Spatial Situation Models and Narrative Understanding: Some Generalizations and Extensions

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The generality of effects of situation models on narrative comprehension was investigated. In three experiments, a spatial gradient of accessibility in situation models was observed. The accessibility of objects contained in the situation model decreased with increasing spatial distance between the object and the focus of attention in the readers’ situation model. A variety of factors that might influence the spatial gradient effect were investigated: the way the relevant spatial information was acquired (studying a text vs. a layout), the spatial scenario (a research center vs. a day care center), the direction of spatial distance (backward vs. forward on the route), the language used (English vs. German), the manner in which the accessibility of objects was probed (object probe pairs vs. anaphoric sentences), the existence of prior knowledge about the objects (objects learned as part of the scenario vs. unknown objects), and the participants’ task (reading narratives vs.

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imagining their own movements). Despite these variations, a spatial gradient was observed in all three experiments, indicating that the effects of spatial situation models may be generalized to a variety of experimental paradigms and cognitive tasks.

Many theories of text comprehension assume that readers form mental models or situation models of the information described by texts (e.g., Garnham & Oakhill, in press; Gentner & Stevens, 1983; Graesser, Singer, & Trabasso, 1994; Johnson-Laird, 1983; Kintsch, 1988, 1992; van Dijk & Kintsch, 1983). Situation models constitute a level of text representation different from other levels such as the text base or the surface level (e.g., Fletcher & Chrysler, 1989; Perrig & Kintsch, 1985; Schmalhofer & Glavano, 1986), and serve to integrate the information stated in a text with general information supplied by the reader’s world knowledge. As Glenberg, Meyer, and Lindem (1987, p. 70) stated, “Mental models represent what the text is about, not the text itself.” It has been argued whether situation models are generally constructed during narrative comprehension (McKoon & Ratcliff, 1992; Morrow, 1994; Zwaan & van Oostendorp, 1993, 1994), and different definitions of the term situation model have been proposed (see Wilson & Rutherford, 1989). However, one consensual feature of situation models seems to be that, given they are constructed by the reader, they can represent many different aspects of the situation described in a text. Among these aspects are the goals, actions, and emotions of the main character as well as the causal, temporal, and spatial relations of objects, characters, and actions in the situation. Moreover, the situation changes and evolves during the course of a narrative; for example, the characters’ goals, emotions, and locations change. Thus, readers continually have to change parts of their situation model during reading, a process known as updating of situation models (de Vega, 1995; Morrow, Bower, & Greenspan, 1989).

These studies investigated the updating of spatial relations in spatial situation models. The spatial relations that are represented in situation models would include information about the protagonist’s present location, the path the protagonist follows when moving through space, what the described locations are like, and where important objects and actors are located. Many studies have shown that spatial characteristics of situation models guide the allocation of attention. Specifically, readers focus their attention on the protagonist of the narrative and on his or her location. As a result, objects spatially close to the protagonist become more primed and accessible than spatially distant objects (Bower & Morrow, 1990; de Vega, 1995; Glenberg et al., 1987; Haenggi, Gernsbacker, & Bolliger, 1994; Haenggi, Kintsch, & Gernsbacker, 1995; Morrow, 1985; Morrow et al., 1989; Morrow, Greenspan, & Bower, 1987; Morrow, Leirer, Altieri, & Fitzsimmons, 1994; Morrow, Leirer, Andrassy, & Stine, 1994; O’Brien & Albrecht, 1992; Rinck & Bower, 1995; Wilson, Rinck, McNamara, Bower, & Morrow, 1993).

In the experiments reported by Morrow et al. (1987, 1989), a spatial gradient of accessibility was repeatedly observed. The accessibility of objects gradually decreased with increasing distance from the protagonist. Those studies followed a common procedure in which participants first learned the layout of a building (similar to the one depicted in Figure 1) and the location of numerous objects in that building. Afterwards, they read a series of narratives about activities occurring in that building. Thus, for each narrative, the participants’ situation model represents an integrated body of knowledge acquired from the layout, the narrative, and prior knowledge. The narratives contained motion sentences that described the protagonist’s movement from a “Source Room” through an unmentioned “Path Room” into a “Location Room”; for example, “Wilbur walked from the library into the storage room” (see Figure 1). The accessibility of objects in readers’ memory was measured on-line with test probes consisting of pairs of named objects presented just after participants had read a motion sentence in the narrative, for example, “computer - scales.” For each test probe, those participating had to decide whether the two objects were located in the same room or in different rooms.

The decision times observed by Morrow et al. (1987, 1989) revealed a gradu-
al spatial distance effect: The objects were more accessible if they were closer to the participants' current focus of attention, which was usually the current location of the protagonist. Objects located in the same room as the protagonist (the Location Room) were more quickly accessed than objects from the unmentioned Path Room that the protagonist had just passed through in moving to the Location Room. These Path Room objects were in turn more quickly accessed than (a) objects in the Source Room from which the protagonist had commenced his or her movement, and (b) objects in some "Other" Room of the building which was not recently visited in the narrative. The higher accessibility of Path Room objects is particularly important because it cannot be explained by any text-based account of comprehension, thereby supporting the notion of situation models.

Although those experiments indicate that the spatial distance effect is real and replicable, serious doubts about the generality of the effect remain. Most replication studies used the same spatial scenario (a fictitious research center with a number of objects in it), similar narratives, the same way of acquiring the relevant spatial information (by studying a spatial layout), and the same measure of accessibility (judging probes of object pairs). These similarities limit the value of converging evidence from different replications because it remains unclear whether the occurrence of a spatial gradient is limited to the exact experimental conditions that were investigated. In fact, the spatial gradient has proved to be sensitive to slight variations in the kind of test probes used (Wilson et al., 1993). In order to observe a spatial gradient, so-called "protagonist probes" need to be included among the experimental test probes. Protagonist probes consist of an object and the protagonist's name; for example, "Wilbur—crates," and participants have to decide whether they are located in the same room at the time of probe presentation. These probes persuade participants to keep track of the protagonist's location while reading the narrative, thereby inducing deeper processing of spatial information. As Wilson et al. (1993) showed, simply leaving out the protagonist probes can eliminate the spatial gradient completely. On the other hand, Rinck and Bower (1995) found robust spatial gradients when participants read anaphoric references to objects at varying distances from the protagonist, in a "natural reading" task involving no location-probe tests at all.

Although the results of Wilson et al. (1993) might be interpreted as evidence for the claim that spatial distance effects and the building of situation models are limited to very specific experimental conditions (McKoon & Ratcliff, 1992), some evidence for the generality of the effect has been reported as well. At least a difference in accessibility for objects spatially close to the protagonist versus spatially far from the protagonist has been observed in several studies using different materials and paradigms (Glenberg et al., 1987; Haenggi et al., 1994, 1995). Results of these studies indicate that spatially close objects are more accessible than distant objects. Second, as noted earlier, Rinck and Bower (1995) showed that the occurrence of a spatial gradient is not limited to the specific task of judging object probes. In four experiments, Rinck and Bower measured acces-

sibility by the time participants needed to read and resolve anaphoric references (see also Morrow, Leirer, Andrassy, & Stine, 1994). Instead of judging object probes, their participants merely read target sentences containing anaphoric references to an object that lay at varying distances from the protagonist (e.g., "Wilbur thought that the shelves in the library still looked like a mess"). Reading times of the target sentences revealed a spatial gradient similar to that observed by Morrow et al. (1989).

Therefore, it seems important to determine the exact conditions that affect the occurrence of distance effects in situation models. If the occurrence of a spatial gradient were limited to a specific set of conditions, materials, or paradigms, the importance of the phenomenon would be seriously compromised. In three experiments, we investigated several factors that might be expected to affect the distance effect. One factor was the manner in which the relevant spatial information was acquired; participants studied either a visual layout or a textual description of it. Second, different narratives and spatial scenarios were used, namely, a research center and a day care center. Third, we probed the accessibility of objects that were in rooms ahead of, as well as behind, the protagonist along his or her path through the building. Fourth, English materials were presented to American participants or German materials to German participants. Fifth, the method of probing the accessibility of objects was varied; we used either object probe pairs or anaphoric sentences. Sixth, the objects referred to by anaphoric sentences were either learned as part of the scenario or were unknown before reading of the narratives. Finally, the participants' task was either to read narratives or to imagine their own movements between named locations in the spatial layout.

EXPERIMENT 1

This experiment investigated three factors that might possibly limit the effects of situation models and the occurrence of a spatial gradient. First, a novel spatial scenario (a fictitious day care center) and new narratives were used instead of the research center used in the Morrow et al. studies (1987, 1989; Morrow, Leirer, Altieri, & Fitzsimmons, 1994; Morrow, Leirer, Andrassy, & Stine, 1994). To our knowledge, the only other scenario ever investigated was a medieval castle, used by Haenggi et al. (1994, 1995). Haenggi et al., however, did not investigate a spatial gradient of accessibility. In addition to extending the paradigm to a new scenario, the day care center eliminated some potential problems with buildings used in previous experiments, in which objects were often highly associated with the rooms they were located in, rooms were different sizes, and only one room contained a door to the outside. The day care center used in Experiment 1 contained five classrooms of equal surface area, each designated by a neutral name (see Figure 2). Thus, the probe objects, though more or less associated with day care centers in general, had comparable preexperimental associations with each of the individual rooms.
Second, we developed two different sets of materials to teach participants about the day care center. In the layout condition, participants studied a bird's-eye, overview layout of the entire building, as in previous experiments. In the text condition, participants read a narrative description of the building, with successive paragraphs describing each room and its contents. After learning the building layout from either the layout or the text, participants read narratives and responded to object probes in the same manner as in Morrow et al. (1987). We anticipated that participants in both learning conditions would be faster to respond to objects that were spatially close to the protagonist than to spatially distant objects. This finding would confirm those from other studies indicating that participants use situation models in a similar fashion, regardless of whether those models were acquired from a text or a map (e.g., Denis & Cocude, 1989, 1992; Denis & Zimmer, 1992; Haenggi et al., 1995; Taylor & Tversky, 1992). Naturally, one would not expect identical representations of the spatial relations after learning about them from text or layouts. For instance, the layout contains more detailed configurational information and presents all rooms simultaneously. However, for the purposes of this study, the two learning conditions should be functionally equivalent because the same critical knowledge should be acquired in both conditions; that is, which objects are located in each room and how the rooms are connected to each other.

Third, in addition to probing the accessibility of objects located in rooms that the protagonist had already visited, we also used test probes that contained objects from rooms further ahead on the protagonist's route. Conceivably, once they infer the protagonist's route, readers might extrapolate the protagonist's current location to activate the location next-in-line, similar to the representational "momentum" observed by Freyd (1987). If accessibility of objects is affected mainly by their distance from the protagonist, a spatial gradient should be observed for both directions. Specifically, objects located in the same room as the protagonist should be easiest to access, and objects located in rooms close ahead should be easier to access in memory than objects far ahead, just as objects close behind are more accessible than objects far behind. In addition, one might expect rooms behind to be more accessible than rooms ahead because only the former have been recently activated explicitly or implicitly. Thus, the spatial gradient around the protagonist's current location is not expected to be symmetric. However, if there is a representational momentum, there should be a monotonic decrease in accessibility as a function of increasing distance in both directions.

Method

Participants. Sixty-seven Stanford University undergraduates participated in the experiment. They were compensated either by cash payment or course credit. A total of seven of these students were excluded from the analyses. Four text participants could not learn the building description to criterion, so they were excluded from the story phase. Three others were also excluded; one participant from each condition failed to understand the instructions, and one layout participants' performance indicated that he was answering questions randomly. Complete data were available for 30 participants in each learning condition.

Learning Materials. The experimental building was described as a day care center, with five rooms and four objects in each room (see Figure 2). Each room was a classroom, designated by a teacher's name. All rooms had the same surface area and included a door to the outside. Participants in the layout condition studied the layout as shown in Figure 2. Those in the text condition read a narrative description of the building, with one paragraph describing each room. A sample paragraph is presented below.

"Passing through the door into Ms. Lee’s room, notice the huge globe that Ms. Lee uses to teach geography. She is the only teacher in the building that finds it necessary to have a desk (she thinks it’s a symbol of authority). But lest you think she is too authoritarian, look inside the toybox, which is spilling over with goodies. The school’s computer is located here, and its educational software is used by all the children. This room is connected to Ms. Smith’s room, Ms. May’s room, and the outside.”

Figure 2. Building layout memorized by participants in the Layout condition of Experiment 1.
It should be noted that the paragraph does not indicate the exact locations of objects within a room; therefore, the information presented in the description is somewhat more ambiguous than that presented in the layout. However, precise object locations were not required in order to convey the room−object and room−room associations that were needed for an adequate representation of the building. Moreover, including exact locations would have made the text cumbersome and unnatural. One half of the text participants read a “clockwise” narrative that started in Ms. Smith's room and ended in Ms. Brown's room, whereas the other half read a “counterclockwise” text that used identical paragraphs, but started in Ms. Brown's room and ended in Ms. Smith's room.

**Narratives and Probes.** We developed one practice and 10 test stories, each consisting of 20 sentences (an example is given in Table 1). The main character was first introduced, located in a particular room, given a goal that he or she had to complete, then moved sequentially through the other four rooms, and eventually returning to the starting point. In half the stories, the protagonist moved clockwise through the building; in the other half, he or she moved counterclockwise. While reading the stories, participants were interrupted at certain points with two object names and required to decide whether the two objects were in the same room with one another in different rooms. A probe occurred after each motion sentence, (“Then he walked from Ms. May's room into Ms. Hill's room”), as well as after other randomly selected sentences.

Five same room and two different room probe types were used. The same room probes consisted of two objects from a room that was a particular route distance away from the room the protagonist had just moved into; for example, after a motion sentence such as “Then Arnold walked from Ms. Brown's room into Ms. Hill's room.” Location room probes were from the room that served as the protagonist’s goal in the previous motion sentence (e.g., rug-clock), –1 room probes were from the room the protagonist had just moved out of (e.g., map-casel), +1 room probes were from the next room the protagonist would visit along the route (e.g., mirror-blocks), and –2 room probes (e.g., fountain-chalkboard) and +2 room probes (e.g., globe-desk) were from two rooms backwards or forwards along the route from the protagonist’s current location. Across stories, every participant saw six instances of each of these five probe types.

The two analogous different room probe types were location/other probes and other/other probes. The former contained one object from the location room and one from another room (e.g., stage-cot), whereas the latter contained two objects from two rooms other than the location room (couch-globe). Across the 10 stories, each participant responded to 10 of each of these probe types. The final 2 probe types were protagonist probes, which paired the name of the protagonist with an object. Participants were to answer “Same” if, at the time of the probe, the protagonist was in the room containing the object named in the probe (e.g., Arnold-sink), and “Different” otherwise (e.g., Arnold-closet). These probes were included to ensure that participants kept track of the protagonist’s movements (see Wilson et al., 1993). Whereas the other seven probe types occurred only after motion sentences, protagonist probes came only after sentences in which the protagonist did not move, thus upsetting the otherwise regular routine of motion sentences and test probes. Across test stories, every participant had to respond “Same” 38 times and “Different” 29 times. There were five different sets of probes, so that across subjects, every potential same room object pair was used equally often in each probe type.

**Procedure.** The entire procedure, including all instructions, was controlled by a Macintosh computer. After receiving initial instructions, participants began the learning phase. Depending on the experimental condition, they first saw the visual layout or read the description of the building. Layout participants were shown the building layout for 2 min. Text participants saw paragraphs describing the individual rooms. One paragraph appeared on the screen at a time. Participants could move on to the next paragraph by pressing a designated key. If they
had not pressed the key after 60 s, the computer moved on to the next paragraph automatically. After having studied the layout or all five paragraphs, participants were tested on the critical information about the rooms and objects. Tests were identical for both learning conditions and consisted of 10 questions of the form “In which room is the fountain?” and 2 of the form “Which two rooms are adjacent to Ms. Hill’s room?” These questions required that participants learn both the room-locations of the objects and the spatial adjacencies of the rooms. The tests were administered and scored by the computer. These study-test cycles were repeated until participants reached the criterion of perfect scores on two consecutive tests, at which point they moved on to the reading phase of the experiment. Participants who were unable to attain 2 correct tests in 10 trials were not allowed to proceed. Four text participants, but no layout participants, were replaced for failing to reach learning criterion.

In the reading phase, those who participated read stories presented one sentence at a time on the computer screen. Each person read 1 practice story, then 10 test stories. They pressed the space bar to begin each narrative and to proceed from one sentence to the next. When an object pair probe appeared instead of a sentence, they pressed a key labeled “Same” (the J key) to respond “Same room” or a key labeled “Different” (the F key). Sentences and probes appeared 500 ms after the space bar was pressed. Participants were instructed to read the narratives carefully and to respond to the test probes as quickly and accurately as possible. After each story, they were cautioned if they had responded incorrectly to any probes.

Each story was followed by two comprehension questions. The first queried an action that occurred in the story, and asked in which room that action had taken place; for example, “In whose room did Arnold see the drawing of himself?” The second was a multiple-choice question about some fact mentioned in the story; for example, “What did Arnold think of the paintings in Ms. Smith’s room? a) they were offensive, b) they were silly, c) they were creative.” Immediately after the reading phase, participants were given a blank piece of paper and asked to draw what they thought the building layout looked like. These drawings indicated how text subjects “pictured” the building and served as a recall measure for all conditions.

Design. Independent analyses were conducted for same room and different room probes. Both analyses involved the between-subjects factor learning condition (30 participants studying the layout, 30 the text) and the within-subjects factor target room type. Target room type had five types of same room probes (−2, −1, Location +1, +2 Room), and two types of different room probes (location/other, other/other). In addition, layout and text participants’ performance during the learning task and during responses to protagonist probes was compared. Number of learning trials, latencies of responses to test probes and error rates of the responses served as dependent variables.

Results and Discussion
Statistical analyses were carried out using the logarithmic transformations of object probe reaction times (RTs). Log transformations were computed because the distribution of RTs was positively skewed. Several incidental variables (probed room, protagonist location room, object probe list, direction of learning, direction of protagonist movement) were counterbalanced in the experimental design, and none of these factors produced significant effects or interacted with variables of interest. All effect sizes reported below (with the $f$ statistic) were computed according to Cohen (1988).

Layout Learning and Protagonist Probes. Layout participants learned the layout more quickly, taking an average of 4.0 test trials to reach criterion in the learning phase, compared to 5.5 trials for those text participants who reached criterion, $t(58) = 3.52, p < .01, f = .45$. On protagonist probes, layout participants responded faster than text participants ($3.23 \text{ vs. } 4.07$ s; $F(1, 58) = 7.88, p < .01, f = .21$), indicating that those who learned the building from a layout were able to update and retrieve the protagonist’s current location more easily than text participants. The error rates on Protagonist Probes did not differ significantly between layout and text participants (1.7% vs. 3.0%; $F(1, 58) = 1.48, ns$, $f = .15$). This evidence suggests possible differences in the ease of updating the situation model, depending on how the building layout was learned. In accordance with the results observed by Haenggi et al. (1995), it is possible that text participants had to infer spatial relations during narrative comprehension whereas layout participants had learned these relations before. Indeed, many of the Text participants’ postexperimental drawings of the building bore little resemblance to the drawings reproduced by layout participants—a result not uncommon for participants who construct maps from verbal descriptions (Ferguson & Hegarty, 1994). However, the critical spatial relations were almost always correct in both conditions: Objects were located in the correct rooms and adjacent rooms were connected to each other correctly.

Same Room and Different Room Probes. The patterns of reaction times for same and different room probes provided no evidence that participants in different learning conditions updated their situation models differently. Mean probe reaction times and error rates for different room and same room probes are given in Table 2. Error rates were low in all conditions and did not vary systematically with experimental conditions within same room or different room probes. As expected for the different room probes, participants responded more quickly to location/other probes than to other/other probes (3.08 s vs. 3.21 s). However, this effect fell short of statistical significance, $F(1, 58) = 2.2, p < .15, f = .08$. Neither learning condition nor the interaction of learning condition and probe type had a statistically reliable effect on different room RTs (both $F(1, 58) < 1, f < .06$).
TABLE 2
Mean Reaction Times in Seconds (With Standard Deviations) and Error Rates for Different
and Same Room Probes in Experiment 1

<table>
<thead>
<tr>
<th>Learning Condition</th>
<th>Location/ Other</th>
<th>Other/ Other</th>
<th>-2 Room</th>
<th>-1 Room</th>
<th>Location Room</th>
<th>+1 Room</th>
<th>+2 Room</th>
</tr>
</thead>
<tbody>
<tr>
<td>Text</td>
<td>3.13</td>
<td>3.25</td>
<td>3.43</td>
<td>3.24</td>
<td>3.11</td>
<td>3.46</td>
<td>3.35</td>
</tr>
<tr>
<td>SD</td>
<td>.71</td>
<td>.91</td>
<td>1.02</td>
<td>.89</td>
<td>.68</td>
<td>.91</td>
<td>1.00</td>
</tr>
<tr>
<td>Errors</td>
<td>2.0%</td>
<td>1.7%</td>
<td>6.7%</td>
<td>7.2%</td>
<td>6.7%</td>
<td>7.2%</td>
<td>11.7%</td>
</tr>
</tbody>
</table>

| Layout             | 3.03            | 3.17         | 3.07    | 2.97    | 2.85          | 3.03    | 2.89    |
| SD                 | .68             | .86          | .93     | .63     | .81           | .85     | .68     |
| Errors             | 1.0%            | 3.7%         | 9.5%    | 5.6%    | 6.7%          | 10.6%   | 7.2%    |

Mean response latencies for same room probes varied significantly by target room type, $F(4, 232) = 2.59, p < .05, f = .12$, and marginally by learning condition, $F(1, 58) = 3.15, p < .10, f = .21$. The latter result indicates that layout participants tended to respond a little faster than text participants. As expected, the interaction of the two factors was not significant, $F(4, 232) < 1, f = .04$, so subsequent analyses were collapsed over learning conditions. For the most part, the pattern of distance effects replicates those found previously (Morrow et al., 1987, 1989; Morrow, Leier, Altieri, & Fitzsimmons, 1994; Morrow, Leier, Andrassy, & Stine, 1994). For same room probes, reaction times should increase as the distance between the location room and the probed target room increases. A linear contrast test indicated that RTs indeed increased from the location room to the -1 room and further to the -2 room, $F(1, 118) = 7.18, p < .01$. Also as expected, location room probes were responded to faster than +1 room probes ($t(59) = 2.71, p < .01$). However, the spatial gradient did not extend to the +2 room probes: Responses to these probes did not differ significantly from the +1 room probes ($t(59) = 1.38, n.s.$). In fact, the difference fell in the unexpected direction: Responses to +2 room probes were somewhat faster than responses to +1 room probes.

To summarize, the results of Experiment 1 clearly indicate that the occurrence of a spatial gradient of accessibility is not limited to a specific spatial layout or specific object–room assignments. The pattern of RTs observed for target rooms used in previous studies (namely, location room, -1 room, and -2 room) was virtually identical to that found previously. Second, the results indicate that different methods of acquiring a situation model do not cause different ways of accessing information from the model during later narrative comprehension. Although participants in the text condition took longer to acquire a situation model and their postexperimental drawings of the building were more variable than the drawings of participants who studied the layout, both groups showed the same pattern of distance effects. Third, extending the investigation of spatial distance effects to rooms ahead of the protagonist’s route revealed that RTs to objects from the +1 room were slower than those from the location room, as was expected by a spatial gradient. The surprising result from the present experiment was that responses to probes from the +2 room were not slower than responses to probes from the +1 room. On the contrary, they seemed to be a bit faster, which runs counter to the expected monotonic effect of distance from the focal point in situation models. If there is a representational momentum, it apparently extends to only one room, not two rooms. Although one could discard this as a chance result, the fact that it appeared in both learning conditions seemed intriguing to us. Therefore, we decided to replicate the +1 room and +2 room conditions in Experiment 2 before dismissing the finding or speculating about possible explanations.

EXPERIMENT 2

The spatial gradient of accessibility in situation models has been studied exclusively with English materials presented to American participants. Therefore, a basic and important test of the spatial gradient is to assess whether it generalizes to different languages and countries. This was achieved by conducting Experiment 2 with a German-labeled layout and German narratives presented to German participants. We expected to find a spatial gradient of accessibility that is comparable to that found in previous studies because situation models are supposed to be nonlinguistic representations. Furthermore, the German language specifies location by prepositions and verb aspect similar to English. Thus, anything but a replication of the spatial gradient of accessibility would cast serious doubts on the generality of the effect.

The same strong expectation holds for our use of anaphoric references to novel objects as a measure of their accessibility. It has been shown repeatedly that spatial distance effects generalize to different measures of accessibility, each with specific advantages and disadvantages (see Haenggi et al., 1994, Exp. 2; Rinck & Bower, 1995; and Wilson et al., 1993). Anaphoric references were used in the present experiment because they allow us to refer to novel objects introduced during narrative comprehension. In all previous studies of the spatial gradient, the objects and their location in the spatial layout were learned before any narratives were read. Admittedly, this is a rather artificial situation. Even if writers use texts or layouts to inform their readers about the spatial scenario of a narrative, they rarely bother to include all objects that might be mentioned later in the narrative. Instead, novel objects and people are constantly introduced during the course of reading, rarely causing comprehension problems. In Experi-
ment 2, after participants had studied a layout containing only room names, target sentences were used to refer to novel objects located in rooms at varying distances from the protagonist's current location. Because these objects had never been mentioned prior to the target sentence, they could not be accessed in memory. Instead, we supposed that readers would call to mind the room in question and then place in it a token representing the novel objects. Alternatively, they would simply set up a location link between the two concepts; for example, the room and the novel object. In either case, the creation of a memory representation for a new object should add some time to the overall comprehension time, but should not affect the time needed to access the target room. The accessibility of the target room itself should decrease directly with the distance between the room and the protagonist's current location. Thus, the target sentences used in Experiment 2 served to extend previous results by probing the accessibility of target rooms instead of objects. As in Experiment 1, we probed the accessibility of rooms that the protagonist had already visited as well as rooms further ahead on his or her route.

One additional variation was included in Experiment 2 in order to answer a question raised by Rinck and Bower (1995). In their experiments, spatial distance between the protagonist and the referent of an anaphoric noun phrase within a target sentence affected comprehension times of the target sentence and also the neutral sentence following the target sentence. For these "following sentences," a spatial gradient was observed that was similar to the gradient observed for the preceding target sentences. Two alternative explanations for this effect were offered by Rinck and Bower (1995). The reshifting of attention explanation states that, after the target sentence has shifted participants' attention to the target room containing the object, they have to shift their attention back to the protagonist's location to understand the following sentence. This shift should take longer the further away the target room is from the protagonist's location in the situation model. The alternative explanation assumes that there is a spill-over of processing from the target sentence (de Vega & Diaz, 1991). That is, if an anaphoric reference in the target sentence is difficult to understand, some additional processing of the anaphor may continue as the following sentence is being read, thus slowing its reading speed.

To test these alternative explanations, we introduced two different types of following sentences in Experiment 2. Half of the following sentences clearly left the focus of attention in the target room by elaborating on the topic mentioned in the target sentence. The other following sentences clearly shifted the focus back to the protagonist's location by introducing a topic related to the current location room. According to the reshifting explanation, a spatial gradient for the reading of the following sentences should be observed only with the latter type of following sentences. If the spill-over explanation is correct, however, a gradient should be observed with both types of following sentences.

Method

Participants. Fifty undergraduates of the Technical University of Dresden, Germany, participated in the experiment to fulfill a course requirement. The data of 3 additional students were excluded from all analyses because of their high error rates on the comprehension questions that followed each narrative (see below).

Layout and Narratives. Participants memorized the layout of a fictitious research center containing 10 rooms. The layout was equivalent to the one depicted in Figure 1; however, it did not contain any objects and the room names were translated into German. Participants studied the layout until they could reproduce the 10 room names perfectly from memory. After learning the layout, 19 narratives were read; namely, 3 practice narratives followed by 16 test narratives. The narratives were translations of the materials used by Rinck and Bower (1995) which were in turn based on the original Morrow et al. (1989) materials. Each narrative was approximately 20 sentences long and described the actions of a protagonist who moved through the building trying to fulfill a goal; for example, to search for a package. An example of a test narrative is shown in Table 3, translated into English. Each test narrative contained critical motion sentences that described a complete motion event in which the protagonist walked from one room (source room) through an unmentioned room (path room) into a third room (location room). After each motion sentence, a motivating sentence was presented to motivate the mental event described in the following target sentence. The target sentence contained a definite noun phrase that referred to some unique object in one of the rooms of the research center. After the target sentence, the following sentence either elaborated on the contents of the target sentence or introduced a new event in the location room. Each narrative was followed by three content questions to check participants' comprehension. To ensure careful reading, participants received an extra 5.00 DM (approx. $3.50) if they answered fewer than 9 of the 57 questions incorrectly. Three participants answered more than 30% of these questions incorrectly, and thus were excluded from all analyses. The average error rate of the remaining 50 participants was 12%.

The accessibility of target rooms was tested with the five different types of target sentences illustrated in Table 3. Each target sentence contained a reference to an object in the building, mentioning the room containing the object. These objects were new to the participants although they were the 40 objects contained in the layout depicted in Figure 1. For example, after a motion sentence such as "So she walked from the office into the library" and a motivating sentence such as "She knew that she had seen a package earlier that day and tried hard to recall where that had been," the target sentence might read "She remembered that she had seen a package below the picture in the office." In this case, the definite noun
TABLE 3
Example of Narrative, Target Sentences, Motivating Sentences, and Following Sentences from Experiment 2

When Maria entered the repair shop, she found a message saying a package had arrived for her. She thought it was probably the new equipment she had been waiting for. Looking around the repair shop, she couldn’t see the package. She asked one of the workers where it was, but he said he couldn’t remember. She got angry because she needed the equipment right away, so she decided to find the package herself. She went into the lounge, but didn’t think the package would be there. Then she walked from the lounge into the reception room. The receptionist remembered signing for the package, but didn’t recall what happened to it after that. Maria was getting more and more impatient, so she went off in a huff to the office. She asked the secretary who shrugged her shoulders and told her to look elsewhere.

**Motion Sentence:**
So Maria walked from the office to the library.

**Motivating Sentence:**
She knew that she had seen a package earlier that day and tried to recall where that had been.

**Target Sentence (one out of five possible types):**
- 2: She remembered that she had seen a package below the picture in the office.
- 1: She remembered that she had seen a package on the table in the conference room.
+ 1: She remembered that she had seen a package beside the copier in the library.
+ 2: She remembered that she had seen a package on the loading dock in the storage room.

**Following Sentence with Focus in Target Room:**
But that package had been for someone else and had been picked up already.

Maria asked the librarian who thought she had seen someone with a package heading for the library sometime in the morning.

Maria felt like giving up, but went into the library for a quick look anyway—but again without success. By now she was feeling pretty disgusted with everyone.

**Motion Sentence:**
Finally, she walked from the laboratory into the wash room.

**Motivating Sentence:**
She started to suspect that some fool had taken her package to hide it somewhere in the building.

**Target Sentence (one out of five possible types):**
- 2: Maybe someone had hidden her package in a strange place, like behind the computer in the laboratory.
- 1: Maybe someone had hidden her package in a strange place, like in the closet in the storage room.
+ 1: Maybe someone had hidden her package in a strange place, like in lockers in the wash rooms.
+ 2: Maybe someone had hidden her package in a strange place, like behind the oven in the repair shop.

**Following Sentence with Focus in Location Room:**
For some reason, all the lights in the wash room were off. Suddenly, the lights came on and a room full of people burst into a song.

She realized the package had been a ruse: While she was chasing after the package, everybody had gathered in the last place she would have thought to look for the package in order to surprise her on her birthday.

**Question 1:** Did the receptionist know anything about Maria’s package?
**Question 2:** Did Maria get some information about her package in the library?
**Question 3:** Did Maria talk to the secretary before talking to the receptionist?

*Note: Original materials were presented in German; explanations are given in the text.*

**Spatial Situation Models**

Phrase *the picture* would refer to an object in the room from which the protagonist had started the last movement (the source room, henceforth −2 room). The target sentence could also refer to an object in the path room (−1 room) that the protagonist had just passed through, or to an object in the room where the protagonist is currently located (location room), or to an object in the next room on the protagonist's route (+1 room), or to an object in the room beyond that one (+2 room). All target sentences described some type of mental action such as thinking, remembering, or deciding about some aspect of the referent object (see Table 3).

In addition to these five different target room types, we also varied whether the following sentence left the focus of attention in the room introduced in the target sentence, or shifted the attention back to the protagonist’s location. "Focus in Target Room" sentences elaborated on the topic mentioned in the target sentence, whereas "Focus in Location Room" sentences described a new event in the Location Room. “But that package had been for someone else” is an example of a sentence that leaves the focus of attention in the target room (see the first following sentence in Table 3). On the other hand, the second following sentence in Table 3 illustrates sentences that shift the focus back to the location room. For instance, the protagonist moves from the laboratory into the wash room, the target sentence refers to an object in the laboratory, and the following sentence “For some reason, all the lights in the wash room were off” shifts the focus back to the wash room.

**Procedure.** In the first part of the experiment, participants memorized the building layout. They studied the layout for 1 min. They were then given a blank diagram with only the room walls shown and asked to recall by writing all the room names they could remember at their correct locations on the diagram. They proceeded through these self-paced, study—test cycles until they could perfectly reproduce all room names in their correct locations. Afterwards, they answered six questions about the location of rooms in the building. Participants required about 15 min to learn the layout and answer the questions perfectly.

In the second part of the experiment, participants read the 19 narratives presented 1 sentence at a time on the CRT screen of a microcomputer (Fezzardi, Hasebrook, & Glowalla, 1992). Presentation of the sentences was self-paced: Participants pressed both buttons of the computer's mouse to advance from one sentence to the next. At the end of each narrative, three yes/no questions were presented testing comprehension of the narrative’s contents (see Table 3). Participants answered each question by pressing either the left or the right mouse button, with the assignment of yes and no to the buttons randomly varying across subjects. After each answer, feedback about the correctness was provided on the screen. After a wrong answer, a message urging participants to read more carefully was displayed. They were instructed to read carefully but at their natural speed. Reading times, question answering times, and correctness of the
answers were recorded by the computer. After reading the narratives, participants completed a short questionnaire about their reading strategies. It took them about 60 min to read the narratives and answer the questions.

**Design.** Both factors, target room type (−2, −1, location, +1, and +2 room) and following sentence type (Focus in target room or location room), were completely crossed and varied within subjects. Each person read 3 different target sentences in each of the 10 experimental conditions, that is, altogether 30 target sentences distributed over 16 test narratives. Ten different sets of probes were used, so that across subjects, each object appeared about equally often in each condition. For a given participant, each object was used only once to ensure novelty of the object. Reading times of the target sentences and the sentences following them were recorded as dependent variables.

**Results and Discussion**

Reading times of target sentences and of the sentences following them were analyzed. Because the sentences differed considerably in length, we adjusted for length by dividing the reading time of each sentence by its number of syllables, thus obtaining mean reading times per syllable in milliseconds (RTs). Outlier RTs (5% of the RTs) were excluded from the analyses. Outliers were determined for each participant and experimental condition. First, difference scores were computed by subtracting each participant’s median RT from his or her RTs. Then, separately for each dependent variable and each experimental condition, the upper and lower 2.5% of the difference scores were determined and the corresponding RTs were removed as outliers. From the remaining RTs, each participants’ mean RT for each condition was calculated (see Rinck, 1994). The mean RTs observed in Experiment 2 were analyzed by Analyses of Variance (ANOVAs) with target room type and following sentence type as repeated measures factors. Table 4 displays the mean RTs and corresponding standard deviations of all target sentences and following sentences. The displayed RTs of target sentences are averaged over both types of following sentences, because this factor did not influence RTs of the preceding target sentences.

**Target Sentences.** For the mean reading times per syllable of target sentences, a significant distance effect was observed, \( F(4, 196) = 6.32, p < .001, f = .15 \). The expected spatial gradient was observed for rooms involved in the protagonist’s last movement (−2, −1, and location room). Comparisons of adjoining pairs indicated that RTs for the −1 Room were significantly longer than those for the location room, \( t(49) = 2.71, p < .01, f = .13 \). Also in accordance with our expectations, RTs for the +1 Room were longer than those for the location room, \( t(49) = 5.18, p < .001, f = .24 \). However, just as in the first experiment, RTs for the +2 Room tended to be shorter instead of longer than those for the +1 Room, although the difference fell short of statistical significance again, \( t(49) = 1.56, p < .13, f = .07 \). Unlike Experiment 1, in this experiment the difference seemed mostly due to long RTs for the +1 Room, not so much to unexpectedly short RTs for the +2 Room. The latter RTs were comparable to the −2 Room RTs, whereas +1 Room RTs were significantly longer than −1 Room RTs, \( t(49) = 3.02, p < .01, f = .12 \).

The fact that the +1 Room was less accessible than the −1 Room seems plausible because only the latter was involved in the previous motion event (the unmentioned path room). Also, the nonsignificant difference between the +1 and +2 rooms might be dismissed as a chance result. However, the fact that it replicates the result observed in Experiment 1 merits a search for possible explanations. Upon closer inspection of the test narratives, an interesting difference was discovered. Whenever a target sentence appeared late in a narrative, the +1 Room was not only the next room on the protagonist’s route, but was also the protagonist’s location at the beginning of the narrative. Likewise, the +2 Room was the very first room that the protagonist had moved into on the way through the building, for example, the first location room. This is illustrated by the last target sentence given in Table 6. At this position in the narrative, the +1 Room and +2 Room (repair shop and lounge) are the first two rooms mentioned at the beginning of the narrative. We found that this was the case for 10 of the 30 target sentence positions, and indeed, it affected the RTs observed for the +1 rooms.
and +2 rooms. The unexpected decrease of RTs from +1 rooms to +2 rooms was almost entirely due to rooms mentioned already at the beginning of the narrative (243 vs. 211 ms). For rooms not mentioned before, RTs were longer and the difference was negligible (265 vs. 261 ms). Accordingly, a 2x2-ANOVA of these data yielded a significant interaction of target room type and previous mentioning $F(1, 49) = 4.58, p < .05, f = .10$. Moreover, we found a similar pattern when we reanalyzed the earlier results of Experiment 1. If the +1 room and the +2 room had been mentioned earlier in the narrative, there was a large RT difference (3.11 vs. 2.89 s for layout participants; 3.99 vs. 3.42 s for text participants). If the rooms had not been mentioned before, the difference was considerably smaller (3.02 vs. 2.90 s for layout participants; 3.28 vs. 3.25 s for text participants). However, in Experiment 1 the interaction of target room type and previous mentioning was not significant, perhaps because only 18 of the 30 participants in each group contributed a complete data set and could be included in the analysis. In the General Discussion section, we will discuss the implications of these findings.

Following Sentences. Table 4 displays the mean reading times per syllable of the sentences that followed the target sentences. A clear and symmetric spatial gradient was observed for following sentences that shifted the focus of attention back to the location room, $F(4, 196) = 7.56, p < .001, f = .20$. With these sentences, comparisons of adjoining pairs yielded significant differences between the −1 room and location room, $t(49) = 4.12, p < .001, f = .24$, the location room and +1 room, $t(49) = 3.24, p < .001, f = .18$, and a marginally significant difference between the +1 room and +2 room, $t(49) = 1.83, p < .10, f = .11$. With these sentences, the spatial gradient was much stronger than with sentences that left the focus in the target room, as reflected by a significant interaction of target room type and following sentence type, $F(4, 196) = 3.36, p < .05, f = .09$. However, a weaker distance effect was observed with focus in target room sentences as well, $F(4, 196) = 4.8, p < .001, f = .14$, and the difference between the −2 room and the −1 room was significant, $t(49) = 2.57, p < .05, f = .14$. The latter effect can only be attributed to spill-over of processing, whereas the much stronger effect observed with focus in location room sentences seems mostly due to resifting of attention. These results suggest that, contrary to the tentative interpretation we offered earlier (Rinck & Bower, 1995), resifting of attention is a more important determinant of comprehension time than spill-over of processing. In fact, the spatial gradient observed with following sentences was just as strong as the one observed with target sentences. Apparently, shifting the reader’s attention away from the protagonist’s location seems to take about as long as shifting it back.

In addition to these effects, consistently longer overall RTs were observed for focus in location room sentences, $F(1, 49) = 160.38, p < .001, f = .34$. Therefore, in addition to the effect of spatial distance in situation models, the introduction of a new topic in these sentences slowed down comprehension. The result is also consistent with earlier findings by Morrow et al. (1989, Exp. 2) who reported that the protagonist’s mental location was more accessible than his or her physical location or an unmentioned, irrelevant room. It should also be noted that the spatial gradient observed for following sentences was perfectly symmetric, unlike that for target sentences. This indicates that the variables affecting the accessibility of +1 rooms and +2 rooms did not affect comprehension of the following sentences. Apparently, once the rooms and objects are accessed and the target sentence comprehended, the previously mentioned and unmentioned target rooms no longer differ because both have been activated to a comparably high level by the target sentence.

To summarize, the results of Experiment 2 provide evidence for the generality of spatial distance effects across different languages, countries, and measures of accessibility. Second, the effects of spatial distance in situation models on the accessibility of objects extend to the accessibility of rooms. Third, we did not find access to the +2 room to be any harder than access to the +1 room. Because this unexpected finding replicates the result of Experiment 1, we will discuss both of them together in the General Discussion section. Fourth, the results of Experiment 2 provide a stronger explanation for the spatial gradient observed with following sentences than the experiments of Rinck and Bower (1995) could.

**EXPERIMENT 3**

The third experiment extended the investigation of spatial distance effects to a task other than narrative comprehension. Instead of reading stories that describe movements of a protagonist through a building, participants simply imagined their own movements through that building, much like a walk through a simulated environment (Golledge, 1987). The participants’ task in Experiment 3 had several features in common with the mental scanning task investigated by Koslyn, Ball, and Reiser (1978, Exp. 2) who found that times for mental movements across an imaginary scenario mirrored the times one would expect from real movements across the real scenario. Similar results were reported by Denis and Cocude (1989, 1992) who found that the time needed to mentally scan across the representation of a verbally described map mirrored the time needed to scan a visible map or the memory representation of a map studied shortly before.

If the time course of mental scanning in an imagined spatial scenario mirrors real movements in the physical world, one might hypothesize that mental movements also correlate with movements described in a narrative. In particular, distance between the focus of attention, for example, the participants’ own imagined location, and an object located somewhere in the situation model should affect accessibility of the object. This line of reasoning leads to the hypothesis that the spatial gradient of accessibility observed in studies of narrative comprehension should occur just as clearly in a mental imagery task. The
manner in which spatial situation models guide the focus of attention should be independent of whether the model represents the described movements of a fictitious character or the imagined movements of the reader, given that comprehension of narratives often involves imagery (Dennis, 1982) and that situation models of narratives are similar to perceptually based models (Franklin & Tversky, 1990). Thus, the observed spatial gradient of accessibility should not be limited to narrative understanding even though this has been the main area of its investigation. Furthermore, a positive finding would strengthen the argument for distance effects in mental imagery because the Morrow et al. probe task seems less prone to an explanation by demand characteristics than does the Kosslyn et al. mental scanning task (see the controversy between Pylyshyn, 1981; and Jolicour & Kosslyn, 1985). Instead of asking our participants directly to produce RTs depending on scanned distance, they were asked to respond as quickly as possible in each case, no matter what type of probe or amount of distance from the focus of attention. Except for the participants’ task, Experiment 3 was comparable to the Morrow et al. (1989) study. Object probes and a very similar spatial scenario were used, knowledge about the scenario was acquired by studying the building layout complete with room names and object names, and the imaginary participant movements corresponded exactly to the protagonist movements contained in the Morrow et al. (1989) narratives.

Experiment 3 also involved a more detailed analysis of the different room probes and protagonist probes presented to the subjects. Perhaps because so few of the many possibilities were sampled, different room probes (these contain two objects from different rooms) and protagonist probes (containing the protagonist’s name and an object) were seldom analyzed in previous studies. Results on the few protagonist probes were usually not reported in detail (e.g., Morrow et al., 1987, 1989), and the expected reaction time differences for different room probes were often not statistically significant, as in Experiment 1 above. This might be due to the fact that most experiments included more same room than different room probes, decreasing the experiments’ power in analyses of the latter. Furthermore, protagonist probes were only included to ensure that participants attended to the protagonist’s movements, with little interest in distinguishing between different types of protagonist probes.

But in retrospect, spatial distance in the situation model should affect the accessibility of objects contained in different room probes and protagonist probes, just as it affects those contained in same room probes. In addition to the distance between the probe items and the focus of attention, spatial distance between the two probe items themselves might affect reaction times. Specifically, we expected an effect analogous to the symbolic distance effect in judgments of linear order (see Moyer & Dumais, 1978, for a review). That is, the farther apart the two probe objects are in the situation model, the easier it might be to recognize them as being located in different rooms. This should be true both for Different Room probes (both probe items are objects) and Protagonist probes (one item is the protagonist’s name). Similar distance effects have been reported by Maki (1981, 1982) and Wagener-Wender and Wender (1990) with regard to distance between cities and spatially arranged objects, respectively. It is important to note the difference between this inverse distance effect and the spatial gradient observed before. Whereas the spatial gradient refers to accessibility and predicts longer RTs with increasing distance between the probe items and the focus of attention, the inverse distance effect refers to decision processes involved in judging the test probes and predicts shorter RTs with increasing distance between the probe items themselves. Experiment 3 was designed to test the spatial gradient of accessibility as well as the inverse distance effect by using different types of different room probes and probes equivalent to protagonist probes (the subject probes, see later).

**Method**

**Participants.** Forty-eight Stanford University undergraduates participated in the experiment to fulfill a service requirement for an Introductory Psychology course. The data of four additional students were excluded from all analyses due to unusual error rates higher than 20%. The remaining 48 participants had an average error rate of 7%.

**Layout.** Participants memorized the layout of a fictitious research center depicted in Figure 1. The center was very similar to the one used by Morrow et al. (1989), containing 10 rooms, with 4 objects in each room. Participants studied the layout until they could perfectly reproduce from memory the room names and the locations of all 40 objects.

**Motion Statements and Test Probes.** No narratives were used in Experiment 3. Instead, those who participated performed imaginary walks through the spatial scenario. They read a series of motion statements asking them to imagine their own movements through the building from room to room. The statements were presented sentence by sentence on the screen of a microcomputer, reading was self-paced, and participants were instructed to advance from one sentence to the next as soon as they had imagined the movement. At certain points, a test probe was presented instead of the next statement. As in Experiment 1 and the Morrow et al. (1987, 1989) experiments, most test probes consisted of two object names learned before, and participants had to decide whether these were located in the same room or in different rooms. The motion statements and test probe locations corresponded exactly to those contained in the Morrow et al. (1989) narratives. The motion statements were divided into 19 imaginary walks through the building (3 practice and 16 test walks), and each imaginary route corresponded to one of the original narratives. An example of an imaginary walk is given in Table 5. The motion events and test probe locations in this imaginary walk correspond exactly to those contained in the sample narrative given by Morrow et al. (1989).
TABLE 5
Example of Imaginary Walk and Test Probe Positions
From Experiment 3

<table>
<thead>
<tr>
<th>Probe of two objects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imagine that you are in the library.</td>
</tr>
<tr>
<td>[Subject Probe]</td>
</tr>
<tr>
<td>Imagine that you walk into the laboratory.</td>
</tr>
<tr>
<td>Imagine that you walk from the laboratory into the wash room.</td>
</tr>
<tr>
<td>[Probe of two objects]</td>
</tr>
<tr>
<td>Imagine that you walk into the repair shop.</td>
</tr>
<tr>
<td>Imagine that you walk from the repair shop into the experiment room.</td>
</tr>
<tr>
<td>[Probe of two objects]</td>
</tr>
<tr>
<td>Imagine that you walk into the reception room.</td>
</tr>
<tr>
<td>Imagine that you walk from the reception room into the conference room.</td>
</tr>
</tbody>
</table>

Four same room probe types, three different room probe types, and three types of subject probes were presented to the participants. As in the Morrow et al. (1989) experiments, same room and different room probes were always presented after critical motion statements that asked participants to imagine the movement from a source room (the −2 room) through an unmentioned path room (the −1 room) into the next room on the route (the location room), for example, “Imagine that you walk from the laboratory into the wash room” (see Figure 1). Subject probes corresponded to the original protagonist probes, containing an object name and the term “You.” Upon presentation of a subject probe, participants had to decide whether their current mental location room was identical to the room the object was located in. Subject probes were presented at varying locations, disrupting the regular routine of motion statements followed by test probes. With same room probes, the two objects could be located in the room the participant just imagined walking into (location room, e.g., lockers-sink), the room the participant just mentally walked through (−1 room, e.g., closet-crate), the room from which the participant had started the mental movement (−2 room, e.g., scale-microscope), or another room located somewhere in the building (other room, e.g., plant-desk). Different room probes always contained an object from an other room, either paired with an object from the location room (location/other, e.g., mirror-carpet), from the −1 room (−1/other, e.g., lifter-lamp), or from the −2 Room (−2/other, e.g., computer-radio). Subject probes consisted of the term “You” paired with an object from the location room (subject same room, e.g., You-toilet), from a room spatially close to the location room (subject different close other, e.g., You-tools), or from a room far away from it (subject different far other, e.g., You-projector). Close other rooms would be the −1 room or +1 room, whereas far other rooms would be at least three rooms away from the location room. The further away an object is from the imagined location of the subject, the easier it should be to decide that

they are in different rooms. Thus, we expected judgments of far other probes to be easier than judgments of close other probes. However, it is unclear whether this effect would be strong enough to outweigh the accessibility advantage of objects close to the protagonist. Across imaginary walks, each participant saw nine instances of each same room probe type, six instances of each different room probe type, nine subject same room probes, four subject different close other probes, and five subject different far other probes. Across the 16 test walks, participants had to respond “Same” to 45 test probes and “Different” to 27 probes. Eight different sets of probes were used, so that across subjects, each object appeared about equally often in each probe type.

Procedure. In the first part of the experiment, participants memorized the building layout. They studied the layout for a few minutes, then were given a blank diagram showing only the room walls and asked to recall by writing all the room labels and object names they could remember at their correct locations within the diagram. They proceeded through these self-paced, study–test cycles until they could perfectly reproduce all room and object names in their correct locations. Afterwards, they answered six questions about the location of objects in the building. They required about 45 min to learn the layout and answer the questions perfectly.

In the second part of the experiment, participants performed the 19 imaginary walks presented one motion statement at a time on the CRT screen of a microcomputer, again controlled by the “VTX” software (Frazzard et al., 1992). Presentation of the statements was self-paced: Participants pressed both buttons of the computer's mouse to advance from one statement to the next. Three practice walks were presented before the 16 test walks. Whenever a test probe was presented instead of a motion statement, those who participated responded to the test probe by pressing either the left or the right mouse button, with the assignment of Same and Different to the buttons randomly varying across subjects. After each response, feedback about the correctness was provided on the screen. After an error, a message urgent participants to work more carefully was displayed. Participants were instructed to imagine all movements carefully and respond to each test probe correctly and as quickly as possible. Reading times of motion statements as well as probe response times and correctness of the responses were recorded by the computer. About 20 min was required to imagine the walks and respond to the test probes.

Design. Independent analyses were conducted for same room, different room, and subject probes. Each analysis involved the factor target room type that was varied within subjects. The factor had 4 levels for same room probes (location, −1, −2, other room), 3 levels for different room probes (location/other, −1/other, −2/other), and 2 levels for Subject probes (close other, far other).
TABLE 6
Mean Reaction Times in Milliseconds and Error Rates (With Standard Deviations) for Test Probes in Experiment 3

<table>
<thead>
<tr>
<th></th>
<th>Location Room</th>
<th>−1 Room</th>
<th>−2 Room</th>
<th>Other Room</th>
</tr>
</thead>
<tbody>
<tr>
<td>RT (SD)</td>
<td>1836 (464)</td>
<td>2088</td>
<td>2138</td>
<td>2173</td>
</tr>
<tr>
<td>Error Rate (SD)</td>
<td>2.3% (4.6)</td>
<td>4.2%</td>
<td>6.9%</td>
<td>10.2%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Location/Other</th>
<th>−1/Other</th>
<th>−2/Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>RT (SD)</td>
<td>1906 (395)</td>
<td>1969</td>
<td>2135</td>
</tr>
<tr>
<td>Error Rate (SD)</td>
<td>1.7% (6.2)</td>
<td>1.0%</td>
<td>2.1%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Same Room</th>
<th>Subject Probes</th>
<th>Different Close Other</th>
<th>Different Far Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>RT (SD)</td>
<td>1805</td>
<td>2008</td>
<td>(527)</td>
<td>(455)</td>
</tr>
<tr>
<td>Error Rate (SD)</td>
<td>6.5%</td>
<td>10.4%</td>
<td>4.4%</td>
<td>4.9%</td>
</tr>
</tbody>
</table>

Latencies of correct responses to test probes and error rates of the responses served as dependent variables. Outliers among the RTs were treated as in Experiment 2.

Results and Discussion

Same Room Probes. Table 6 shows the mean RTs and error rates together with the corresponding standard deviations for all probe types. Analyses of the same room probes yielded significant effects of target room type for both RTs and error rates, indicating that both variables increased with increasing distance between the participants mental location and the target room. This spatial distance effect was highly significant both for RTs ($F(3, 141) = 24.61$, $p < .001, f = .27$) and error rates ($F(3, 141) = 9.05$, $p < .001, f = .33$). Planned pairwise comparisons of the RTs revealed that responses to location room probes were faster than to all other rooms (all $t(47) > 7.71$, $p < .001, f > .28$). For error rates, the difference between location room and −1 room missed statistical significance ($t(47) = 1.59$, $p < .12, f = .16$), whereas the differences between −1 room and −2 room as well as between −2 room and other room tended to be significant (both $t(49) > 1.81$, $p < .10, f > .15$). For both RTs and error rates, linear trend tests over distance were highly significant, both $F(1, 141) > 26.78$, $p < .001$, indicating increasing difficulty of same room probes with increasing distance between the participant’s mental location and the probed objects.

Different Room Probes. Mean reaction times (RTs) and error rates for different room probes are depicted in Table 6. The spatial gradient observed for RTs of these probes mirrors that for same room probes: RTs increased with increasing distance between the participant’s mental location and the probed objects, $F(2, 94) = 14.60$, $p < .001, f = .25$. Planned comparisons of adjoining pairs revealed that RTs to location/other probes and −1/other probes did not differ significantly, $t(47) = 1.45, p < .16, f = .08$, whereas RTs for −1/other probes were faster than RTs for −2/Other probes, $t(47) = 3.96, p < .001, f = .21$. Error rates were uniformly low in all conditions and did not differ significantly, $F(2, 94) < 1, n.s., f = .08$.

To explore the effects of spatial distance between the two objects of a test probe in more detail, we divided each type of different room probes further into three subgroups. For short distance probes, spatial distance between the two objects contained in the test probe was three rooms or less. For medium distance and large distance probes, the two objects were four and five rooms apart, respectively. This post hoc subdivision yielded subgroups of comparable sample size that were not confounded with the three different room probe types analyzed above, thereby allowing statistical analyses. As before, these analyses revealed no differences in error rates. However, a pattern of results close to the expected inverse distance effect on RTs was found. RTs for large distance probes ($M = 1893$ ms, $SD = 393$ ms) were shorter than RTs for medium distance ($M = 2054$ ms, $SD = 432$ ms) and short distance ($M = 2040$ ms, $SD = 557$ ms) probes, $F(2, 94) = 8.72, p < .001, f = .18$. The latter two probe types did not differ significantly.

Subject Probes. For subject probes, RTs and error rates of subject different close other and far other probes were analyzed. Subject same room probes cannot be compared to these, because the correct responses differ (same vs. different). As Table 6 indicates, an inverse distance effect was observed for close other and far other probes. Responses to far other probes were faster (1683 vs. 2008 msec; $t(47) = 4.91, p < .001, f = .33$) than responses to close other probes and contained fewer errors (1.3% vs. 10.4%; $t(47) = 3.86, p < .001, f = .40$).

To summarize, the results of Experiment 3 indicate that spatial distance between the focus of attention and items located somewhere in a situation model affects accessibility of the objects in mental imagery tasks just as it does in narrative comprehension. This finding points to the generality of spatial situation models in different cognitive tasks. Moreover, it extends previous research on mental imagery, using a more indirect measure of distance in imagined scenarios which seems less prone to demand effects than the mental scanning task used in previous studies. The reaction times and error rates observed with same room probes replicated previous results. In addition, different room probes and subject probes indicated that spatial distance in the participants’ situation model affects reactions to test probes both by making items close to the focus of attention more
accessible and by making the test probes easier to judge the farther apart the two probe items are from each other. In the case of Subject probes, the latter inverse spatial distance effect was strong enough to offset the effect of spatial distance on the accessibility of objects. These results are compatible with those reported by Wagener-Wender and Wender (1990) who also observed both spatial priming and an inverse distance effect.

The inverse distance effect is reminiscent of the symbolic distance effect observed in judgments of item pairs within linear orders (e.g., Moyer & Bayer, 1976). However, it is actual spatial distance that is represented in the situation models studied here, just as in the experiments reported by Maki (1981, 1982). Moreover, it was possible to confirm the results observed with subject probes in this experiment by a reanalysis of the equivalent protagonist probes used in Experiment 4 of Wilson et al. (1993). In that experiment, 36 participants received protagonist probes, and these could be divided post hoc into same room, different close other and different far other probes. In the reanalysis, we found the same inverse distance effect as in the current experiment. Responses to far other probes were faster than to close other probes (2027 vs. 2455 ms, t(35) = 3.28, p < .01, f = .29), and error rates were lower (4.6% vs. 13.9%, t(35) = 2.25, p < .05, f = .28). This result indicates that the inverse distance effect on decision times, just as the spatial gradient of accessibility, can be observed with different cognitive tasks, in this case narrative comprehension and imagery.

**GENERAL DISCUSSION**

Taken together, the three experiments reported here provide evidence for the claim that spatial distance affects the focusing of attention and the updating of spatial situation models during narrative comprehension in a very general way. As the first and second experiment showed, the spatial gradient of accessibility observed in previous studies generalizes to a variety of materials, learning conditions, languages, subject groups, and measures of accessibility. This result is compatible with other studies of situation models; for example, Glenberg et al. (1987) and Haeggi et al. (1994, 1995). Furthermore, Experiment 3 demonstrated that the spatial gradient can also be observed with cognitive tasks other than narrative comprehension, namely, imagined movements through space.

Beyond demonstrating the generality of previously observed spatial distance effects, the experiments reported here also provide new findings. Experiments 1 and 2 indicate that the spatial gradient of accessibility is not symmetric around the focus of attention. Despite potentially important differences between the two experiments; for example, different layouts with different numbers of rooms, the same unexpected result was observed: In both experiments, objects in the +2 room were accessed slightly faster than were objects in the +1 room, if the rooms had been previously mentioned at the beginning of the narrative. Even though this difference was not statistically significant in any of the experiments, its replication leaves us puzzled.

It seems quite plausible that in Experiment 2, previously unmentioned +1 rooms and +2 rooms were harder to access than −1 rooms and −2 rooms, because only the latter were involved in the motion event described before presentation of the target sentence. However, why would previous mentioning of the +1 and +2 room speed up access to objects in the +2 room more than access to those in the +1 room? Perhaps the room where the protagonist begins the narrative (the later +1' Room) is not as memorable as the first room he or she moves into (the later +2 room). Or perhaps the +2 room is more accessible because it was explicitly mentioned more recently than the +1 room.

Another plausible possibility is that the important variable determining accessibility is not distance per se, but recency of room activation from memory. According to this hypothesis, objects in the location room are most accessible because this is the last room that readers activated by focusing their attention on it during comprehension of the motivating sentence. Before that, they focused briefly on the −1 room as they imagined the movement path while reading the motion sentence. Prior to that, their attention was focused on the −2 room. This hypothesis would be compatible with the spatial gradient observed repeatedly. Moreover, it could explain the reaction times found for +1 rooms and +2 rooms. If they were not mentioned earlier in the narrative, no difference should be observed because readers never focused attention on either of them during reading of the narrative. If they were mentioned, on the other hand, the +2 room and its objects should be more accessible because participants focused on the +2 room more recently than on the +1 room. Note that this explanation is based on recency of activation of the rooms, not recency of explicit mentioning, because the −1 room is more accessible than the −2 room, even though only the latter is explicitly mentioned in the motion sentences (see Table 4).

The assumption that participants represent the protagonist’s motion through the unmentioned path room might seem at odds with the results of de Vega (1995) who did not find any evidence of on-line updating of situation models. However, his experiments and the ones reported here differ in important aspects, including subjects’ knowledge about the spatial relations in the scenario and the necessity to represent spatial relations in the situation model. Furthermore, his conclusions refer to the updating of fairly detailed spatial information, such as relative object locations in the model, whereas our hypothesis refers to rather general information; namely, the rooms visited by the protagonist. It might well be that readers do not update detailed aspects of the model until it becomes necessary, whereas they update the global aspects on-line. Thus, updating would include the rooms visited by the protagonist which in turn would prime the objects located in those rooms.
The hypothesis suggested above is compatible with the probe reaction times of Experiment 1 and the target sentence reading times of Experiment 2. In addition, the hypothesis predicts that comprehension times of the following sentences in Experiment 2 should not be affected by previous mentioning at the beginning of the narrative. At the time the following sentence is presented, both the target room and the location room have been mentioned recently (the target room in the target sentence, and the location room in the preceding motion sentence). Thus, we would expect a symmetric spatial gradient for the following sentences, which is exactly what we found. In conclusion, it seems obvious that other factors in addition to spatial distance strongly affect the accessibility of objects in rooms further ahead of the protagonist on his or her route through the spatial scenario. A similar conclusion was recently drawn by Langston, Kramer, and Glenberg (1994). The exact nature of these factors and their interaction with spatial distance, however, must be left to future investigations.

Another topic not investigated in detail by previous studies are the different ways that spatial distance can affect subjects’ responses to object test probes. The results of Experiment 3 indicate that spatial distance between the two items of a test probe affects different room response times and error rates of participants’ decisions independently of, and at least as strongly as, spatial distance from the focus of attention affects accessibility of the probe items. Test probes containing items from different rooms revealed an inverse distance effect, indicating that greater distance between the probe items made it easier to respond “Different.” Naturally, spatial distance between the probe items cannot affect same room probes or anaphoric references because with the former, the distance always amounts to zero rooms, and with the latter, only one object is referred to. Because most studies of spatial distance in situation models either concentrated on same room probes or used anaphoric references, it is understandable that the effect was not reported before (see Wagenar-Wender & Wender, 1990, for an exception).

Recently, it has been debated whether and under which circumstances situation models are constructed during “natural” narrative comprehension (e.g., Foerstch & Gernsbacher, 1994; Garnham, 1992; Glenberg & Mathew, 1992; McKoon & Ratcliff, 1992; Morrow, 1994; Singer, Graesser, & Trabasso, 1994; Zwaan & Graesser, 1993; Zwaan & van Oostendorp, 1993, 1994). The experiments reported here do not directly address this question because our experimental task strongly encouraged the creation of spatial situation models, and we were mainly interested in the processes involved in updating these models. However, considering the findings reported here, it seems safe to conclude that the updating of situation models, given that they are constructed by the reader, affects comprehension in a very general way: Effects of spatial distance were observed using a variety of materials, learning conditions, languages, measures of accessibility, and cognitive tasks.

REFERENCES

SPATIAL SITUATION MODELS


