8 Situation models in memory: Texts and stories

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Part of everyday memory is the ability to remember the situations that are described in conversation, texts we read, films we see, and so on. This memory requires a mental representation that will capture the important aspects of a described event. This representation, in some sense, serves as mental analogue for the situation in the world. By remembering a mental analogue of the situation, we are remembering the described event. These mental representations of described situations are called *situation models* (Van Dijk & Kintsch, 1983; Zwaan & Radvansky, 1998). This chapter will look at a number of ways that memory for events is influenced by the use of these situation models. A general description of memory for situations is first provided. After this, the chapter will look at the long-term memory for events, how the dynamic characteristics of events can change memory as we update our understanding of the event, and how event memory is affected by the natural ageing process.

LEVELS OF COMPREHENSION AND MEMORY

When you read a story in a newspaper or hear a story on the news, it is important what words were used to convey the message. However, as time passes, the precise wording used becomes less and less important, and our memory for that information becomes progressively worse. Over long periods of time what we remember is not the exact wording used, but the situation that was described. Research on memory for language and text has delineated between three levels of mental representation (Van Dijk & Kintsch, 1983): the surface form, the propositional textbase, and the situation model. The *surface form* is essentially a person's memory for the exact words and syntax used. While precise wording may be important, verbatim memory is generally very poor. Memory for the surface form is very fragile and may be forgotten within a few minutes or even seconds (Sachs, 1967), unless there is extensive practice (Noice & Noice, 2002) or wording is critical, as with jokes (Kintsch & Bates, 1977).

In comparison to the surface form, the *propositional textbase* is a more abstract representation. The textbase is a mental representation of the ideas conveyed by the text, independent of the precise wording used. For example, the sentences "The girl hit the boy" and "The boy was hit by the girl" differ in their wording, but essentially mean the same thing. This common underlying idea would be the textbase. While the textbase is remembered longer than the surface form, people still tend to forget this information at a fairly rapid rate. As will be seen, textbase information begins to be lost after a few minutes of reading a text.

The referential memory for a described situation is the *situation model* (Johnson-Laird, 1983; Van Dijk & Kintsch, 1983; Zwaan & Radvansky, 1998). This is a memory representation for the situation described by a text apart from memories of the text itself. A situation model is a mental simulation of the event being described. While these mental representations isomorphically capture the important components of a situation, they are not complete and do not capture every aspect of an event. There are a number of components that can be identified in a situation model (Wyer & Radvansky, 1999). First, a situation is embedded in a *spatial–temporal framework*. This is a location in space that the situation unfolds in, and the span of time in which the situation operates. The spatial–temporal framework provides the context that defines a static situation (e.g., Bower & Morrow, 1990; Radvansky & Zacks, 1991; Radvansky, Zwaan, Federico, & Franklin, 1998).

Within the spatial–temporal framework are a number of *tokens* that stand for the entities, such as people, animals, objects, abstract concepts, etc. Associated with these tokens are various relevant *properties*, including external (e.g., physical) and internal (e.g., mental or emotional) properties. Finally, there are *structural relations* among the tokens, including spatial, social, and ownership relations. The probability that these components are included in the situation model is a function of the degree to which they involve an actual or likely interaction among those elements (Radvansky & Copeland, 2000; Radvansky, Spieler, & Zacks, 1993; Radvansky, Wyer, Curiel, & Lutz, 1997).

In addition to moments in time, a situation model can capture dynamic aspects of an event. This is done by joining a series of spatial–temporal frameworks by *linking relations* including temporal and causal relations. These relations are presumably grounded in the tokens of the situation model that stand for the entities that are undergoing transition in the situation. During the reading of a text, reading times increase when there are breaks in causal coherence (Zwaan, Magliano, & Graesser, 1995) and temporal contiguity (Zwaan, 1996; Zwaan et al., 1995). Furthermore, the degree of causal connectivity of story constituents is a primary predictor of recall and summarisation (see Van den Broek, 1994).

Unlike the surface form and textbase, memory for the situation model is much more durable, lasting for long periods of time. For example, when you think about a newspaper article you may have read, you are unlikely to remember the wording of the article, but are likely to remember the events in the world that the article was describing. This is the superior memory of the situation model relative to the surface form and textbase.

This differential memory of the surface form, textbase, and situation models levels over time has been illustrated most clearly in a study by Kintsch, Welsch, Schmalhofer, and Zimny (1990; see also Radvansky, Zwaan, Curiel, & Copeland, 2001). In this study, people were given texts to read. They were then tested for their memory of the text immediately after reading, 40 minutes later, 2 days later, or 4 days later. The results of this study are shown in Figure 8.1. What was observed was that although memory at all three levels of representation were relatively high immediately after reading, as time passed there were marked differences in the rate of forgetting.

An important aspect of this study is that it used a method developed by Schmalhofer and Glavanov (1986) to separate out memory for the three levels of

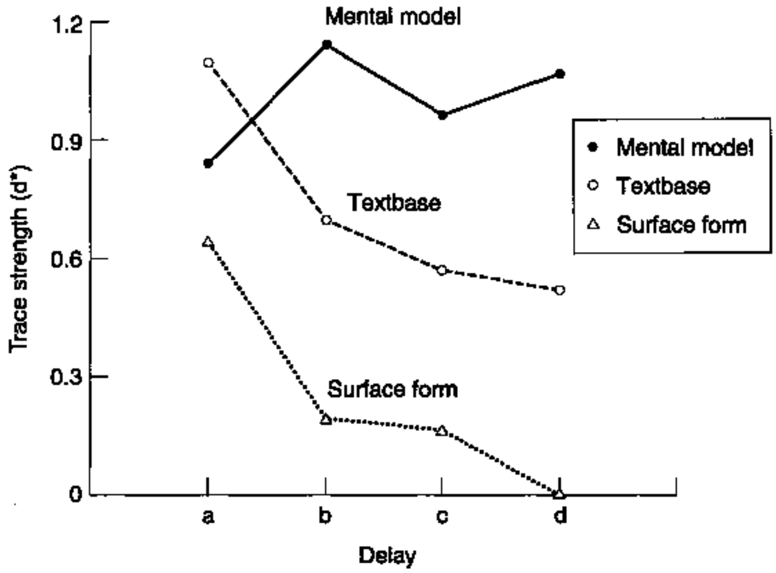

Figure 8.1 Results of the Kintsch, Welsch, Schmalhofer, and Zimny (1990) study showing the forgetting of information at the surface form and textbase levels, but relatively well-preserved memory at the situation model level. Redrawn from data reported by Kintsch, Welsch, Schmalhofer, and Zimny (1990), *Journal of Memory and Language*, *29*, 133–159.

representation. This analysis uses the rate at which people say they remember verbatim, paraphrase, inference, and incorrect statements as having been read before. A signal detection analysis is applied to these data by strategically comparing these different types of item. For the surface form, memory performance declined very rapidly after the first 40 minutes, and within a few days, people were essentially at chance in their ability to discriminate between sentences that had actually been read, and those that captured the same meaning, but differed in their wording.

For the textbase, the rate of forgetting was less pronounced. Although there was some evidence of forgetting even after 40 minutes, it was not as extreme as with the surface form representation. Over the next few days, performance did decline over time, although people were still above chance in their ability to discriminate ideas that were in the text versus those that could be inferred, but were not explicitly mentioned. In comparison, memory at the situation model level showed no appreciable forgetting across the various retention intervals. In some ways, this result is not too surprising. After all, when we read something, we are often not overly concerned with the words themselves, but with the situation that is being described. We care about the events, not the words, and so our memory is oriented around remembering the described circumstances rather than the language used.

LONG-TERM MEMORY FOR SITUATIONS

This portion of the chapter will look at long-term memory for described situations and how the structure of situations influences how well different pieces of information are retained and retrieved in memory. Given that situation models are efficiently retained longer than other sorts of memory traces, and that these memories capture the described events, it is expected that this will have a meaningful influence on long-term memory performance. Specifically, memory should be more situation-based rather than language-based. That is, people should make memory judgements based on whether the information matches the described situation, not based on linguistic correspondences.

Sentence memory

A classic illustration of this sort of situation-based memory comes from work on sentence memory. Specifically, it has been shown that people are more likely to misidentify a sentence that is different from one heard earlier if it describes the same situation. The classic example of this is a study by Bransford, Barclay, and Franks (1972; see also Garnham, 1981; Jahn, 2004). In this study people heard sentences such as "Three turtles rested on a log and a fish swam beneath them". Later, these people were likely to mistakenly identify the sentence "Three turtles rested on a log and a fish swam beneath it" as having been heard before. This error occurs because both of these sentences describe the same situation. This is in comparison to a condition in which people heard sentences such as "Three turtles rested beside a log and a fish swam beneath them". In this case, people are much less likely to mistakenly say that they heard the sentence "Three turtles rested beside a log and a fish swam beneath it" because this more clearly describes a different situation, even though the change in wording between these two versions of the sentence is the same as the change in wording in the first pair.

Overall, what these sorts of studies show is that people's memory even for simple sentences is guided by a memory for the described situation, not a memory for the language itself. People depend on their situation models to make memory decisions. They do not have very good memories for the language used to make those descriptions.

The use of situation models during memory retrieval, even for simple sentences, can be clearly seen in work on the fan effect. A *fan effect* is an increase in retrieval time or error rates on a recognition test that accompanies an increase in the number of newly learned associations with a concept (Anderson, 1974). In other words, the more new things a person learns about something, the harder it is to retrieve any one of them. For example, suppose people first memorised a set of sentences that included "The bulletin board is in the school" "The bulletin board is in the city hall" and "The bulletin board is in the car dealership". Then, during a recognition test, because there are three places that the bulletin board is in, people will take longer to verify any one of these sentences compared to a condition in which only one thing was learned about the bulletin board. This memory retrieval slow-down is the fan effect.

According to a situation model view, the reason this interference effect occurs is because people are creating a separate situation model for each location the bulletin board is in. This is because each of those three sentences is likely to be interpreted as referring to a different situation in the world. As such, what we have are three separate situation models about the bulletin board stored in long-term memory. During retrieval, when the person is presented with a fact to verify, such as "The

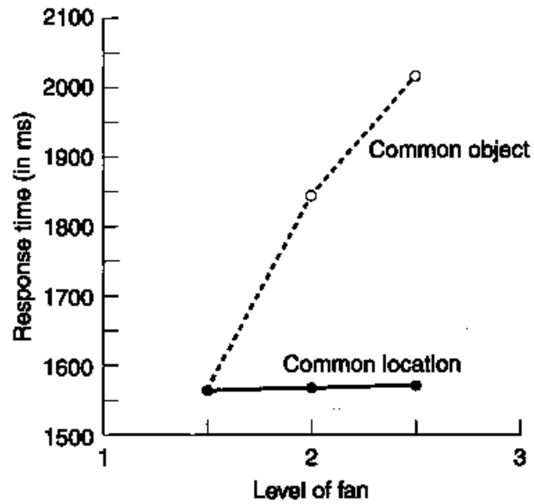

Figure 8.2 Different interference effect for multiple location (one object in multiple location) and single location (multiple objects in one location) conditions. Level of fan refers to the number of associations with either an object or location. Drawn from data reported by Radvansky, Spieler, and Zacks (1993) *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19*, 95–114.

bulletin board is in the car dealership", not only is the car dealership model activated, but so are the school and city hall models, because they also contain a bulletin board. As such, these related and irrelevant models interfere with the retrieval of the appropriate one, producing interference and slowing retrieval down, producing a fan effect.

In comparison, suppose as part of the set of sentences, people learned the sentences "The potted palm is in the hotel" "The pay phone is in the hotel" and "The ceiling fan is in the hotel". Under these circumstances, although there are three different sentences about the hotel, it is easy for people to imagine a single situation that is consistent with these three facts. As such, people can integrate this information into a common situation model, and store that one model in memory. Then at retrieval, when a person needs to recognise any one of those facts, because there is only a single situation model about the hotel, there are no related and irrelevant models that would be activated and produce interference. As such, no fan effect is observed (Radvansky, 1999; Radvansky et al., 1993; Radvansky & Zacks, 1991). This differential interference effect for multiple location and single location conditions can be seen in Figure 8.2.

This differential interference effect is not specific to spatial locations, but applies to situation models more generally, and how people conceive of the way that situations are structured in the world. For example, if people memorise sentences about people in small locations that typically contain only a single person (such as a dressing room at a store) then the information is organised into situation models oriented around the person (who can travel from place to place as a sequence of events) rather than the location (Radvansky et al., 1993). Also, situation models are organised around people for statements of ownership rather than objects (Radvansky et al., 1997), or around common time periods (Radvansky et al., 1998). Thus, people are using their understanding of events in the world to create situation models, and then using these situation models during retrieval, which can then influence memory performance.

This sort of interference effect is not only observed when people memorise sets of individual sentences, but also when people have extensive prior knowledge and are reading longer texts. In a study by Bower and Rinck (2001), people first memorised a map of a building. An example of one of these maps is shown in Figure 8.3. This building had many rooms, with several objects in each room. Moreover, different instances of some of the objects could occur in multiple rooms. For example, two or three rooms could have a desk. After memorising the map, people read narratives that described events that occurred within that building. On critical trials, sentences mentioned objects that were either grouped together in a single room, or that occurred in multiple rooms. What was observed was that people showed evidence of interference when there were several instances spread across multiple locations, but not when there were several objects in one location. Thus, the principles of memory and the use of situation models to structure information and influence retrieval were observed both with simple sentences and with more complex event descriptions.

Overall, there is clear evidence that when people remember information they have heard or read, there is a tendency to rely on situation models of the described situations rather than a memory for the text itself. This tendency becomes more pronounced as time passes, and the memories become older and older. Moreover, how information is structured and organised into situation models can have a profound impact on how the information is retrieved later. For example, information that has been integrated into a common situation model can be remembered with more facility than information that refers to common situational elements, but is stored across multiple situation models.

Narrative memory

While the research on sentence memory is instructive, people are often called upon to remember complex sets of information, such as that presented in the context of a narrative. As mentioned earlier, the Schmalhofer and Glavanov (1986) analysis of people's memory for text shows that they retain their situation model representations for a longer period of time than their more text-oriented representations. However, different aspects of a situation model are differentially remembered depending on the role they play in the situation. In this section, we look at some factors that can influence performance, such as functional relations, causality, and stereotypes.

People create situation models of the narratives they hear and read. These situation models are made up of a number of components that correspond to different elements of the situation, including information about the spatial–temporal framework, entities, their properties, structural relations such as spatial and ownership relations and linking relations, such as temporal and causal relations (Wyer & Radvansky, 1999; Zwaan & Radvansky, 1998). The relative importance of each of these components varies with the role it plays in the situation.

One distinction that can be made is between different types of structural relations. Take the example of spatial relations that convey how different entities in a situation

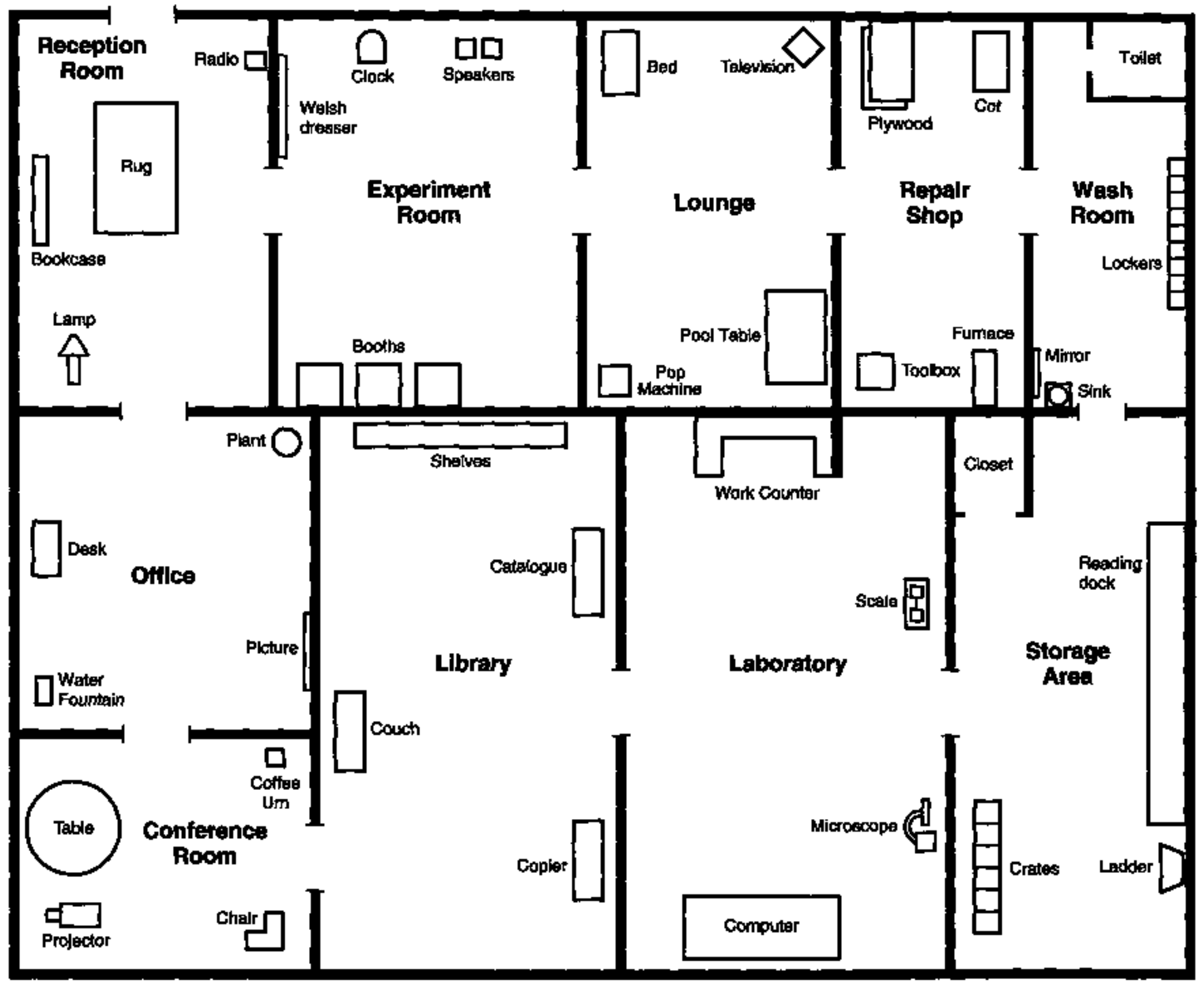

Figure 8.3 An example of a map memorised by subjects in studies showing the effects of multiple objects in multiple locations. Reprinted from *Journal of Memory and Language*, 26, Morrow, Greenspan, and Bower, *Accessibility and situation models in narrative comprehension* pp. 165–187, copyright © 1987, with permission from Elsevier.

are oriented with respect to one another. When people read about the arrangement of objects with respect to a story protagonist, if they are sufficiently motivated, they will create situation models to capture this framework. Thus, objects that are directly ahead of the protagonist will be directly ahead in the situation model. Objects that are to the right will be to the right in the model. This has implications for the availability of information within a situation model. Specifically, the availability of information retrieved from a situation model varies as a function of characteristics of the real world, and how the story protagonist would interact with those objects if that were a real environment. In a study by Franklin and Tversky (1990), people read stories that described the relative position of objects with respect to the story protagonist. Then people were probed for information about those objects.

What Franklin and Tversky (1990) found, as can be seen in Figure 8.4, was that the availability of information about objects in working memory was greatest for items along the above–below axis, intermediate for objects along the front–back axis, and least available for objects along the left–right axis. The thinking is that objects along the above–below axis are most available because this dimension of space is clearly defined by presence of gravity and the asymmetry of a person's body along this axis. Information along the front–back axis is moderately available because, while the environment does not clearly define this axis, the asymmetry of a person's front versus back does. Finally, the left–right axis is the most difficult to use because it is neither clearly defined by the environment nor a person's body, because we are symmetrical (more or less) along the left–right axis. Thus, the availability of information in working memory is influenced by the structure of a person's situation model and how this model is being used.

Not all spatial relations between entities are important to understanding the situation. For example, suppose it is raining. If a person were to stand next to the

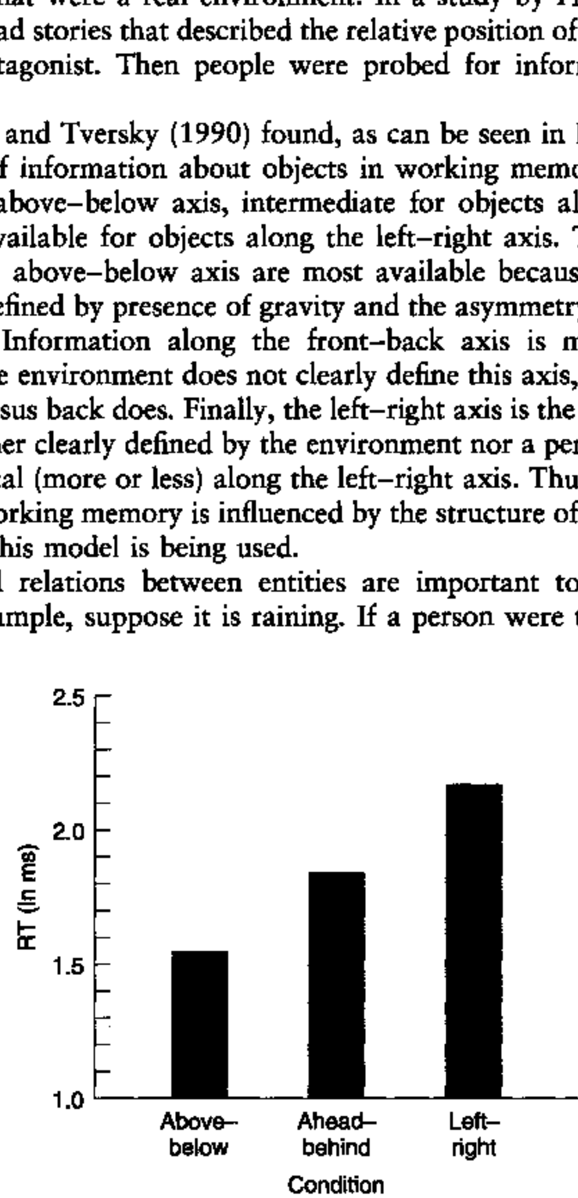

Figure 8.4 Availability of object information in working memory as a function of the spatial orientation relative to a story protagonist. Drawn from data reported by Franklin and Tversky (1990) *Journal of Experimental Psychology: General, 119*, 63–76.

bridge there is no functional relation here, and it would not be important for people to remember this spatial relation. However, if a person were to stand below the bridge, this would serve the function of keeping the person out of the rain and not getting wet. Because the spatial relation between the two entities (the person and the bridge) serves some function, there is now some reason to remember it. This distinction between functional and nonfunctional relations has important consequences for event memory. Specifically, people are more likely to remember functional relations than nonfunctional ones (Radvansky & Copeland, 2001). This is because the functional relations are the more important ones in the content of the event.

This influence of functional relations even extends to sentence memory. As a reminder, Bransford et al. (1972) were able to show that people mistakenly remembered sentences that described the same situation as an original one. More recent work by Jahn (2004) has found that this can be affected by the presence or absence of causal relations. Specifically, if people read sentences about animals in spatial relation to one another, they were more likely to make memory errors when the sentences were consistent with a causal predator–prey relation than when that relation was absent. This predator–prey relation is a functional one that is critical to a person understanding the described event. This further supports the idea that people are creating situation models of events and using them to make memory decisions, even when the information is conveyed by something as small as a single sentence. Moreover, how these situation models are structured is based on how entities interact in the world.

The influence of causal information on memory for situation is very clearly observed in studies of narrative comprehension that have looked at how causal structure influences memory for a narrative. In general, a given piece of narrative information is more likely to be remembered if it is causally more important. Causal importance is quantified at the beginning of a study by having an experimenter indicate, for each text unit (such as a sentence), whether it is causally connected to other events that have occurred in the story, and if so which ones (Trabasso & Sperry, 1985; Trabasso & Van den Broek, 1985). Through this type of analysis, a causal network of the story can be readily derived. What this network will indicate is the degree to which a given text element is causally connected to the other portions of the text. This is important because it has been found that sentences that have a greater number of causal connections are remembered better than sentences that have a lesser number. Thus, people are using the causal structure of described situations to create situation models, and this causal structure has a direct influence on memory performance. This importance of causal connectedness on memory for situations not only applies to those situations that are read about, but also those that are experienced and are represented in autobiographical memory (Radvansky, Copeland, & Zwaan, 2005a).

The importance of causal relations in memory for situations can also be observed in the ability of people to use causal inferences they derive from texts as they read them. For example, in one study by Singer, Halldorson, Lear, and Andrusiak (1992), people read brief stories that either did or did not imply a causal relation among situational elements. For example, if a person first read the sentence "Mark poured the bucket of water on the bonfire" followed by the sentence "The bonfire went out," then they were later able to verify more quickly the statement "Does water extinguish fire?" than if the first sentence that was read was "Mark placed the bucket of water by the fire." This suggests that when situation models are created, the memory for an inferred causal relation can influence later performance. People have situation models in memory that include not only information about what was read, but also about what was implied.

This memory for causal relations can be exploited during retrieval. In a series of studies (Duffy, Shinjo, & Myers, 1990; Keenan, Baillet, & Brown, 1984; Myers, Shinjo, & Duffy, 1987), people were presented with sentence pairs. Later they were given the first sentence and asked to recall the second. Recall was more successful when the sentences were casually related than when they were not. This further supports the idea that causal relations are stored in our memory for situations and can be used to retrieve information at a later point.

The aspects of narrative memory that have been considered so far are somewhat neutral, in that they involve physical or natural causal relations among entities. However, people actively evaluate social aspects of the situations they are confronted with. Among the social implications of stories are the social stereotypes that may become involved and prejudices that the reader may have. These may be used to evaluate the story characters that can become incorporated into the situation models that are created and stored in memory. We all have stereotypes of people that we carry around with us in our heads, even if we don't agree with or believe in the stereotypes. That is, we know what the stereotypes are, even if we don't accept their application. These stereotypes can sometimes provide information that would be incorporated into a person's situation model, and then this situation model is used to make decisions. If these decisions are based on stereotypical information, then a person may act in a prejudicial manner even if they want to be egalitarian.

When a person reads a text, inferences need to be made because not all of the information needed to understand it is explicitly stated. People rely on their general knowledge to make these inferences, and most of the time this occurs in a rapid and unconscious manner. One of the potential sources of information in long-term memory that could be used to make inferences is our stereotypes. What can happen is that people unconsciously make inferences using their stereotypes to fill in the gaps of the text. Later, when people need to remember information they read earlier, they will have a hard time distinguishing between what was read and what was inferred. As such, people are more likely to think mistakenly that the stereotypical information that they inferred had actually been read (Radvansky, Copeland, & Von Hippel, 2006). A person may therefore think and act in a prejudicial manner towards the person they had read about earlier.

MEMORY AND UPDATING SITUATIONS

While some situations are static states-of-affairs, others are more dynamic courses-of-events, in which the situation changes and develops over time (Barwise & Perry, 1983). Memory must take into account this dynamic aspect of situations in two general ways. First, as a person is actively processing information about an ongoing situation in a text they are reading, they need to be able to update the contents of their working memory so that they continue to think about information that is relevant to the current situation, but so that newly irrelevant information is removed from the current situation model and is not actively maintained in working memory.

The other thing that memory must do is keep track of the sequence of events as they occur for the time when this information needs to be later reconstructed.

There are a number of ways that the situations we read about can change. One type of change that can occur is a change in spatial location; people we read about can move from one location to another. Often, this sort of change is viewed as a significant change in the ongoing situation, and readers need to update their situation models. When they do this, relevant information needs to remain in the highly active foreground in working memory, whereas information that was relevant in the prior location, but less relevant in the current situation, should be removed from a high state of availability in working memory.

In one study of spatial updating, Glenberg, Meyer, and Lindem (1987; see also Radvansky & Copeland, 2001; Radvansky, Copeland, Berish, & Dijkstra, 2003a) had people read brief texts in which a critical object was either associated with or dissociated from the story protagonist. Then the protagonist moved to a new location. An example of this is the story below:

> John was preparing for a marathon in August. After doing a few exercises, he put on/took off his sweatshirt and went jogging. He jogged halfway around the lake without much difficulty. Further along his route, however, John's muscles began to ache.

According to situation model theory, things that were associated with the protagonist should stay in the foreground of the situation model because they move to the new location with the protagonist. However, objects that were dissociated from the protagonist should not be carried along to the new location, and so would not be relevant to that situation, and should fall away from the foreground of the situation model. This was tested in Glenberg et al.'s study by asking people questions or presenting memory probes that referred to the critical object in the story (in this case the sweatshirt) that was either associated with or dissociated from the story protagonist.

What Glenberg et al. (1987) observed was that information about the critical object was less available when it was dissociated than when it was associated. People were faster to respond to questions or probes that referred to a critical object that was associated with the story protagonist, and thus maintained when the spatial shift occurred, relative to dissociated objects that remained in the prior location. Thus, spatial updating of a situation model as a person strives to understand the described situation affects the working memory availability of information about objects in that situation.

The monitoring of situational information across spatial shifts takes into account not only information about the current state of the situation, but general world knowledge about the larger context. This is most clearly seen in a series of studies by Bower and colleagues (e.g., Morrow, Greenspan, & Bower, 1987; Rinck & Bower, 1995). In these studies, people first memorise a map of a building with multiple rooms and multiple objects in each room, like the one shown in Figure 8.8. Then, after the map is memorised, people read narratives about characters moving about in those buildings. During reading, people were probed for information about objects in those buildings. In essence, what was found was that as the distance from the story protagonists' current location in the building to the objects increased, there was an increase in processing time. This spatial gradient suggests that people are updating their situation models when there are spatial shifts, and that people take into account the broader context in which that situation is embedded.

While people can monitor spatial shifts in long-term memory, this does not mean that they always do so. For example, people do not show the spatial gradient of availability when they are not focused on the protagonist (Wilson, Rinck, McNamara, Bower, & Morrow, 1993) or do not have extensive prior knowledge about the larger spatial layout (Zwaan, Radvansky, Hilliard, & Curiel, 1998). The structure of the situation model is more likely to affect memory retrieval when cognitive processing is oriented towards understanding the unfolding events, but not otherwise. Thus, situation models do not necessarily have an overpowering influence on cognitive processes but are likely to have an influence in everyday memory use, since most of what we think about are the events and situations in our world. When situation model processing is engaged, the structure of a situation model can overcome other mental structures and organisations. For example, if people memorise a map in a way that emphasises a temporal ordering (e.g., Clayton & Habibi, 1991; Curiel & Radvansky, 1998), during simple memory retrieval, a temporal organization of the information is observed. However, if people need to use that information to process events, such as reading the stories that were used by Bower and colleagues, they exhibit the spatial gradient of availability (Curiel & Radvansky, 2002). Essentially, the use of situation models in working memory causes the knowledge to be mentally restructured to capture the organisation of an event as it would occur in the world, and not reflect the prior structure of the information in long-term memory.

Another way that a situation can change is that there could be a shift in time (e.g., Radvansky et al., 2003a; Zwaan, 1996). Shifts in time vary in their importance in monitoring knowledge in working memory depending on the size of the time shift. For relatively short shifts, based on a reader's knowledge of how long events typically last, the situation model in working memory may require little or no modification, whereas for larger time shifts beyond the normal duration of an event of a particular type, people will need to update their situation models in some way (Anderson, Garrod, & Sanford, 1983). For example, if a reader is told that a person has started watching a movie, an hour later the person is still likely to be watching the movie, but 5 hours later the situation may well have changed. These larger time shifts are cues to readers to update their situation models by creating a new spatial–temporal context. Again, some of the information from the previous event will be relevant in the new situation, and other information will become irrelevant.

A study by Zwaan (1996) looked at temporal updating in a way that is somewhat similar to the Glenberg et al. (1987) study described earlier. In that study, people read texts that described a person engaged in an activity. Then there was a statement that indicated either a short or a long temporal shift. Here is an example of one of the stories used:

> Today was the grand opening of Maurice's new art gallery. He had invited everybody in town who was important in the arts. Everyone who had been invited had said that they would come. It seemed like the opening would be a big success. At seven o'clock, the first guests arrived.
>
> Maurice was in an excellent mood. He was shaking hands and beaming. A *moment/day later*, he turned very pale. He had completely forgotten to invite the

local art critic. And sure enough, the opening was very negatively reviewed in the weekend edition of the local newspaper. Maurice decided to take some Advil and stay in bed the whole day.

Again, the idea was that information that was relevant to the first situation, but temporally limited, should still be available. However, after a longer time shift, information about the protagonists' activities should be removed from working memory. In this case, a reader could be probed with the word "beaming" after the temporal shift sentence, with the task of verifying whether it had occurred before. When the temporal shift was a short one, people should be faster to verify the probe than after a long shift. After a long temporal shift, information that was relevant to the previous event, but not to the current situation, should have been removed from the foreground of the situation model in working memory.

What was found in Zwaan's (1996) study was that people were, in fact, slower to verify these probes when there had been a long temporal shift than when there had been only a short shift. These results further support the idea that people are creating mental simulations of the world when they read about events that happen in the world, and that these situation models are updated to take into account the current state of affairs. Working memory contents are being managed to keep relevant information available, whereas less relevant information is removed when it no longer pertains to the current situation.

Events can change in more subtle ways than by shifts in time and space. Another set of elements of a situation that can change are the goals and desires of the people involved. When people read a text, they need to keep track of what the story characters want and are trying to achieve. This provides an understanding of what motivates people to do different things, and helps explain why they take various actions. In other words, what happens in a narrative situation is often driven by the intentions of the characters. When a person's goals change, the situation changes as well. Goals can change in a situation in a number of ways, including becoming a goal for a person, becoming more or less important, or being completed and no longer relevant. Our focus here will be on cases in which a person's goal has been completed. This type of goal change nicely parallels the work on spatial and temporal shifts we have covered up to this point.

Essentially, when a person completes a goal, information about the need for that person to achieve that goal has to be removed from working memory. This is because it no longer motivates a person's actions. For example, if Jimmy wants a bike, and then gets one, then there is no reason to think that any of his future actions involve him trying to get a bike. This process of updating goal information was assessed in a study by Suh and Trabasso (1993; see also Lutz & Radvansky, 1997; Radvansky & Curiel, 1998). In that study, people read a series of stories in which the characters had explicitly stated goals. At a later point during the story, the protagonist was able either to complete that goal successfully or not. What was found was that information about the goal became much less available when the goal was completed, but remained highly available in working memory if it was not. Thus, when people are reading, the situation model they create is actively monitoring events in the world by regulating the active contents of working memory. This applies to many aspects of a situation, including non-perceptual changes such as a shift in goal relevance.

This work on understanding how people remember events that they read from a text is important in other domains, not just memory for text. For example, take the finding by Glenberg et al. (1987) that, when people read about a spatial shift, they retain information about objects that were associated with the story protagonist, but remove information about dissociated objects from the foreground of their situation model. A study by Radvansky and Copeland (2006) extended this finding to interaction with events in virtual reality. In their study, people navigated a virtual environment, picking up and setting down objects along the way. They also probed people for the names of objects they were either carrying or had just set down. What they found was that the Glenberg et al. (1987) result recurred in these virtual reality environments. Specifically, memory for objects was worse for objects that had been set down as compared to objects that were currently being carried. Moreover, if a person walked through a doorway, a marked spatial shift, memory for the objects was even worse, particularly for those that the person was carrying. Essentially, walking through doorways causes forgetting.

AGEING

Now that we've covered a number of issues relating to memory for situations in normal, college-aged people, let's look at how these principles of memory and comprehension can be extended to older adults. Old age brings with it a number of psychological changes (see Chapter 11). For example, relative to younger adults, older adults process information more slowly (Salthouse, 1996), are more likely to make errors on memory tests (Johnson, 2003), are less able to maintain information in working memory (Craik & Byrd, 1982), and are less able to suppress irrelevant information from entering the current stream of processing (Hasher & Zacks, 1988). Because of the importance for creating, maintaining, and retrieving information from situation models to everyday comprehension and memory, it is also of interest to see how the natural ageing process affects this.

As mentioned earlier, after people read a text, memory for that information can be analysed at three levels: the surface form, textbase, and situation model (e.g., Kintsch et al., 1990). Using the sort of analysis that was described earlier to tease apart memory at these three levels, we can then assess how younger and older adults differ or are the same. This was done in a study by Radvansky et al. (2001), who found that older adults had poorer memory than younger adults at the surface form and textbase levels. This is consistent with a great deal of work on ageing and memory (see Johnson, 2003). However, what is interesting is that at the situation model level, the older adults did as well as, if not better than, the younger adults. Thus, while there are declines at lower levels, memory at the situation model level was relatively well preserved. Older adults are as able as younger adults to construct situation models of a described event, and then remember them later.

As a reminder, when people construct situation models they are taking information from a text that they are reading and combining it with inferences they draw from their prior knowledge about the world, and how the described situation is likely to be operating. While this process seems to work well for older adults in general, there are some ways in which their age-related deficits can hinder their performance. An example of this would be cases where people make and retain inferences about things that they read although they feel these are inappropriate. For example, in one study by Hamm and Hasher (1992), people read texts that initially misled them about what sort of situation the protagonist was in. Then, part-way through the story, it was made clear that another situation was operating. An example of one of those stories is presented below:

> Carol was not feeling well and decided to find out what was wrong. She called her friend who was a nurse to ask her for some advice. The friend told Carol what to do. Carol went into town and apprehensively entered the large building hoping to find an answer. She walked through the doors and took an elevator to the third floor. She found a book that seemed relevant to her problem. Carol then went to the main desk and checked out the book for two weeks so that she could read it at home. When she left the building she saw that it had started snowing hard and she hailed a taxi to take her home.

In this story, it initially implies that the building Carol is going into is a hospital. However, this is misleading, and the passage then makes clear that the building is a library. One of the problems that older adults have is in suppressing inappropriate information (Hasher & Zacks, 1988). Consistent with this, older adults not only made inferences about the correct interpretation of the situation (that Carol went to a library), but they continued to hold on to the inappropriate interpretation (that the building was a hospital) after it was made clear that another was operating. That is, they were maintaining two different situation models of the same description.

In another study by Radvansky et al. (2006), people read texts about stereotyped members of the community, such as African–Americans and Jews. It was found that older adults were more likely to draw and maintain inferences about the story characters consistent with the stereotypes. That is, older people were more likely to draw inferences based on their stereotypes and to integrate them into their situation model. These situation models with a greater amount of stereotype-consistent information were then used to make memory decisions later. This occurred even in face of the fact that older adults were more motivated to be egalitarian than the younger adults. These older adults' memories led them to be prejudicial against their will.

Evidence for the idea that older adults are using situation models in memory in a manner similar to younger adults can also be seen in a study by Radvansky, Gerard, Zacks, and Hasher (1990), in which people were presented with confusable and non-confusable sentences, similarly to the study by Bransford et al. (1972). In this study, younger and older adults were confusing sentences that had been heard before with ones that were different, but plausibly described the same situation. Both groups made fewer confusions for sentences that were unlikely to be interpreted as describing the same situation. Thus, older adults, like younger adults, use their situation model memories to make decisions about what has and has not been presented before.

The influence of situation models on memory retrieval is similar across younger and older adults. Specifically, younger and older adults both show fan effect interference during memory retrieval for information that is shared across multiple models in memory, although the older adults show larger interference effects. However, both younger and older adults are able to avoid this interference if they can integrate this information into a single situation model (Radvansky, Zacks, & Hasher, 1996, 2005b). Thus, the use of situation models in memory not only affects how information is encoded, but also how it is retrieved, showing that this use of situation models in retrieval is similar across age groups.

This age-invariant influence of situation models can also been seen in the selective processing of causal information. A study by Radvansky, Copeland, and Zwaan (2003b) involved having people read stories conveying functional or non-functional spatial relations. What was observed was that the older adults showed a memory benefit for functional information, like the younger adults. Moreover, this benefit was greater for older adults such that the normal memory deficit that is observed with ageing was completely absent. Thus, when older adults are creating situation models as they read, they are more likely to select out and encode that information that is more central or important to understanding the situation, and are less likely to encode more peripheral details of an event they are reading about.

Finally, work on situation models in memory and ageing also shows that older adults process situation model information in working memory in a manner similar to younger adults. This is evident when they are presented with a situation in which people need to update their situation models. Situation model updating involves an increase in the processing load on working memory resources because a person needs to maintain aspects of the situation that continue to be relevant, remove elements that are no longer relevant, and incorporate new elements that are important in the new situation. This all needs to be done relatively quickly and with a minimum of error in order for successful understanding to be achieved. Despite the general processing difficulties older adults have with working memory and other aspects of cognition, it does not appear that older adults have any greater difficulty with this updating process per se. Research has found that older adults are as effective as younger adults in updating their situation models when there has been a shift in space or time (Radvansky et al., 2003a) or after the successful completion of a character's goal (Radvansky & Curiel, 1998). Thus, older adults are also effective in processing situation models in working memory as well as having preserved abilities in long-term memory.

Not only does long-term memory for situations appear to be well preserved in older adults, but the way that they manage information about a described situation also appears to be similar to that of younger adults. Studies looking at the updating of situation models in working memory with ageing show that, across situational shifts, older adults continue to maintain information that is relevant, and successfully remove information that has become irrelevant. Thus, there is a preserved ability to handle information in memory when that information is integrated into a person's interpretation of a set of circumstances.

CONCLUSIONS

This chapter has looked at what situation models are and how they influence and are influenced by various memory processes. These situation models are referential representations that capture the circumstances that a text describes; they are not representations of a text itself. Thus, in the real world, these are the memory representations that people are most likely to use in their day-to-day activities. This is supported by the finding that many memory decisions involve the use of information that is stored in a situation model, and that these sorts of representations are the most enduring. We care about the events that we read about. It is much rarer that we are interested in the language used to describe those events.

Situation models in memory help us integrate not only a text that we may read but also the inferences we draw. By putting all of this information together in a more complete understanding of the world we can improve our memory for those events. Even the active comprehension of events and situations in working memory reflects some of the advantages that can occur when we possess an awareness of the structure of the situation and how it unfolds. This ability is relatively robust. The ability to create and use situation models when comprehending text appears to reflect a more primitive ability to understand situations, and this is used in remembering events that are experienced through film or even in an interactive environment. Furthermore, although there are a number of cognitive declines that accompany age-related changes in the nervous system, we retain the ability to remember the events that we have encountered, even when we only read about those events.

REFERENCES

Anderson, A., Garrod, S.C., & Sanford, A.J. (1983). The accessibility of pronominal antecedents as a function of episode shifts in narrative texts. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 35(A)*, 427–440.

Anderson, J.R. (1974). Retrieval of propositional information from long-term memory. *Cognitive Psychology, 6*, 451–474.

Barwise, J., & Perry, J. (1983). *Situations and attitudes*. Cambridge, MA: MIT Press.

Bower, G.H., & Morrow, D.G. (1990). Mental models in narrative comprehension. *Science, 247*, 44–48.

Bower, G.H., & Rinck, M. (2001). Selecting one among many referents in spatial mental models. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 27*, 81–98.

Bransford, J.D., Barclay, J.R., & Franks, J.J. (1972). Sentence memory: A constructive versus interpretive approach. *Cognitive Psychology, 3*, 193–209.

Clayton, K., & Habibi, A. (1991). Contribution of temporal contiguity to the spatial priming effect. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17*, 263–271.

Craik, F.I.M., & Byrd, M. (1982). Aging and cognitive deficits: The role of attentional resources. In F.I.M. Craik & S. Trehaub (Eds.), *Aging and cognitive processes* (pp. 191–211). New York: Plenum Press.

Curiel, J.M., & Radvansky, G.A. (1998). Mental organization of maps. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 24*, 202–214.

Curiel, J.M., & Radvansky, G.A. (2002). Mental maps in memory retrieval and comprehension. *Memory, 10*, 113–126.

Duffy, S.A., Shinjo, M., Myers, J.L. (1990). The effect of encoding task on memory for sentence pairs varying in causal relatedness. *Journal of Memory and Language, 29*, 27–42.

Franklin, N., & Tversky, B. (1990). Searching imagined environments. *Journal of Experimental Psychology: General, 119*, 63–76.

Garnham, A. (1981). Mental models as representations of text. *Memory & Cognition, 9*, 560–565.

Glenberg, A.M., Meyer, M., & Lindem, K. (1987). Situation models contribute to foregrounding during text comprehension. *Journal of Memory and Language*, *26*, 69–83.
Hamm, V.P., & Hasher, L. (1992). Age and the availability of inferences. *Psychology and Aging*, *7*, 56–64.
Hasher, L., & Zacks, R.T. (1988). Working memory, comprehension, and aging: A review and a new view. G. Bower (Ed.), *The psychology of learning and motivation: Advances in research and theory*, *Vol. 22* (pp. 193–225). San Diego, CA: Academic Press.
Jahn, G. (2004). Three turtles in danger: Spontaneous construction of causally relevant spatial situation models. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *30*, 969–987.
Johnson, R.E. (2003). Aging and the remembering of text. *Developmental Review*, *23*, 261–346.
Johnson-Laird, P.N. (1983). *Mental models: Towards a cognitive science of language, inference, and consciousness.* Cambridge, MA: Harvard University Press.
Keenan, J.M., Baillet, S.D., & Brown, P. (1984). The effects of causal cohesion on comprehension and memory. *Journal of Verbal Learning and Verbal Behavior*, *23*, 115–126.
Kintsch, W., & Bates, E. (1977). Recognition memory for statements from a classroom lecture. *Journal of Experimental Psychology: Human Learning and Memory*, *3*, 150–159.
Kintsch, W., Welsch, D., Schmalhofer, F., & Zimny, S. (1990). Sentence memory: A theoretical analysis. *Journal of Memory and Language*, *29*, 133–159.
Lutz, M.F., & Radvansky, G.A. (1997). The fate of completed goal information in narrative comprehension. *Journal of Memory and Language*, *36*, 293–310.
Morrow, D.G., Greenspan, S.L., & Bower, G.H. (1987). Accessibility and situation models in narrative comprehension. *Journal of Memory and Language*, *26*, 165–187.
Myers, J.L., Shinjo, M., & Duffy, S.A. (1987). Degree of causal relatedness and memory. *Journal of Memory and Language*, *26*, 453–465.
Noice, T., & Noice, H. (2002). Very long-term recall and recognition of well-learned material. *Applied Cognitive Psychology*, *16*, 259–272.
Radvansky, G.A. (1999). The fan effect: A tale of two theories. *Journal of Experimental Psychology: General*, *128*, 198–206.
Radvansky, G.A., & Copeland, D.E. (2000). Functionality and spatial relations in situation models. *Memory & Cognition*, *28*, 987–992.
Radvansky, G.A., & Copeland, D.E. (2001). Working memory and situation model updating. *Memory & Cognition*, *29*, 1073–1080.
Radvansky, G.A., & Copeland, D.E. (2006). Walking through doorways causes forgetting. *Memory & Cognition*, *34*, 1150–1156.
Radvansky, G.A., Copeland, D.E., Berish, D.E., & Dijkstra, K. (2003a). Aging and situation model updating. *Aging, Neuropsychology and Cognition*, *10*, 158–166.
Radvansky, G.A., Copeland, D.E., & Von Hippel, W. (2006). *Stereotype activation, prejudice and aging.* Manuscript submitted for publication.
Radvansky, G.A., Copeland, D.E., & Zwaan, R.A. (2003b). Aging and functional spatial relations in comprehension and memory. *Psychology and Aging*, *18*, 161–165.
Radvansky, G.A., Copeland, D.E., & Zwaan, R.A. (2005a). A novel study: The mental organization of events. *Memory*, *13*, 796–814.
Radvansky, G.A., & Curiel, J.M. (1998). Narrative comprehension and aging: The fate of completed goal information. *Psychology and Aging*, *13*, 69–79.
Radvansky, G.A., Gerard, L.D., Zacks, R.T., & Hasher, L. (1990). Younger and older adults' use of mental models as representations for text materials. *Psychology and Aging*, *5*, 209–214.
Radvansky, G.A., Spieler, D.H., & Zacks, R.T. (1993). Mental model organization. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *19*, 95–114.
Radvansky, G.A., Wyer, R.S., Curiel, J.C., & Lutz, M.F. (1997). Situation models and

abstract ownership relations. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *23*, 1233–1246.

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

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

Radvansky, G.A., Zacks, R.T., & Hasher, L. (2005b). Age and inhibition: The retrieval of situation models. *Journal of Gerontology: Psychological Sciences*, *60B*, 276–278.

Radvansky, G.A., Zwaan, R.A., Curiel, J.M., & Copeland, D.E. (2001). Situation models and aging. *Psychology and Aging*, *16*, 145–160.

Radvansky, G.A., Zwaan, R.A., Federico, T., & Franklin, N. (1998). Retrieval from temporally organized situation models. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 24, 1224–1237.

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

Sachs, J.S. (1967). Recognition memory for syntactic and semantic aspects of connected discourse. *Perception & Psychophysics*, 2, 437–442.

Salthouse, T.A. (1996). The processing-speed theory of adult age differences in cognition. *Psychological Review*, *103*, 403–428.

Schmalhofer, F., & Glavanov, D. (1986). Three components of understanding a programmer's manual: Verbatim, propositional, and situational representations. *Journal of Memory and Language*, *25*, 279–294.

Singer, M., Halldorson, M., Lear, J.C., & Andrusiak, P. (1992). Validation of causal bridging inferences in discourse understanding. *Journal of Memory and Language*, *31*, 507–524.

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

Trabasso, T., & Sperry, L.L. (1985). Causal relatedness and importance of story events. *Journal of Memory and Language*, *24*, 595–611.

Trabasso, T., & Van den Broek, P.W. (1985). Causal thinking and the representation of narrative events. *Journal of Memory and Language*, *24*, 612–630.

Van den Broek, P. (1994). Comprehension and memory of narrative texts: Inferences and coherence. In M.A. Gernsbacher (Ed.), *Handbook of psycholinguistics* (pp. 539–588). San Diego, CA: Academic Press.

Van Dijk, T.A., & Kintsch, W. (1983). *Strategies in discourse comprehension*. New York: Academic Press.

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

Wyer, R.S., & Radvansky, G.A. (1999). The comprehension and validation of social information. *Psychological Review*, *106*, 89–118.

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

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

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

Zwaan, R.A., Radvansky, G.A., Hilliard, A.E., & Curiel, J.M. (1998). Constructing multidimensional situation models during reading. *Scientific Studies of Reading*, 2, 199–220.

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