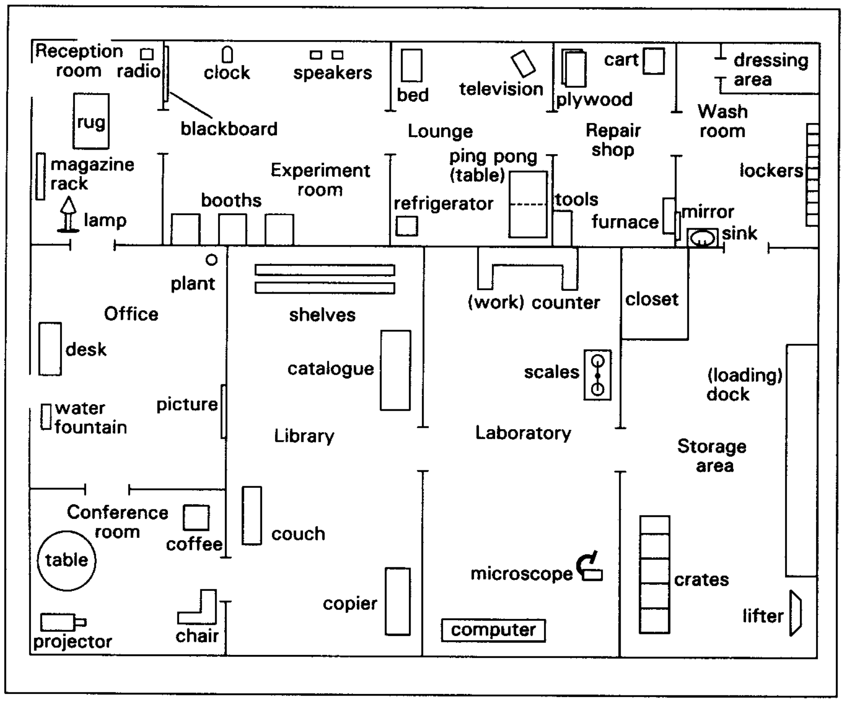


FIG. 7.4. Sample layout of a research centre originally presented in Morrow et al. (1989). Copyright © 1987 by Academic Press, Inc. Reprinted with permission.

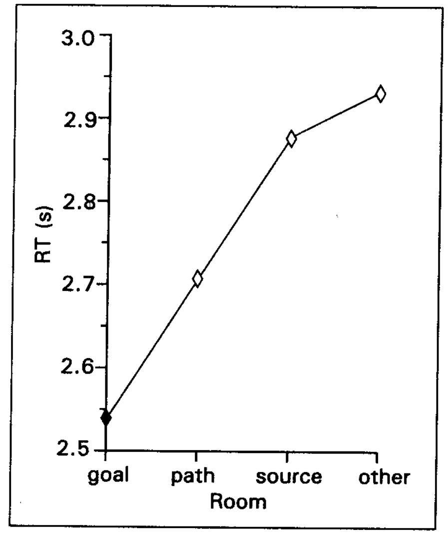


FIG. 7.5. RT for verifying that target object pairs are in the same room, relative to the room where the protagonist is. Derived from data presented in Morrow et al. (1989).

The result of one experiment is shown in Figure 7.5. The protagonist had started from the source room, passed through the "path" room and arrived in the "goal" room. "Other" refers to some other room in the building. Probe identification was fastest when the objects were in the same room as the story protagonist. Thus, information in the foreground of the model along with the protagonist was more available than other pieces of information. Responses were slower when the room the objects were located in was either the one the protagonist had started from or an unmentioned room along the protagonist's path of travel. Response time was mediated by the distance between the protagonist and the room the objects were in. (See O'Brien & Albrecht 1992, and Wilson et al. 1993 on the importance of having a focus on the protagonist.) 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.

Finally, we would like to mention one further study by Morrow and colleagues that demonstrated that this pattern of results is not exclusively tied to a story protagonist's spatial location. In one experiment, observations were based on the room the protagonist was thinking about, rather than the room the protagonist was in. For example, in one passage, while the protagonist was said to be located 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." Subjects responded to objects in the room that was being thought about 180 ms faster than to objects in other rooms. Therefore, it appears that the foreground of a situation model is capable of shifting to portions of the model other than the protagonist's spatial location.

Summary

The results of these studies show that the retrieval of situation-specific information from a situation model during on-line processing is guided by the structure of the model and by the current focus within that situation model. The structure of the situation model is analogous to the structure of a situation in the world that it represents. In other words, the availability of information about different parts of a situation is mediated by functional relations of a situation, such as spatial characteristics, and by whether entities and relations are foregrounded in the model.

MEMORY RETRIEVAL FROM FIXED SITUATION MODEL STRUCTURES

In addition to influencing information retrieval from working memory, the organization of information into situation models can also affect the retrieval of information from long-term memory. This is an important issue to consider because we often need to draw on information about situations other than the one that currently has our attention. Studies of this aspect of situation models have explored the extent to which the representation captures either gist or verbatim information, as well as how the storage of information in either one or several situation models affects the ease with which that information can be retrieved.

Gist representation

A central characteristic of situation models is that they represent the situation described by a text rather than the text itself or the propositions composing that text (Johnson-Laird 1983, Kintsch 1994, Glenberg et al. 1987). As such, information retrieval from situation models stored in long-term memory should reflect this gist-like nature. One prediction is that recognition test confusion errors (false alarms) should occur for statements that potentially describe the same situation, but are propositionally distinct.

In a classic demonstration of this effect, Bransford et al. (1972) had people listen to one member of a list of pairs of sentences. For example, they heard either the sentence "Three turtles rested *on* a log and a fish swam beneath them" or "Three turtles rested *beside* a log and a fish swam beneath them". On a subsequent recognition test, people were given the original sentence and a distractor sentence. For the distractor sentence, the last word was changed from "them" to "it". People who had originally heard the first sentence were less accurate than people who had heard the second. This suggests that a representation that conveys the gist of a described situation is relied on to make these decisions: a situation model (see also Garnham 1982, and Radvansky et al. 1990).

This notion has been expanded by Taylor & Tversky (1992) from single-sentence stimuli, open to a large number of interpretations because of a lack of context, to lengthy descriptions of a spatial layout. According to our view, the structure of a spatial situation model should correspond to the structure of an actual spatial framework such that all of the relevant spatial characteristics of the situation are represented in the model. Provided that the person is not trying to take the perspective of an observer within the situation, this situation model should be perspective-free. As a result, retrieval time should be unaffected by the original perspective embedded in the narrative. That is, attempts to retrieve information from the model will be dependent on the spatial relations among the entities in that situation, and not on the position of some hypothetical or ideal observer.

In a series of experiments, Taylor & Tversky (1992) asked subjects to read descriptions of environments, such as a resort or a zoo. An example of the zoo layout can be seen in Figure 7.6. Subjects were instructed to memorize these layouts from a description given in a text and without the benefit of a map (i.e. they never saw the layout in Figure 7.6). Half of the subjects were given *route descriptions* that gave the reader a perspective of the environment of a person walking through the area. To emphasize this perspective, the spatial descriptions used viewer-relative spatial terms such as "to the right" or "in front of". The other half of the subjects were given *survey descriptions* that gave an overview perspective of the environment, as though one were viewing a map of the area. To encourage subjects to adopt this perspective during encoding, the survey descriptions used spatial terms such as "to the south", or "in the centre".

Immediately after reading the descriptions, subjects were given a recognition test for phrases used in the description. The results are presented in Figure 7.7. As can be seen, verbatim statements were verified faster when they conformed to the original perspective. This was explained as the use of a propositional representation (discussed in more detail below) that more accurately preserved the original wording than the situation model. The important result is the performance on the inference statements. In particular, subjects were as fast and as

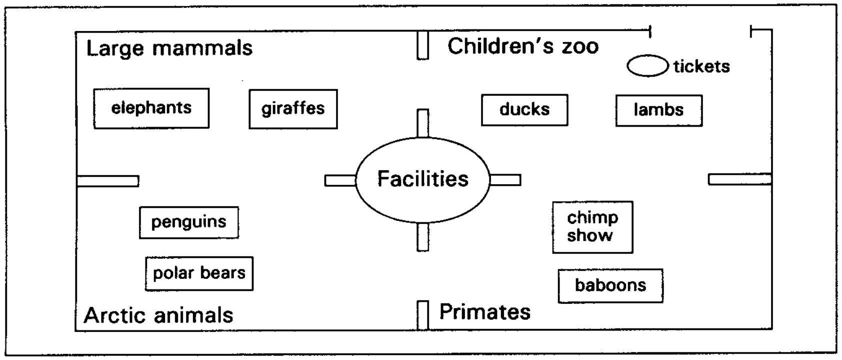


FIG. 7.6. Sample layout of a zoo. Originally presented in Taylor & Tversky (1992). Copyright © 1992 by Academic Press, Inc. Reprinted with permission.

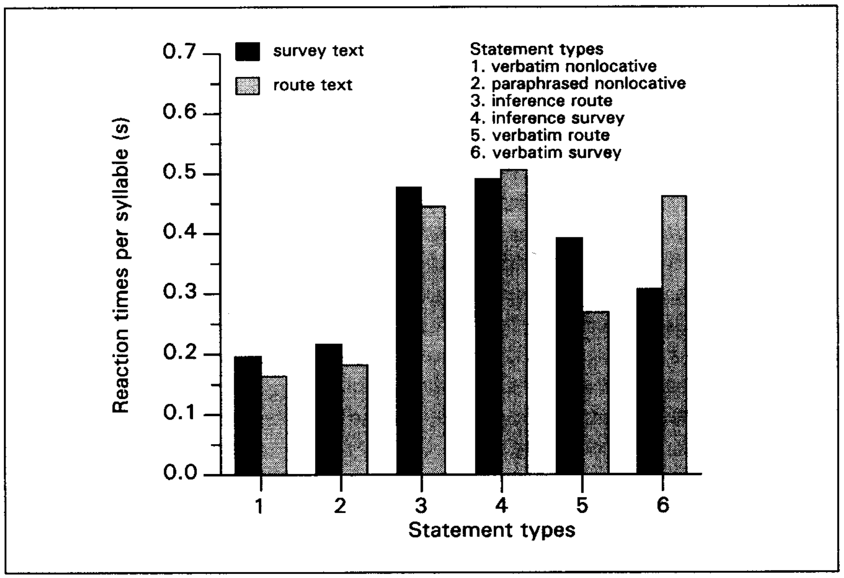


FIG. 7.7. Reaction times per syllable to memory probes, for description types and test statement types. Originally presented in Taylor & Tversky (1992). Copyright © 1992 by Academic Press, Inc. Reprinted with permission.

accurate for inference statements conforming to either perspective regardless of the form of the original text. Taylor & Tversky (1992) concluded that spatial situation models were being used that captured the major spatial characteristics of the described environments but were perspective free.

Information integration

A single situation model is capable of representing several pieces of information that pertain to a single situation. However, in order for information to be integrated into a situation model, relevant task goals must be present, and it must be clear that all of the pieces refer to the same situation. Integration does not occur when it is unclear that several facts refer to the same situation. Under such circumstances, subjects rely on separate representations. This characteristic of the creation of situation models should have an effect on the retrieval of information from long-term memory. In particular, memory performance should be better when the information can be easily integrated into one situation model than when it cannot, resulting in the information being stored across a number of representations.

A demonstration of this effect was provided by Mani & Johnson-Laird (1982). Subjects were presented with descriptions of four or five objects with the task of remembering these descriptions. These descriptions referred to the placement of objects with respect to one another in a two-dimensional plane. The objects formed arrangements such as the following:

A	B	C
D		

A description that indicated a coherent and unique arrangement of the objects allowed for the creation of a single situation model. For example, the following three sentences uniquely describe 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. In other words, this description refers to one and only one possible situation in the world, namely the one depicted in the diagram.

However, descriptions that do not refer to a unique set of circumstances, but are consistent with a number of situations do not result in the creation of a single situation model. The following three sentences are an example of such a description for the arrangement above: (a) A is behind D, (b) A is to the left of B, and (c) C is to the right of A. Like the previous example, this description can refer to the arrangement of objects in the diagram. However, unlike the first example, this description can also refer to other possible arrangements. As such, it is unlikely that people will notice that all these statements refer to the same situation.

Descriptions that conformed to a single situation showed more evidence of gist memory on a subsequent recognition test than descriptions that could refer to multiple situations. That is, for descriptions like the first example above, subjects were more likely to accept inference statements as having been presented than was the case for descriptions such as the second example. This suggests that the integration of situation-specific information occurs only when a set of facts clearly refers to a single situation, not when it refers to several different situations. Furthermore, the success or failure in integrating a set of information into a single situation model has an effect on the nature of the representation used during long-term memory retrieval. Knowledge that can be integrated is more amenable for the recognition of any consistent description, whereas knowledge that cannot be integrated is more "frozen" in the sense that accurate recognition occurs only for more verbatim items.

Retrieval set size

When we speak of retrieval set size, we are referring to the number of situation models involved in the retrieval set. Memory retrieval is affected by the number of situation models composing a search set. In particular, retrieval is influenced by whether a set of facts, that are related by virtue of overlapping concepts, refers to a single situation, and thus a single model, or to multiple situations, and thus several models. In a series of experiments, we (Radvansky & Zacks 1991, Radvansky 1992, Radvansky et al. 1993, 1996 in press) have used a fan-effect paradigm to assess such an impact of situation models on memory retrieval. A *fan effect* is an increase in retrieval time with an increase in the number of associations with a concept in a memory probe (Anderson 1974).

The general idea is that a fan effect emerges in cases where a set of related facts refers to several situations, and therefore these facts are stored across several situation models in long-term memory. During memory retrieval, all of those models containing the concepts expressed in the memory probe are activated. Provided the subject is engaging in more than just a familiarity test, one model must be selected to be brought into working memory to have its contents verified. The activation of multiple situation models produces competition and retrieval interference, leading to a fan effect. The greater the number of irrelevant situation models that contain concepts present in the memory probe, the longer the response time. In contrast, a fan effect does not emerge when a set of related facts refers to a single situation, and is therefore stored in a single situation model. During memory retrieval, there are no additional competing representations to produce interference. As a consequence, response time is unchanged and no fan effect is observed. (This argument assumes that the models themselves are relatively simple; otherwise the complexity of the structure of the model will also have an impact on response time.)

In the most basic experiment, subjects memorized a list of 18

sentences about objects in locations, such as "The potted palm is in the hotel". These sentences were studied one at a time and in a random order, so that any organization was imposed by the subject. Across the entire list, each object and location had 1 to 3 associations. An illustration of the object and location concepts, along with the associations used to generate the study sentences is presented in Figure 7.8. These sentences can be classified into three types. Those sentences in which an object is in several locations, but each location has only a single object are in the *multiple-location* condition. Those sentences in which an object is in only one location and the location contains many objects represent the *single-location* condition. The rest of the sentences with several associations for both the object and location concepts provide the appropriate number of associations in the single- and multiple-location conditions and otherwise serve as *fillers*.

Let us consider the multiple-location and single-location conditions in more detail. In the multiple-location condition, a single object is described as being in several locations. For example, a "potted palm" may be in a "hotel", a "cocktail lounge", and a "high school". In the real world, it is unlikely that such an object will travel from place to place as part of a single situation. As a result, a separate situation model is created for each of those situations corresponding to the different locations of the object. During retrieval, when the subject is required to verify a multiple-location fact, not only is the appropriate situation model activated, but so are the other situation models that also contain

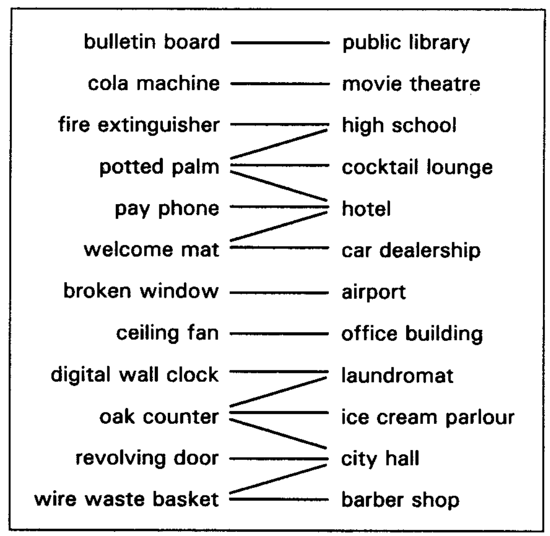


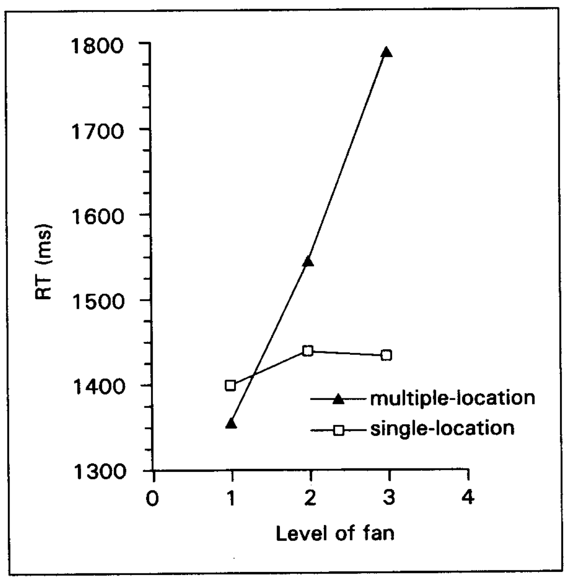
FIG. 7.8. Structure of the study list associations for objects and locations in situation model fan-effect experiments.

the concepts in the memory probe. For example, in verifying the fact "The potted palm is in the hotel", not only is the hotel model activated, but so are the cocktail lounge and high school models, although to a lesser degree. These associated but irrelevant situation models interfere with a subject's ability to retrieve the desired representation. As a result, there is an increase in retrieval time accompanying an increase in the number of these distracting models, hence a fan effect.

Now consider the single-location condition in which several objects are in a single location. For example, in the "city hall" there may be an "oak counter", a "revolving door", and a "waste basket". Unlike the multiple-location condition, these facts are all consistent with a single situation in the real world, and only a single situation model needs to be created. During retrieval, only one model is activated; there are no related distractor models. As a result, response time is relatively constant with an increase in the number of objects associated with the location. The pattern of data for multiple- and single-location conditions is illustrated in Figure 7.9.

This pattern of retrieval times holds across a variety of circumstances. It does not change when the nature of the articles used is manipulated, making them either definite (i.e. "the") or indefinite (i.e. "a" or "an") (Radvansky et al. 1993), or with the order of the concepts in the sentences (Radvansky & Zacks 1991, Radvansky et al. 1993, 1996). It is also unaffected by instructions to overtly try to organize a set of

FIG. 7.9. Typical pattern of response times for single- and multiple-location conditions. Data taken from a study originally reported in Radvansky et al. (1993).



facts based on one method or another (Radvansky & Zacks 1991), by the transportability of the described objects (Radvansky et al. 1993), and by whether the subjects are college students or elderly people (Radvansky et al. 1996).

It is important to note that in this series of experiments, subjects are not presented with a structure at encoding, such as a narrative. Instead, organization into situation models is imposed by the subjects themselves. In other words, even in the absence of cues to organization and structure, subjects actively evaluate what situations are described by the facts they are memorizing, and they organize the information around those situations.

One question about these studies relates to the fact that other research has found that the structure of the situation model, while it is in working memory, affects the availability of information from that representation (e.g. Morrow et al. 1987, 1989). Intuitively, one would expect that as the situation model itself becomes more complex (i.e. as more objects are included in a single location), it should be more difficult to access any one part of the model and this should influence retrieval times. Yet, in the Radvansky et al. experiments, there was no effect of the number of objects (fan level) in the single-location condition. We believe this apparent difference from the studies described earlier relates to differences in the complexity of materials used. Typically, in the working memory retrieval studies a described situation is very complex. In contrast, in our long-term memory retrieval studies, the situation models are much simpler. Some evidence that we have gathered (Radvansky & Shoben 1994) also suggests that with more complex information, for single-location conditions, response time may increase with model complexity (i.e. a fan effect emerges). However, this increase in retrieval time does not approach the size of the effect observed when information is stored across several situation models.

Nonspatial situation models

In many of the studies that have been described in this paper, the situation models have been either explicitly or tacitly based on some sort of spatial representation. Consequently, some readers may infer that situation models are almost exclusively location-based or that perhaps they are little more than souped-up mental images. If this were true, then the study of how situation models affect memory retrieval would be better framed as a consideration of how spatial memory representations affect memory retrieval discarding, all of the baggage about situations. However, there are two other types of situation models that have been evaluated using our procedure, both of which focuses on person-based situations, not location-based situations.

Small locations

In one study (Radvansky et al. 1993), subjects memorized lists of facts about people in locations, such as "The banker is in the phone booth". The person concepts were referred to by their occupational title, such as banker, lawyer, or farmer. Unlike the large locations used in the experiment described above, the locations 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, subjects create situation models that are person-based[2]. Therefore, facts about a person going from place to place are integrated into a single model, whereas facts about several people occupying a small location are stored across separate models. On a recognition test, a fan effect is observed for multiple-person–single-location conditions, but not for single-person–multiple-location conditions. This pattern exemplifies the distinction between situation models of states-of-affairs and courses-of-events (Barwise & Perry 1983). Sets of facts, such as "The oak counter is in the city hall", "The revolving door is in the city hall", and "The waste basket is in the city hall" are more consistent with state-of-affairs situations, whereas sets of facts such as "The banker is in the phone booth", "The banker is on the witness stand", and "The banker is in the Greyhound bus's bathroom" are more consistent with course-of-events situations.

Ownership

A course-of-events is not the only type of situation that would lead to a person-based organization. In another study (Radvansky et al. in press), a person-based organization was observed when the situations were states-of-affairs rather than courses-of-events. The situations in this case used the abstract relation of ownership, rather than the spatial relation of containment. Subjects memorized facts about people buying objects. 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 person-based organizations. The information is only integrated 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", a "computer", or a "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.

Summary

Situation models impact on the way information is retrieved from long-term memory. In general, memory for information stored in a situation model reflects the fact that the model captures the gist of the situation, not the specific information used to originally construct it. Furthermore, when a set of related facts is understood as being part of a single situation, the facts are integrated into a single situation model. Because the information has been integrated, it will be easier to retrieve it at a later point in time. In contrast, when a set of facts have a common concept, but refer to several situations in the world, or it is unclear how they describe a single situation, these facts will be stored across several situation models. As a result, during memory retrieval, it will be more difficult to retrieve any one of those facts.

WHEN SITUATION MODELS ARE NOT USED

We have outlined some of the ways situation models can affect memory retrieval. However, it is not always the case that an influence will be observed. Most obviously, it will not be observed when the information is not situation-specific. However, it is also possible that situation models will not affect retrieval even though they have been created. Two circumstances where this may occur are considered. First, certain memory tasks may not access the model, but may use another type of representational code, such as a propositional or mental image code. Second, the task may not focus attention on the situation represented by the model. Finally, we consider some arguments which maintain that situation models are not stored in long-term memory and so would not affect long-term memory retrieval.

Type of memory test

Situation models do not dominate all aspects of memory retrieval. Memory retrieval tasks that do not require a subject to focus on the situations as a whole may result in the use of other representational codes. For example, in a study by Radvansky (1992), subjects memorized a list of facts about people in small places, such as "The banker is in the phone booth", similar to the study described above in the section on small locations. After memorizing the sentences, subjects were given both recognition and free recall tests. The striking result was that two different types of organization were observed for the same subjects. The recognition test data reflected a person-based organization, consistent with a course-of-events situation, as found in the earlier studies. Specifically, a fan effect was observed for the single-location–multiple-person condition, but not for the multiple-location–single-person condition. In contrast, a location-based organization was observed on the free recall test. Subjects strongly tended to recall together sentences that referred to a common location.

The explanation for this finding is based on the notion that situation models were affecting retrieval under only one of these conditions. In particular, the situation model affected recognition, but not free recall. During recognition, the subject does not need to engage in an extensive search of all of the situation models that were created earlier. Instead, only those models that contain concepts in the memory probe are activated (e.g. all of the models containing the *banker* and *phone booth* concepts). So, any difference in response time can be attributed to the organization of the information into situation models.

In contrast, during free recall, subjects need to access all of the information in such a way that would allow them to recover all of the facts. Situation models would be a poor choice for accessing this information because each representation is stored separately from the others. The notion that the situation models were not used is supported by the fact that a person-based organization was not observed. According to our view, there are two other representational codes that could be used to retrieve the needed information: propositional and mental image codes.

One alternative is that, during free recall, subjects may rely more on information stored in a propositional network. In such a case, the facts would all be interconnected in the representation, making it easier to access the entire set. However, a problem with this explanation is that it does not directly account for why the observed organization was location-based, rather than person-based, or some other organization. Another possible explanation is that subjects may have been using mental images to guide their fact retrieval. This could explain why the free recall data was location-based. Visual mental images would appear to be largely location-based because location provides a framework in which an image can be created. By changing the person, the image needs to be changed less than by keeping the person constant and changing the surrounding location. The problem with this second explanation is that it does not account for how all of the needed images were recalled. In order to do this, some sort of location-based retrieval plan needs to be hypothesized. However, this is not too large a step since the creation of such retrieval plans during free recall is well known.

The situation model is not the most relevant

Another reason that situation models may not impact on memory retrieval is that subjects may not need to rely on them in certain circumstances. Although the retrieval task does not preclude their usage, there may be cases in which the target information is more easily accessed from another source (O'Brien & Albrecht 1992, Wilson et al. 1993). In these cases, a propositional or mental image code may be used. For example, in a study similar to those done by Morrow et al. (1987, 1989), Wilson et al. had subjects memorize the layout of a building. Afterwards, subjects read a narrative about a person walking through that building. Occasionally during the course of reading the narrative, subjects were given memory probes in which they were asked to say whether two objects were located in the same room or not. For half the subjects, the narrative protagonist was included in the probe set, whereas for the other half, it was left out. The results are summarized in Figure 7.10. Response time was affected by situation model foregrounding only for the group that had probes that contained the protagonist.

It appears to us that subjects are relying on a situation model when the protagonist is included in the probe set. This is because it is only the situation model that contains a token for the protagonist, whereas a general spatial map of the location does not. As a result, the foregrounding of information in the situation model affects retrieval. In contrast, for the other group, because the protagonist was not included in the

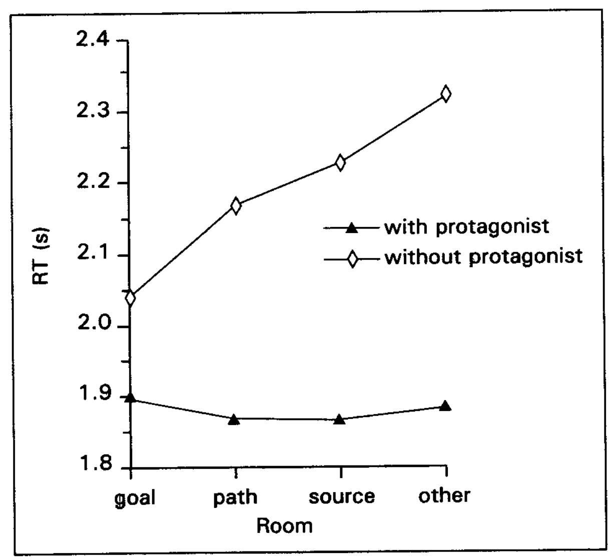


FIG. 7.10. RT for verifying that target object pairs are in the same room, relative to the room a protagonist is currently in when protagonist is either included or excluded from probe set. Derived from Wilson et al. (1993).

memory probe set, subjects did not need to access the situation model for the verification task. Instead, the subjects needed only to use a general spatial map of the building that they had built up earlier (a building schema), or perhaps even a propositional representation that encoded the object locations in a more abstract fashion. As a result, foregrounding in the situation model would have no effect on retrieval times. The notion that a more abstract representation is being used by the protagonist-absent group is supported by the fact that their response times are faster relative to the protagonist-present group.

Another example of this type of finding comes from the study by Taylor & Tversky (1992) described earlier. As can be seen in Figure 7.7, subjects verified verbatim statements faster than inference statements. Taylor & Tversky argued that the verification of verbatim statements relied more on a propositional representation that had this verbal information directly encoded into it than on a situation model. In contrast, for the inference statements, verification required a more complex understanding of the spatial arrangement. As a result, subjects were forced to use a more complex spatial situation model, which consequently took a longer period of time.

In sum, the use of a situation model to access information during memory retrieval is affected by whether the task either requires a person to consider the entire situation, or whether the task is readily accommodated by the structure of a situation model. When situation models do not most readily yield the required information, subjects may opt to use some other representational form, such as a propositional or mental image code.

Arguments against the long-term storage of situation models

While the research we have reviewed here seems to suggest that situation models are stored in long-term memory and that they directly influence memory performance, there are other opinions. Recently, some theorists have argued that situation models are used in working memory, but are not stored in long-term memory. Instead, what is stored in long-term memory is a propositional representation that is derived from the situation model(s) created earlier (Glenberg & Langston 1992), perhaps along with the set of procedures that were used to create the situation model (Payne 1993). These procedures would allow for the easy reconstruction of the situation model at a later time. However, situation model structure could have no direct effect on memory retrieval itself. (This view is similar to Kosslyn's (1983) theory of imagery in which it is thought that images themselves are not stored in long-term memory, but exist only in working memory, and can be created from previously stored propositions.)

Glenberg & Langston (1992: 147–8) argue for their view on the basis of parsimony, stating that "...we need not propose a new type of long-term representation format (or even a separate long-term representation of the situation model), and we can take advantage of the tremendous literature supporting propositional representational formats." While all good scientists should strive for parsimony whenever possible, the parsimony argument may not be applicable in the present context. Although propositional codes are well known in cognitive psychology, they are certainly not the only long-term representation that has received serious consideration. Also, in order to accept Glenberg & Langston's position, one needs to consider the storage, somehow, of the processes that translate the information from a situation model into a propositional representation (and vice versa). If not, all of the information that is gained by constructing a situation model would be lost. In such a case, it may be better to retain the situation model construct.

Payne (1993) has also argued against the long-term memory storage of situation models, based on a replication and extension of the study by Mani & Johnson-Laird (1982). In Mani & Johnson-Laird's original study, it was found that gist memory was better for descriptions that were consistent with a single situation, whereas verbatim memory was better for descriptions that were not consistent with a single situation. Payne not only failed to replicate Mani & Johnson-Laird's results, but also showed that recognition memory was mediated by the number of overlapping propositions and the order in which propositions were encountered. This led him to theorize that what was stored in long-term memory was not a situation model, but a propositional code along with the processes that were used in the original creation of the situation model, such as the order in which the idea units were encountered, and the manner in which they overlapped. While Payne's data raises doubts about whether situation models are stored in long-term memory, it may be that he failed to find any evidence of situation models because the task he used did not successfully tap into stored models (Radvansky 1992). Only future research will be able to answer this question. Until such a time, we find the arguments for the influence of situation models on memory retrieval to be more compelling than those against their consideration.

SITUATION MODELS, PROPOSITIONS, AND MENTAL IMAGES

As stated earlier, we assume that in addition to creating situation models, people also may use other representational codes to capture different aspects of situation-specific information. In this section we consider how two other representational codes, propositional networks and mental images, represent situation-specific knowledge, how information is structured in these codes, and what mechanisms are used during memory retrieval.

Propositional networks

Characteristics of propositional networks

Propositional representations have received a great deal of attention over the last few decades. Propositions themselves are simple idea units that have some sort of argument structure to convey the important concepts and the associative relations among them. For example, the sentence "The yuppie is in the BMW dealership" is comprised of a single proposition containing the concepts "yuppie" and "BMW dealership" that are associated by a containment relation. Furthermore, the sentence "The yuppie is in the BMW dealership in Cleveland" is composed of two propositions, "the yuppie is in the BMW dealership" and "the BMW dealership is in Cleveland".

For the present discussion, we will limit ourselves to propositional network models of the adaptive character of thought (ACT*) variety (Anderson, 1983). A propositional network is a complex of nodes and links. The nodes correspond to the concepts and the links represent the associations among the concepts. A combination of two nodes and an associative link forms a single proposition. Each concept can be linked to a wide variety of other concepts, leading to a network structure. This form of propositional representation is attractive to researchers because information can be organized rather directly in the network. Specifically, concepts that are related to one another have this relation explicitly encoded in the network. As such, the network is a purely abstract representation of the situation with few or no analogue qualities.

Propositional networks attempt to capture situation-specific information through the distinction between type and token nodes. Type nodes refer to concepts in general, whereas token nodes refer to specific instances of those concepts. For example, a person could have a type node that refers to hotels in general (i.e. general knowledge), and a token node that refers to a specific hotel.

Propositional networks are appealing because it is relatively straightforward to see how knowledge can be built up from a collection of simple propositional units. When a new piece of information is learned, it is simply added to the structure of propositions that are already connected in memory. In an ideal representation, no pieces of information would be left out. Information is structured in a propositional network in terms of the concepts and relations that have been expressed.

Information is retrieved from a propositional network through a process of spreading activation. During retrieval, the nodes for the currently relevant concepts are activated. This activation then spreads along the links until an intersection occurs. At that point, a person can verify a fact is known. In the case of an unknown fact, if an initial plausibility check is passed (Reder & Ross 1983), the activation spreads throughout the network for a certain waiting period (King & Anderson 1976). At the end of that period, a person can verify that the fact is not known. This prevents activation from spreading indefinitely through the network, avoiding the possibility of spurious intersections.

Limitations of propositional networks

A propositional network view would have difficulty predicting or accounting for some of the research done on situation models. For example, in the research by Franklin & Tversky (1990), Glenberg et al. (1987), and Morrow et al. (1987, 1989) this type of theory would have trouble accounting for data suggesting that the availability of information is mediated by the structure of the situation. It is also unclear how and why a propositional network would differentiate among changes in the orientation of an observer, the foregrounding of information, and the increased availability of portions of a situation that a story protagonist has recently passed through, but were left unmentioned in the text.

Despite this it may be possible to modify a propositional network model to account for viewer orientation effects. This is largely attributable to the fact that such models can represent just about anything, psychologically plausible or not. For example, there may be elaborations that alter various node and link strengths whenever the viewer changed orientation or location. However, such additions would result in an increasingly cumbersome model, and are tantamount to using a situation model explanation with the extra assumption that the situation model itself is composed of a complex of propositions. We think that a situation model view provides a better perspective from which to draw predictions and answer questions about how viewer orientation may affect memory retrieval.

Another argument against using propositional networks as the sole representational code to explain a person's understanding of situations is based on what these networks exactly represent. A propositional network conveys how concepts are related to one another. However, the representation does not directly convey how these relations correspond to the relations among entities in the world. For example, if a person encoded the ideas that "George is to the left of Scott" and "Scott is to the left of Roger", the idea that "George is to the left of Roger" would not be encoded in the network. However, this information should be stored directly in a situation model. Network representations, like ACT*, are viewed by some theorists as being little more than verbal/linguistic translations of information (Johnson-Laird, Herrmann & Chaffin, 1984).

This limitation of propositional networks can be seen in the experimental work by Radvansky & Zacks (1991, Radvansky et al. 1993). In particular, it is not easy to determine how the structure of a propositional network would be constrained by whether a set of information pertained to a single situation or multiple situations. Presumably, a propositional network would represent both situations similarly. According to a propositional network view, the availability of information should be mediated by the number of associations with each concept, the relative strength of the different concepts and associations based on frequency of usage, and/or whether that part of the network is currently in an active state (in working memory). The number of situations involved is not considered to be a factor[3].

However, before rejecting the capability of network codes just yet, it should be noted that some provision has been made for propositional networks to handle thematically related concepts (McCloskey & Bigler 1980, Reder & Anderson 1980). Specifically, it has been argued that sets of thematically related ideas are clustered in the network by means of associative links joining the related concepts to a common concept or *theme node*. This theme node is strategically placed in the network so that it serves to reduce the number of associative links that need to be searched during memory retrieval. However, this mechanism still does not specify which thematic relations correspond to situations in the world. In the case of the Radvansky & Zacks (1991) study, there does not appear to be any *a priori* reason to select object or locations concepts as theme nodes. Why should the hotel concept be more likely to serve as a theme node for a set of facts about a hotel than the cola machine for a set of facts about a cola machine? The factor that apparently identifies which facts are organized together is whether the sentences refer to a common situation in the world. A propositional network would be required to take on all of the procedures used to structure a situation model in order to account for such a pattern of results.

Mental images

Characteristics of mental images

Mental images are internally generated perceptual events that roughly correspond to real perceptual events of some real or imagined situation (although some theorists argue that mental images can be accounted

for by propositions, e.g. Pylyshyn 1984). Despite the close correspondence between real perceptual experiences and visual images, there are important differences. For example, mental images are typically less detailed than visual events.

Like situation models, mental images represent single situations. It is easy for people to conjure up an image of a single event in the world. People do not form images that simultaneously correspond to two different situations, such as forming an image of a state fair and a jury trial. Furthermore, situation models and mental images are similar in that information is represented in an analogue form. In mental images, this refers to the notion that the structure of the image corresponds to the structure of a perceptual event. The analogue form of images is evident from research that suggests that people may scan mental images in a manner similar to scanning perceptual scenes (Kosslyn et al. 1978), that people manipulate mental images in a fashion similar to perceptually available displays (Shepard & Metzler 1971), and that mental imagery tasks can interfere with similar analogue perceptual processing (Brooks 1968).

Information is thought to be retrieved through a process of scanning the mental image. Characteristics of this scanning process should be evident in memory retrieval tasks. It has been found that it takes longer to scan a large distance in a mental image than a short distance (Kosslyn et al. 1978). Furthermore, the access of information from a mental image can be affected by the other components of the images, such as the size of other entities in the imagined situation. For example, it is easier to identify the parts of a rabbit when the rabbit is embedded in an image along with a fly, than if the rabbit is embedded in an image along with an elephant (Kosslyn 1983).

While the notion of a mental image is useful, it does not provide a complete account of how people mentally represent situations. A mental image may be able to represent visual aspects of a situation, such as space and possibly time, but it has difficulty representing aspects of a situation that are not perceptual. For example, a mental image cannot easily or directly incorporate abstract relations and concepts such as ownership and kinship relations. In contrast, a situation model does represent such relations (Radvansky et al. in press).

Franklin & Tversky's (1990) spatial framework findings are also inconsistent with a mental imagery account. Mental imagery theory would predict that information directly in front of the viewer should be most available. Information would become less available the more an observer needs to rotate in the scene. This is not the case. As a reminder, it was found that information along the above–below axis was the most salient. This is accounted for by the strong salience of gravity. Furthermore, if one assumes that mental rotation to directions other than ahead of the viewer is involved, then the identity of objects to the left or right should be more available than the identity of objects behind the viewer. Again, this prediction was not upheld. Instead, the retrieval of object information appears to be mediated more by the functional relations among objects along primary axes oriented around an observer.

Finally, the results of the studies by Radvansky et al. (1993, in press), particularly those from the small location and ownership studies, are difficult to explain using only an imagery-based account. If subjects use mental images, rather than situation models, a location-based organization should always be observed. This is because a location provides an appropriate frame from which to construct a mental image and organize information, whereas a person travelling from place to place provides a poor image frame. Also, there is no provision for incorporating abstract relations such as ownership into a mental image. Instead, what is observed is that situation models are formed based on concepts other than location, such as person concepts, and that these situation models represent relations that would not be represented in a mental image, namely ownership.

Multiple representational codes

While propositional and mental image codes have competed with situation models as the means by which situation-specific knowledge is stored and structured, the view advocated by most situation model theorists is that these other codes coexist with situation models (e.g. Johnson-Laird 1983, Kintsch 1994). That is, the situation model view argues for "...the existence of at least three types of mental representation: propositional representations which are strings of symbols that correspond to natural language, [situation] models which are structural analogues of the world, and images which are perceptual correlates of models from a particular point of view" (Johnson-Laird 1983: 165) (see also Schmalhofer & Glavanov 1986). Each of these representational codes is assumed to play a different role in mental processing.

While all three different representational codes may be used, one or more codes may be absent, depending on the nature of the information. For example, while some situation-specific information may have a large imagistic component, such as "The weathered red life-boat is tied to the long dock out on the frozen lake", others may have a minimal or nonexistent imagery component, such as "Someone owns the television", "I am the President's half-brother", or "All artists are beekeepers".

We would also like to emphasize that the creation and use of situation models is not an automatic process, but only proceeds when the person is motivated to consider the situations described. Additionally, attention can be directed to other representational codes depending on the current task demands (Graesser et al. 1994, Singer et al. 1994). Such effects were observed in the Taylor & Tversky's (1992) experiments where subjects verified previously seen statements from a description of a spatial environment. Specifically, verbatim probes were verified faster than inference statements. Taylor & Tversky argued that verbatim statements could be identified more directly using a propositional code, whereas the verification of inference probes required a more elaborate model of the situation. Moreover, a series of experiments by Wilson et al. (1993) found that situation model structure influenced memory retrieval only under certain conditions. These experiments were based on the paradigm developed by Morrow et al. (1987, 1989) in which a narrative was read about a person travelling through a previously memorized space. Subjects were intermittently interrupted with probes of two objects from the space and had to indicate whether the objects were in the same room in the building. Wilson et al. found that distance effects were not observed if the story protagonist was not included in the set of memory probe items. Under such circumstances, people may be less willing to use a situation model to verify the location of entities when they can use a general mental map they constructed during the initial learning period.

LIMITATIONS OF OUR SITUATION MODEL VIEW

In this chapter we have proposed a version of a theory of situation models and how they affect memory retrieval. Evidence was provided to support this view, and reasons were given for why a situation model view is superior to propositional network or mental imagery explanations alone. At this point we would like to address some of the gaps in our theory and in some future directions of research.

Structure of situation models

Earlier in this chapter, we considered some characteristics that are important aspects of situation model structure. Despite those efforts, as well as the efforts of other situation model theorists, the precise nature and underlying structure of situation models is still unclear. For example, in Kintsch's (1994) construction–integration theory, situation models can be made up of propositions, mental images, procedural codes, or abstract codes. A situation model captures spatial frameworks (Franklin & Tversky 1990), but it is more than just a spatial or any other framework. It captures both perceptual (e.g. spatial extent, Morrow et al. 1989), and abstract relations (e.g. ownership, Radvansky, et al. in press), but it is not clear by what mechanism this is accomplished, only that the representation should serve this function. As such, situation model theory bases its ideas of organizational structure and how this structure impacts on memory retrieval more on the function the representations serve rather than on an account of the specific structure of the memory representations themselves.

Creation of situation models

A requirement for describing how situation models are created is the need to adequately describe what is and what is not part of a situation. However, this is a difficult task. For example, would a situation of a person placing luggage into her car include the entire driveway? The yard? The neighbour's yard? Because the structure of situations cannot be easily identified, it may sometimes be difficult to determine how information is used to construct a situation model. Recently, this issue has received some attention. Graesser et al. (1994) were able to place limits on the types of inferences that people make when constructing a situation model, thereby constraining the scope of the model. Specifically, a situation model contains only those elements, properties, and relations that can be simply derived, such as backwards causal inferences (a person is putting luggage into her car because she is going on a trip), but not more open-ended aspects of a situation, such as forward causal inferences (the person is going to the airport), or detailed information that, while probably true, is not central to understanding the situation (the person has an operating digestive system).

Presently, we are limited to investigating memory for information that can be clearly classified into certain types of situations. However, some exploration is being made in cases where the situation boundaries are not so clear cut. For example, in studies on ownership relations, we have found that situation model organizations are observed for facts referring to people buying objects commonly found in a drugstore (magazines, toothpaste, and candy), but not when the relation between the people and objects is described as "owns" rather than "is buying", nor when the items are typically purchased in different locations (e.g. compact disc, toothpaste, and diamond ring) (Radvansky et al. in press). This suggests that situation models are more easily constructed when the information refers to a particular region in space (e.g. a drugstore), and a particular region in time ("is buying" is more likely to refer to a discrete event than "owns").

Memory retrieval from situation models

The focus of this chapter has been on the retrieval of information from situation models. We have provided an outline for some of the major

factors that we think can influence retrieval. However, there is still further clarification and specification to be done. For example, it is unclear by what mechanisms memory retrieval is accomplished. What procedure is used when the internal structure of a situation model is searched while the model is in an active state (i.e. in working memory)? How is it that a portion of a situation model can be "foregrounded" with respect to the rest of the model? Is long-term memory retrieval accomplished entirely through an activation process, or is it some combination of activation and inhibitory mechanisms (Anderson & Bjork 1994, Hasher & Zacks 1988)?

As far as the last question goes, we have begun a series of studies using an ignored-distractor priming (negative priming) paradigm (e.g. Tipper 1985) in a standard recognition test. In these studies, those situation models that contain concepts overlapping those contained in the target representation are treated as distractors. For example, consider a situation in which a person knows that a potted palm is in the hotel and in the barber shop. Presumably, two situation models would be created, one for the hotel and the other for the barber shop (Radvansky & Zacks 1991). In the course of verifying the fact that the potted palm is in the hotel, interference from the barber shop model is observed. The question is what should happen concerning retrieval of the fact that the potted palm is in the barber shop? One possibility is that retrieval of the barber shop model will be facilitated as a result of lingering activation from the previous trial. This would be positive priming. The other possibility is that retrieval of the barber shop model will be delayed as a result of this information having been suppressed on the previous trial as part of the effect to isolate the correct representation from related competitors. This would be negative priming. Although we cannot come to a clear conclusion at this point, some pilot data that we have collected suggests that negative priming will be observed.

SUMMARY AND CONCLUSIONS

Over the course of this chapter we have looked at how situation models affect memory retrieval. It has been argued that situation models capture important aspects of described situations and can affect memory retrieval depending on whether the relevant information is stored in a single situation model or across several situation models. Effects of situation models are observed, it has been argued, during both on-line processing and when the knowledge representation is already fixed in memory. Furthermore, the situation model view allows predictions to be made that are not easily derivable from either propositional network or mental image views alone. Propositional networks do not provide insight into how situations are structured and separated. Mental imagery does not account for how abstract situation-specific information will be organized. Although some aspects of the situation model view are in need of further elaboration, we believe there is strong evidence of a central role for situation models in memory retrieval.

NOTES

1. We are concerned here with research where the term *mental model* has been used to refer to situation-specific representations, but not to research where the term is used to describe a person's understanding of a physical device (e.g. Gentner & Stevens 1983), such as an electrical circuit or the thermostat in their house. Although there have been attempts to link these two uses of the term (Johnson-Laird 1989), we consider them to be separate applications.
2. If large locations are used, the data reflect no specific organization, presumably because both location-based and person-based organizations are plausible.
3. One argument that we have encountered on more than one occasion is that, while it is generally true that a fan effect occurs as the number of associations with a concept increases, there are some exceptions. Specifically, Anderson (1976) described a characteristic of his network model called the *min* effect. The *min* effect refers to the notion that a fan effect may be attenuated or absent when one of the concepts has only a single association. Because the object concepts in the single-location condition each have only a single association, the lack of a fan effect could be seen as an instance of the *min* effect. The flaw in this logic is that the location concepts in the multiple-location condition, like the object concepts in the single-location condition, have only a single association. So, a *min* effect should also be observed in this condition, but it is not. In short, the *min* effect cannot be used to explain away our results.

REFERENCES

Anderson, A., S. C. Garrod, A. J. Sanford 1983. The accessibility of pronomial antecedents as a function of episode shifts in narrative text. *Quarterly Journal of Experimental Psychology* **35A**, 427–40.
Anderson, J. R. 1974. Retrieval of propositional information from long-term memory. *Cognitive Psychology* **6**, 451–74.
Anderson, J. R. 1976. *Language, memory, and thought*. Hillsdale, New Jersey: Erlbaum.
Anderson, J. R. 1983. *The architecture of cognition*. Cambridge, Mass.: Harvard University Press.
Anderson, M. C. & R. A. Bjork 1994. Mechanisms of inhibition in long-term memory: a new taxonomy. In *Inhibitory Processes in Attention, Memory, and Language*, D. Dagenbach & T. H. Carr (eds), 265–325. New York: Academic Press.

Barwise, J. 1989. *The situation in logic*. Stanford, Calif.: Center for the Study of Language and Information.
Barwise, J. & J. Perry 1983. *Situations and attitudes*. Cambridge, Mass.: MIT Press.
Bransford, J. D., J. R. Barclay, J. J. Franks 1972. Sentence memory: a constructive versus interpretive approach. *Cognitive Psychology* **3**, 193–209.
Brooks, L. 1968. Spatial and verbal components of the act of recall. *Canadian Journal of Psychology*, **22**, 349–68.
Bryant, D. J., B. Tversky, N. Franklin 1992. Internal and external spatial frameworks for representing described scenes. *Journal of Memory and Language* **31**, 74–98.
Bryant, D. J., B. Tversky, M. Lanca, B. Narasimhan 1993. Mental spatial models guide search of observed spatial arrays. Paper presented at the 34th Annual Meeting of the Psychonomic Society, Washington DC.
Carlson-Radvansky, L. A. & G. A. Radvansky (1996). Functional relations and spatial terms. *Psychological Science*, **7**, 56–60.
Franklin, N. & B. Tversky 1990. Searching imagined environments. *Journal of Experimental Psychology: General* **119**, 63–76.
Garnham, A. 1982. Mental models as representations of text. *Memory and Cognition* **9**, 560–5.
Garrod, S. & A. Sanford 1983. Topic dependent effects in language processing. In *The process of language understanding*, G. B. Flores d'Arcais & R. J. Jarvella (eds). New York: John Wiley.
Gentner, D. & A. L. Stevens 1983. *Mental models*. Hillsdale, New Jersey: Erlbaum.
Gernsbacher, M. A., H. H. Goldsmith, R. W. Robertson 1992. Do readers mentally represent characters' emotional states? *Cognition and Emotion* **6**, 89–111.
Glenberg, A. M. & W. E. Langston 1992. Comprehension of illustrated text: pictures help to build mental models. *Journal of Memory and Language* **31**, 129–51.
Glenberg, A. M., M. Meyer, K. Lindem 1987. Mental models contribute to foregrounding during text comprehension. *Journal of Memory and Language* **26**, 69–83.
Graesser, A. C., M. Singer, T. Trabasso 1994. Constructing inferences during narrative text comprehension. *Psychological Review* **101**, 371–95.
Hasher, L. & M. Griffin 1978. Reconstructive and reproductive processes in memory. *Journal of Experimental Psychology: Human Learning and Memory* **4**, 318–30.
Hasher, L & R. T. Zacks 1988. Working memory, comprehension, and aging: a review and a new view. In *The Psychology of Learning and Motivation* vol. 22, G. H. Bower (ed.), 193–225. New York: Lawrence Erlbaum Associates.
Hintzman, D. L. 1986. "Schema abstraction" in a multiple-trace memory model. *Psychological Review* **93**, 411–28.
Johnson-Laird, P. N. 1983. *Mental models: towards a cognitive science of language, inference and consciousness*. Cambridge, Mass.: Harvard University Press.
Johnson-Laird, P. N. 1989. Mental models. In *Foundations of cognitive science*, M. I. Posner (ed.), 469–500. Cambridge, Mass.: MIT Press.
Johnson-Laird, P. N. 1992. Propositional reasoning by model. *Psychological Review* **99**, 418–39.
Johnson-Laird, P. N., D. J. Herrmann, R. Chaffin 1984. Only connections: a

critique of semantic networks. *Psychological Bulletin* **96**, 292–315.
King &Anderson, J. R. 1976. Long-term memory search: an intersecting activation process. *Journal of Verbal Learning and Verbal Behavior* **15**, 587–605.
Kintsch, W. 1994. The psychology of discourse processing. In *Handbook of Psycholinguistics*, M. A. Gernsbacher (ed.), 721–39. San Diego: Academic Press.
Kosslyn, S. M. 1983. *Ghost in the mind's machine: creating and using images in the brain*. New York: W. W. Norton.
Kosslyn, S. M., T. M. Ball, B. J. Reiser 1978. Visual images preserve metric spatial information: evidence from studies of image scanning. *Journal of Experimental Psychology: Human Perception and Performance* **4**, 47–60.
Logan, G. D. 1995. Linguistic and conceptual control of visual spatial attention. *Cognitive Psychology* **28**, 103–74.
Mani, K. & P. N. Johnson-Laird 1982. The mental representation of spatial descriptions. *Memory and Cognition* **10**, 181–87.
McCloskey, M. & K. Bigler 1980. Focused memory search in fact retrieval. *Memory and Cognition* **8**, 253–64.
McKoon, G. & R. Ratcliff 1992. Inference during reading. *Psychological Review* **99**, 440–66.
McNamara, T. P., J. K. Hardy, S. C. Hirtle 1989. Subjective hierarchies in spatial memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition* **15**, 211–27.
Minsky, M. L. 1986. *The society of mind*. New York: Simon and Schuster.
Morrow, D. G., G. H. Bower, S. L. Greenspan 1989. Updating situation models during narrative comprehension. *Journal of Memory and Language* **28**, 292–312.
Morrow, D. G., S. L. Greenspan, G. H. Bower 1987. Accessibility and situation models in narrative comprehension. *Journal of Memory and Language* **26**, 165–87.
O'Brien, E. J. & J. E. Albrecht 1992. Comprehension strategies in the development of a mental model. *Journal of Experimental Psychology: Learning, Memory and Cognition* **18**, 777–84.
Payne, S. J. 1993. Memory for mental models of spatial descriptions: an episodic-construction-trace hypothesis. *Memory and Cognition* **21**, 591–603.
Pylyshyn, Z. W. 1984. *Computation and cognition*. Cambridge, Mass.: MIT Press.
Radvansky, G. A. 1992. Recognition, recall, and mental models. Unpublished dissertation, Department of Psychology, Michigan State University.
Radvansky, G. A. & E. J. Shoben 1994. Mental model complexity. Unpublished data.
Radvansky, G. A., L. D. Gerard, R. T. Zacks, L. Hasher 1990. Younger and older adults use of mental models as representations for text materials. *Psychology and Aging* **5**, 209–14.
Radvansky, G. A. & R. T. Zacks 1991. Mental models and the fan effect. *Journal of Experimental Psychology: Learning, Memory, and Cognition* **17**, 940–53.
Radvansky, G. A., D. H. Spieler, R. T. Zacks 1993. Mental model organization. *Journal of Experimental Psychology: Learning, Memory, and Cognition* **19**, 95–114.
Radvansky, G. A., R. S. Wyer, J. M. Curiel, M. F. Lutz in press. Mental models and abstract relations. *Journal of Experimental Psychology: Learning, Memory, and Cognition.*
Radvansky, G. A., R. T. Zacks, L. Hasher 1996. Fact retrieval in younger and

older adults: the role of mental models. *Psychology and Aging* **11**, 258–71.
Ratcliff, R. & G. McKoon 1989. Similarity information versus relational information: differences in the time course of retrieval. *Cognitive Psychology* **21**, 139–55.
Reder, L. M. & J. R. Anderson 1980. A partial resolution of the paradox of interference: the role of integrating knowledge. *Cognitive Psychology* **12**, 447–72.
Reder, L. M. & B. H. Ross 1983. Integrated knowledge in different tasks: the role of retrieval strategies on fan effects. *Journal of Experimental Psychology: Learning, Memory, and Cognition* **9**, 55–72.
Schank, R. C. & R. P. Abelson 1977. *Scripts, plans goals and understanding*. Hillsdale, N. J.: Erlbaum.
Schmalhofer, F. & D. Glavanov 1986. Three components of understanding a programmer's manual: verbatim, propositional, and situational representations. *Journal of Memory and Language* **25**, 279–94.
Shepard, R. N. & S. Chipman 1970. Second-order isomorphism of internal representation: shapes of states. *Cognitive Psychology* **1**, 1–17.
Shepard, R. N. & J. Metzler 1971. Mental rotation of three-dimensional objects. *Science* **171**, 701–3.
Singer, M., A. C. Graesser, T. Trabasso 1994. Minimal or global inference during reading. *Journal of Memory and Language* **33**, 421–41.
Taylor, H. A. & B. Tversky 1992. Spatial mental models derived from survey and route descriptions. *Journal of Memory and Language* **31**, 261–92.
Tipper, S. P. 1985. The negative priming effect: inhibitory effects of ignored primes. *Quarterly Journal of Experimental Psychology* **37A**, 571–90.
Tulving, E. 1985. How many memory systems are there? *American Psychologist* **40**, 385–98.
Wilson, S. G., M. Rinck, T. P. McNamara, G. H. Bower, D. G. Morrow 1993. Mental models and narrative comprehension: some qualifications. *Journal of Memory and Language* **32**, 141–54.
Zwaan, R. A. 1994. Effect of genre expectations on text comprehension. *Journal of Experimental Psychology: Learning, Memory, and Cognition* **20**, 920–33.

Studies in Cognition

Editor: Glyn Humphreys
University of Birmingham

Cognitive models of memory Martin A. Conway (ed.)
Cognitive neuroscience Michael D. Rugg (ed.)
Attention Harold Pashler (ed.)
Knowledge, concepts and categories Koen Lamberts & David Shanks (eds.)

COGNITIVE MODELS OF MEMORY

EDITED BY

MARTIN A. CONWAY
UNIVERSITY OF BRISTOL

This is now published by MIT Press

1997

~~Psychology Press~~
~~a member of the Taylor & Francis group~~