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# Anaphora Resolution and the Focus of Attention in Situation Models

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Four experiments investigated how the accessibility of a referent for an anaphoric noun phrase decreases with the spatial distance of the referent from the focus of attention within a situation model. In all experiments, subjects first memorized the diagram of a building and objects located in it, then read narratives describing characters' activities in that building. The narratives contained motion sentences describing how the protagonist moved from room to room through the building. Accessibility of referents was probed by undistinguished "target" sentences that followed the motion sentences. Each target sentence contained a definite noun phrase that referred to a memorized object in one of the building's rooms ("He thought that *the shelves* still looked like an awful mess"). Reading times of target sentences increased with the number of rooms between the object and the protagonist, suggesting that accessibility of the referent decreased with spatial distance between the referent and the focus of attention in the readers' situation model. Experiment 1 showed faster access to referents when target sentences mentioned the room in which the referent was located. Experiment 2 compared motion sentences that explicitly mentioned the protagonist's movement to sentences that mentioned only the protagonist's final location. Similar effects of distance from focus to referent were found, suggesting that readers use situation models to infer movements not explicitly mentioned in the text. Experiment 3 demonstrated that the results were not caused by unexpected or confusing discourse. Experiment 4 showed that the results could not be explained by temporal order of studying the rooms during learning instead of spatial distance. 

A major linguistic device for establishing coherence in discourse is *anaphora*, which comprises a collection of linguistic forms for referring to concepts and entities introduced earlier in the discourse. To illustrate, imagine reading a story about a person named Wilbur in which you encounter the following sentence: "*Wilbur thought that the shelves still looked like an awful mess.*" What makes it easy or difficult to under-

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stand this sentence? One of the many things readers must do in order to understand the sentence is to find the right referent for the anaphor "the shelves," a definite noun phrase. Because anaphora resolution is a prominent way to achieve coherence in texts, it has been frequently studied by psycholinguists (e.g., Sanford & Garrod, 1981). Numerous studies have found that anaphora resolution proceeds quickly if the referent is still activated in memory (also called foregrounded, or in the focus of attention, or in working memory).

Several factors affect the probability that a given entity will be active in memory and therefore highly accessible as a referent for an anaphor (see Sanford & Garrod, 1981; Graesser & Bower, 1990). This paper focuses on a factor that has rarely been investigated, namely, spatial distance in situation models. We wanted to find out whether references to objects like *the shelves* are easier to understand if the objects are spatially close to the focus of attention, which is usually on the most recently mentioned actor in the narrative. Although the term *situation model* has been defined in different ways (Johnson-Laird, 1983; Wilson & Rutherford, 1989), one consensual feature is that situation models contain information about the spatial relations in the situation described in a text. Situation models formed during narrative comprehension would include information about the protagonist's present location, how the protagonist moves around, what the described locations are like, and where important objects and actors are located. Using this knowledge, readers are able to focus their attention on the people, locations, and objects that are most likely to be referred to again (Anderson, Sanford, & Garrod, 1983; Morrow, 1985).

An important study on anaphoric references in situation models was conducted by Glenberg, Meyer, and Lindem (1987) who showed that readers more readily retrieve referents that are spatially close to the protagonist of a narrative. Glenberg et al. (1987) suggested that objects which the protagonist carried with him, as in "He *picked up* his bag and left," would be more accessible than objects he left behind, as in "He *set down* his bag and left." As predicted, Glenberg et al. found that later anaphoric references to these objects, as in "He thought *it* was getting too heavy to carry," were understood faster if the protagonist had taken the object with him. The object-with-protagonist remains in the focus of attention, making it easier to access as a referent for the pronoun "*it*." On the other hand, an abandoned object goes out of focus and becomes harder to access.

Two important questions are left unanswered by that experiment. The first question refers to the nature of the anaphor: Glenberg et al. (1987) always used the pronoun "*it*" to refer to objects. Although the pronoun's referent could be unequivocally identified in their materials, the use of a pronoun is nonetheless infelicitous in such cases: Since it is difficult to understand references to objects that are out of focus, writers would usually use a definite noun phrase such as "*the bag*" instead of an "inconsiderate" pronoun (Sanford & Garrod, 1981). Use of the definite noun phrase would be the common way to help readers find the correct referent in memory. Therefore, we thought that spatial distance effects on anaphora resolution might be more appropriately investigated with definite noun phrases instead of pronouns.

It is not obvious, however, that results similar to those found by Glenberg et al. (1987) would arise with definite noun phrases since several factors could mitigate such effects. First, noun phrases supply the reader with much stronger clues regarding the identity of the referent than do pronouns. For instance, "*the bag*" specifies the exact type of referent, whereas "*it*" only specifies its grammatical number and gender. Since information about the referent is greater with definite noun phrases, any small effect of spatial distance on referent access might be washed out. Second, the effect observed by Glenberg et al. (1987) might have been caused by their use of inconsiderate pronouns. Since it is somewhat unusual to use a pronoun when referring to a backgrounded referent, subjects' longer comprehension times for "it" might have reflected their surprise and confusion instead of spatial distance in the situation model. Noun phrases, on the other hand, are appropriate with foregrounded as well as backgrounded referents. Thus, a distance effect found with noun phrases would provide stronger evidence for the assumption of situation models.

Our second aim was to investigate more points along a possible distance gradient. Glenberg et al. (1987) used only two distances—the object was either very close to the protagonist or far away. We expected that the accessibility of objects should gradually decrease with increasing distance from the protagonist. Such a spatial gradient has been found repeatedly by Morrow, Greenspan, and Bower (1987); Morrow, Bower, and Greenspan (1989); Morrow, Leirer, Altieri, and Fitzsimmons (1992); and Wilson, Rinck, McNamara, Bower, and Morrow (1993). Those studies followed a common procedure in which subjects first learned the layout of a building and the location of numerous objects in that building. Afterward, they read a series of narratives about activities occurring in that building. Accessibility of objects in readers' memory was measured on-line with test probes consisting of pairs of named objects presented while subjects read the narratives. For each test probe, subjects had to decide whether the two objects were located in the same room or in different rooms. The observed decision times revealed a spatial distance effect: accessibility of objects was quicker the smaller the spatial distance between the objects and the subjects' current focus of attention, which was usually the current location of the protagonist of the narrative. Objects located in the same room as the protagonist were easier to access than objects from an unmentioned "path" room that the protagonist had just passed through in moving from a "source" room to a "goal" room. These path room objects were in turn more accessible than objects in the room from which the protagonist had commenced his movement, or objects in some other room not recently visited in the building.

While Morrow et al. (1987, 1989) did not study anaphoric references, their results should help answer our questions about anaphora resolution, since the ease of finding the correct referent should depend on the referent's accessibility. Therefore, we used the same basic paradigm as Morrow et al. (1989), but deleted the probes and simply measured the time subjects took to read target sentences containing an anaphoric reference. In our four experiments, subjects first memorized the diagram of a fictitious research center with four objects located in each room. Afterward, subjects read narratives containing motion sentences describing a protagonist moving from room to room through the building while pursuing some goal. Accessibility of referents was determined by how quickly readers could comprehend target sentences that were presented just after the motion sentences. Each target sentence contained a definite noun phrase that referred to a memorized object in one of the building's rooms. The critical question was how long subjects would take to comprehend these target sentences depending on how distant was the referent. The first three experiments differed in the contents of the motion and target sentences. Experiment 1 compared target sentences that did not mention the name of the target room in which the referent was located ("He thought that *the shelves* still looked like an awful mess") to sentences that explicitly mentioned the target room containing the referent ("He thought that *the shelves in the library* still looked like an awful mess"). Experiment 2 compared motion sentences that specified the protagonist's path ("He walked from the repair shop into the experiment room") to motion sentences that only mentioned the final destination ("His next stop was the experiment room"). In Experiment 3, one sentence was inserted between each motion sentence and the following target sentence in order to motivate the thoughts and actions described in the target sentences, thus smoothing out the text and minimizing readers' surprise and confusion upon reading the target sentence. An example is "In order to devise a list of necessary tasks, he tried to think of everything that looked dirty or messy in the building. He thought that the shelves in the library still looked like an awful mess." In Experiment 4, initial learning of the building layout was varied: Instead of studying the ten rooms of the research center simultaneously as in the first three experiments, the rooms were studied one at a time in a random serial order. This arrangement separates the influence on priming of spatial distance between rooms from the temporal order in which the rooms had been studied during initial learning.

The purpose of the experiments reported here was twofold: First, they further investigated how the focus of attention within a situation model affects anaphora resolution. In this respect, they extend the work by Glenberg et al. (1987). Second, the studies seek converging evidence for the spatial distance effects found by Morrow et al. (1987, 1989) by using time to resolve anaphoric references instead of object probes to measure accessibility. This new method seems particularly important since methodological complications of the object probe paradigm have recently been reported (Wilson et al., 1993).

## Experiment 1

This experiment served to answer two questions: First, does spatial distance in the reader's situation model influence anaphora resolution? Second, is comprehension of the anaphoric reference influenced by the amount of information about the referent contained in the anaphoric sentence? To this end, we compared anaphora resolution times for sentences that did or did not contain the name of the room where the referent object was located. We expected that repeating the room name in the target sentence provides another cue to help subjects retrieve from memory the right referent for the definite noun phrase. Even though subjects should know each unique object and its location perfectly, the room name might still help them to retrieve the referent more quickly. For both kinds of target sentences, we expected that comprehension times for references to objects should increase with increasing spatial distance between these objects and the reader's focus of attention, that is, the protagonist's current location.

### Method

*Subjects.* Forty-eight Stanford University undergraduates participated in the experiment to fulfill a requirement for an Introductory Psychology course. The data of two additional subjects were excluded from all analyses because their high error rates on the comprehension questions following each narrative (see below) indicated careless reading.

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

*Narratives.* After learning the layout, subjects read 19 narratives, namely, 3 practice narratives followed by 16 experimental ones. Each narrative was approximately 20 sentences long and described the actions of a protagonist who moved throughout the building trying to fulfill a goal, e.g., to prepare the center for important visitors. An example of an experimental narrative is shown in Table 1. Each experimental narrative contained three critical *motion sentences* that described a complete motion

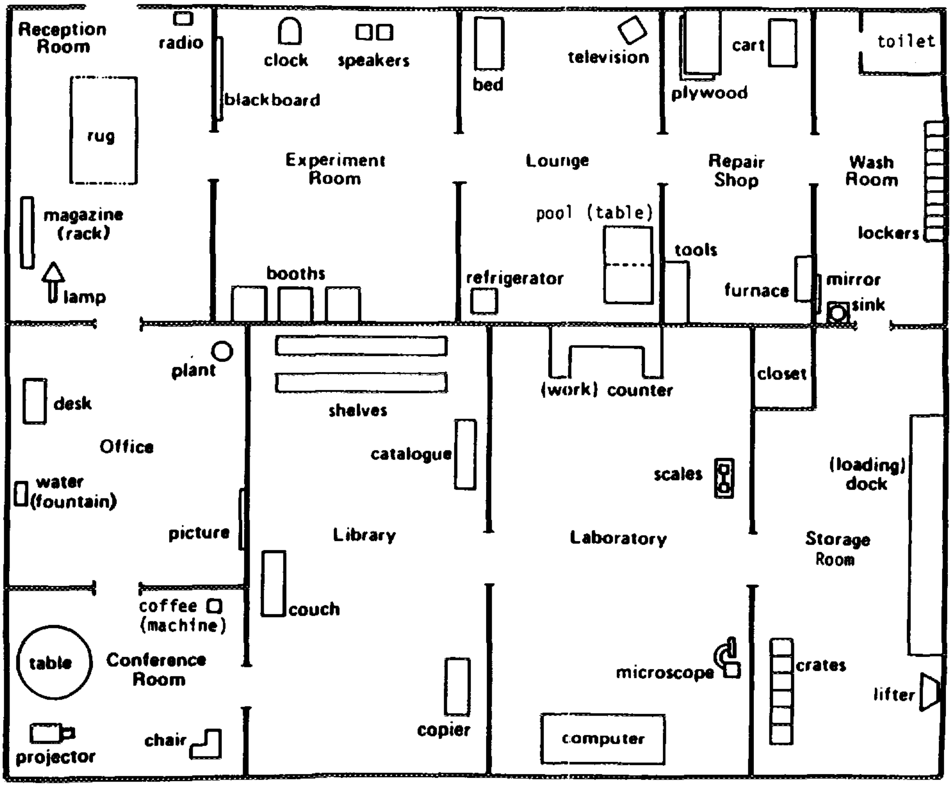


FIG. 1. Building layout memorized by subjects in all experiments.

event in which the protagonist walked from one room (source) through an unmentioned room (path) into a third room (goal). At the end of the motion sentence, the goal room was the current location of the protagonist. After each motion sentence, a *target sentence* was presented. The target sentence contained a definite noun phrase that referred to some unique object in the research center (see Table 2). After the target sentence, the protagonist did something in the goal room before going on into the next room along the route. This succeeding room served in turn as the source room for the next motion sentence.

Each narrative was followed by three content questions to ensure that subjects read carefully. These questions queried such details as the reason for certain actions, the persons involved, the location of certain activities, and the order of activities. As mentioned before, two subjects answered more than 33% of these questions incorrectly and thus were excluded from all analyses. The average error rate of the remaining 48 subjects was 16%.

The accessibility of anaphoric referents was tested with the eight different types of target sentences illustrated in Table 2. Each target sentence contained a reference to one of the forty objects in the building. For example, after a motion sentence such as "He walked from the laboratory into the wash room," the target sentence might read "He thought that *the toilet in the wash room* still looked like an awful mess." In this case, the definite noun phrase *the toilet* would refer to an object in the room where the protagonist was currently located, the *goal room*. The target sentence could also refer to an object in the *path room* that the protagonist had just passed through (the loading dock in the storage room), or to an object in the *source room* from which the

TABLE 1
EXAMPLE OF NARRATIVE FROM EXPERIMENT 1

Wilbur wasn't so sure he wanted to be head of the center anymore.
He had just been informed that the board of directors would be making a surprise inspection tomorrow.
He immediately called all the center's employees together in the library and told them they had less than twenty-four hours to clean up the center.
He explained about the visit and said that all of their jobs were at stake.
He told everyone to spread out and clean and organize every room.
He went into the laboratory and made sure it was being cleaned, and then headed off to supervise the rest of the workers.

*Critical motion sentence*
He walked from the laboratory into the wash room.
*Target sentence (referring to an object in the goal room)*
He thought that the toilet in the wash room still looked like an awful mess.
*Following sentence*
He was pleased to see the wash room's sparkling tile floor since he knew the directors were more impressed by cleanliness than good research.
He hurried into the repair shop and yelled at the foreman for not getting those greasy machine parts out of sight.
Next he thought he'd better check to see that the researchers were getting things organized.

*Critical motion sentence*
So he walked from the repair shop into the experiment room.
*Target sentence (referring to an object in the path room)*
He remembered that the television in the lounge should not be turned on tomorrow.
*Following sentence*
He made sure the experimenters would be busy conducting studies tomorrow so the directors would see how industrious they were.
As he went into the reception room, he thought about the presentation he was planning to make to the directors.
Then he remembered the television in the lounge, it had better not be on tomorrow.

*Critical motion sentence*
Next he walked from the reception room into the conference room.
*Target sentence (referring to an object in the source room)*
He decided that the rug in the reception room needed thorough cleaning as soon as possible.
*Following sentence*
At the table in the conference room, he started to write down notes for his presentation.
He imagined himself giving a high-powered talk, and began to feel the visit might go well after all.

*Question 1:* Did Wilbur call all of the employees together in the library?
*Question 2:* Did Wilbur dislike the wash room's dirty floor because the directors were more impressed by cleanliness than by good research?
*Question 3:* Was Wilbur dissatisfied with the way the repair shop looked?

protagonist had started his last movement (the work counter in the laboratory), or to an object in an *other room* (the shelves in the library). This other room was always the room before the source room, i.e., the third room back from the goal room in the narrative order. All target sentences described some type of mental action such as thinking, remembering, or deciding about some aspect of the referent object (see Table 1). By this means, we shifted the mental focus rather than the physical location of the protagonist, since changing the physical location back and forth is stylistically awkward. Morrow et al. (1989) provided evidence that sentences such as "He thought about the shelves in the library" effectively shift readers' focus of attention to that room.

In addition to these four different target room types, we also varied whether or not the name of the target room was mentioned in the target sentence. For each type of target sentence (goal, path, source, and

TABLE 2
TARGET SENTENCE TYPES

| Critical motion sentence: He walked from the laboratory into the wash room. | |
|---|---|
| Probe type | Target sentence |
| With room name | |
| Goal room | He thought that the toilet in the wash room still looked like an awful mess. |
| Path room | He thought that the loading dock in the storage room still looked like a mess. |
| Source room | He thought that the work counter in the laboratory still looked like a mess. |
| Other room | He thought that the shelves in the library still looked like an awful mess. |
| Without room name | |
| Goal room | He thought that the toilet still looked like an awful mess. |
| Path room | He thought that the loading dock still looked like a mess. |
| Source room | He thought that the work counter still looked like a mess. |
| Other room | He thought that the shelves still looked like an awful mess. |

other), one version included the target room name in the target sentence, as in "*the shelves in the library,*" whereas a second version did not include the room name, as in simply "the *shelves*." Except for this, the versions with and without the target room name were identical. Within each version, the four different types of sentences were matched for length by including filler words like "awful" in shorter sentences (see Table 2).

*Procedure.* In the first part of the experiment, subject memorized the building layout. They studied the layout for a few minutes, then were given a blank diagram with only the room walls shown and asked to recall by writing all the room labels and object 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 and object names in their correct locations. Afterwards, they answered six questions about the location of objects in the building. Subjects required about 45 min to learn the layout and answer the questions perfectly.

In the second part of the experiment, subjects read the 19 narratives presented one sentence at a time on the CRT screen of a microcomputer, controlled by the "VTx" software (Fezzardi, Hasebrook, & Glowalla, 1992). Presentation of the sentences was self-paced: Subjects pressed both buttons of the computer's "mouse" to advance from one sentence to the next. Three practice narratives were presented before the 16 experimental narratives. At the end of each narrative, three yes/no questions were presented testing comprehension of the narrative's contents (see Table 1). Subjects 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 subjects to read more carefully was displayed. Subjects were instructed to read carefully but at their natural speed. Reading times as well as question answering times and correctness of the answers were recorded by the computer. After reading the narratives, subjects completed a short questionnaire about their reading strategies. It took subjects about 45 min to read the narratives and answer the questions.

*Design.* Both factors, "target room type" (goal, path, source, other room) and "mentioning of target room name" (with, without), were varied within subjects. Each subject read six different target sentences in each of the eight experimental conditions, i.e., altogether 48 target sentences in 16 experimental narratives. Each object appeared equally often in each condition. Reading times of the target sentences and the sentences following them were recorded as dependent variables.

*Results*

Reading times (RTs) of target sentences and of the sentences following them were analyzed. Outlier RTs (5% of the correct responses) were excluded from the analyses. Outliers were determined for each subject and experimental condition: First, difference scores were computed by subtracting each subject's median RT from his or her RTs. Then, separately for each dependent variable and the eight experimental conditions, the upper and lower 2.5% of the difference scores were determined and the corresponding RTs removed as outliers. From the remaining RTs, each subject's mean RT for each condition was calculated. The mean reading times were analyzed by ANOVAs with "target room type" and "mentioning of target room name" as repeated measured factors. Each analysis was computed twice, once using the 48 subjects as a random factor, and once the 48 experimental sentences. Below, $F_1$ and $t_1$ values relate to the by-subjects analyses, whereas $F_2$ and $t_2$ values relate to the by-materials analyses. The same procedures were used in Experiments 2, 3, and 4. All effect sizes reported below (with the $f$ statistic) were determined from Cohen (1988).

*Target sentences.* Figure 2 shows the mean reading times per syllable for target sentences with and without the room name

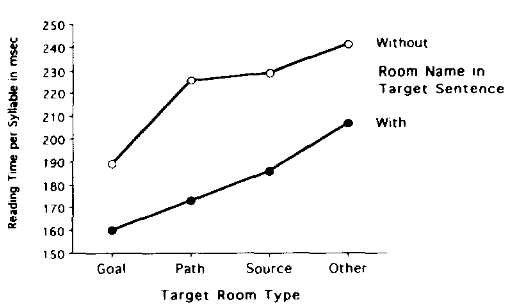


FIG. 2. Experiment 1: Mean reading times per syllable (in milliseconds) of target sentences with and without the target room name, categorized by target room type.

mentioned in the target sentence, divided according to the type of target room. Since the 48 target sentences differed slightly 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. Table 3 displays the mean RTs and corresponding standard deviations of all four experiments. Figure 2 shows the expected distance effect; that is, RTs increased with distance between the referent and the protagonist ($F_1(3,141) = 30.21$, $p < .001$; $F_2(3,141) = 25.27$, $p < .001$; $f = .31$). The distance effect was highly significant, both for sentences with and without the room name (with: $F_1(3,141) = 19.94$, $p < .001$; $F_2(3,141) = 13.72$, $p < .001$; $f = .35$; without: $F_1(3,141) = 15.51$, $p < .001$; $F_2(3,141) = 12.33$, $p < .001$; $f = .29$). A spatial gradient was observed for sentences with the room name (all comparisons of adjoining pairs: $t_1(47) > 2.31$, $p < .03$; $t_2(47) > 1.74$, $p < .09$). However, only a location effect was observed for sentences without the room name; that is, only the difference between the goal room and the path room was significant ($t_1(47) = 5.21$, $p < .001$; $t_2(47) = 4.18$, $p < .001$). The interaction of "room name" and "target room type" was marginally significant in the by-subjects analysis but not significant in the by-materials analysis ($F_1(3,141) = 2.26$, $p < .09$; $F_2(3,141) = 1.52$, n.s.; $f = .36$).

We also observed a large difference between target sentences with and without the room name. Sentences without the room name are shorter, of course, but they were relatively harder to understand on a per syllable basis: The reading time per syllable was longer than that for sentences with the room name ($F_1(1,47) = 83.29$, $p < .001$; $F_2(1,47) = 85.11$, $p < .001$; $f = .34$), and this difference was highly significant for each of the four different target room types (all $t_1(47) > 3.63$, $p < .01$; all $t_2(47) > 3.2$, $p < .01$). Thus, although subjects knew the location of each unique object, naming the target room seemed to help them acti-

TABLE 3

MEAN READING TIMES PER SYLLABLE IN MILLISECONDS (AND STANDARD DEVIATIONS) OF TARGET SENTENCES AND FOLLOWING SENTENCES CATEGORIZED BY TARGET ROOM TYPE IN EXPERIMENTS 1, 2, 3, AND 4

| Experiment and sentence type | Target room type | | | |
|---|---|---|---|---|
| | Goal | Path | Source | Other |
| | | Experiment 1 | | |
| Target sentences | | | | |
| With room name | 160 | 173 | 186 | 207 |
| | (36) | (47) | (49) | (54) |
| Without room name | 189 | 226 | 229 | 241 |
| | (53) | (69) | (73) | (73) |
| Following sentences | | | | |
| With room name | 148 | 160 | 163 | 169 |
| | (33) | (42) | (41) | (48) |
| Without room name | 165 | 172 | 174 | 183 |
| | (39) | (43) | (50) | (53) |
| | | Experiment 2 | | |
| Target sentences | | | | |
| "Walk" motion | 154 | 179 | 184 | 185 |
| | (53) | (51) | (47) | (59) |
| "Jump" motion | 151 | 168 | 180 | 182 |
| | (49) | (53) | (51) | (50) |
| Following sentences | | | | |
| "Walk" motion | 139 | 154 | 159 | 158 |
| | (44) | (45) | (46) | (44) |
| "Jump" motion | 144 | 148 | 153 | 155 |
| | (49) | (44) | (45) | (46) |
| | | Experiment 3 | | |
| Target sentences | 132 | 140 | 151 | 158 |
| | (26) | (31) | (34) | (39) |
| Following sentences | 141 | 146 | 148 | 150 |
| | (26) | (29) | (34) | (30) |
| | | Experiment 4 | | |
| Target sentences | 143 | 152 | 158 | 162 |
| | (51) | (53) | (55) | (55) |
| Following sentences | 153 | 166 | 169 | 170 |
| | (50) | (54) | (55) | (58) |

vate the correct object as the referent for the noun phrase.

However, an alternative explanation for the observed difference between target sentences with and without the room name would hold that it is an artifact of converting sentence reading times to syllable reading times. Suppose that sentence reading time is a linear function of the number of syllables ($RT = a + bS$) and that the room name merely increases S without altering b, the processing time per syllable. Then dividing sentence times by the number of syllables would yield an artifactual advantage for the longer sentences (since $RT/S = a/S + b$). With the present data, it is difficult to rule out this alternative entirely. The method we followed was to analyze a set of control sentences comparable in length to the target sentences. From all 16 experimental narratives, we selected 24 control sentences whose mean number of syllables (16.28) and the corresponding standard deviation (1.45) exactly equaled those of the target sentences *without* the room name. Another 24 control sentences were chosen that exactly matched the length of the target sentences *with* the room name (mean = 22.08, $SD = 1.61$). Control sentences were selected randomly while excluding the first sentence of a narrative, motion sentences, target sentences, or sentences following them. For these 48 control sentences, sentence RTs of the longer sentences averaged 778 ms longer than those of the shorter sentences, whereas the difference between the two types of target sentences amounted to only 427 ms. After division by the number of syllables, the time per syllable of long control sentences was 10 ms faster than that for the short ones. This 10 ms difference may be compared to the difference observed for the target sentences where those with the room name were read 40 ms faster than those without the room name. This comparison suggests that only a small fraction of the difference observed between target sentences with and without the room name can be attributed to our method of estimating per syllable processing times. Furthermore, as will be shown below, a similar difference between conditions was observed for sentences following the target sentences, where it could not have been caused by a data transformation. It should also be mentioned that the transformation problem applies exclusively to interpreting the difference between target sentences with and without the room name; it is not relevant to the distance effects observed in this experiment or later ones.

*Following sentences.* Table 3 also displays the mean reading times per syllable of the sentences that followed the target sentences. Such data are interesting because they appear to reflect a "spill-over" of processing from the preceding target sentences. If an anaphoric reference in the target sentence is difficult to understand, some additional processing of the anaphor might continue as the subject is exposed to the following neutral sentence. The following sentences showed effects similar to those of the target sentences, although somewhat weaker. If the target sentence did not contain the target room name, it took subjects longer to understand the following sentence. This effect was highly significant ($F_1(1,47) = 17.53$, $p < .001$; $F_2(1,47) = 22.98$, $p < .001$; $f = .15$) and cannot be explained by the transformation to syllable RTs since the sentences following target sentences were identical across all target sentence conditions. A distance effect was also evident: The further away the referent was from the protagonist's location, the longer it took subjects to understand the following sentence ($F_1(3,141) = 8.88$, $p < .001$; $F_2(3,141) = 4.59$, $p < .01$; $f = .16$). There was no indication of an interaction (both $F(3,141) < 1$).

### *Discussion*

The results of Experiment 1 indicate that anaphora resolution is indeed affected by spatial distance in the readers' situation model of the narrative. The further away an object is from readers' focus of attention, i.e., the protagonist of the narrative, the longer they take to understand an anaphoric reference to the object. The results indicate that the spatial distance effect can be observed with definite noun phrases as well as with pronouns (Glenberg et al., 1987). Resolution of the anaphor was also quickened by more information in the anaphora: Sentences that named the target room were understood quicker, perhaps because the room name directed readers to shift their attention to the correct room immediately. Part of this difference might be an artifact of the transformation from sentence RTs to RTs per syllable. But analyses of the control sentences and the following sentences indicate that a substantial part of the speed up in comprehension is indeed caused by explicitly naming the target room. Another explanation of this effect is that the room name provides an additional cue that enters into a cue-compound with the object name to facilitate retrieval of the specific referent entity from memory (see the Ratcliff & McKoon, 1988, account of associative priming). However, the cue-compound interpretation would need to be elaborated to explain the observed spatial gradient, especially the fact that references to objects in the unmentioned path room were easier to understand than references to objects in the explicitly mentioned source room.

Spatial distance between the protagonist and referent of the target sentence also affected comprehension times of the following sentence. A possible explanation is that, after the target sentence shifted subjects' attention to the target room, they had to shift their attention back to the protagonist's location to understand the following sentence. This shift may take longer, the further away the target room is from the protagonist's location in the situation model.

By coincidence, our materials provided a post-hoc means for testing this *reshifting* conjecture. Only about half of the following sentences shifted the attention back to the goal room. Since nearly half of the following sentences left the spatial focus of attention in the target room or left it unidentified, we can assess the reshifting explanation by comparing the distance effects in both types of following sentences. According to the reshifting explanation, the distance effect should only appear with following sentences that shift the attention back to the goal room. With the other kind of following sentences, the effect should be absent, or at least attenuated. However, the data indicated that the distance effect observed with the reshifting following sentences was no stronger than the effect with the other sentences (reshift: $F_1(3,141) = 1.96$, $p < .13$; $F_2(3,141) = 2.23$; $p < .10$; no reshift: $F_1(3,141) = 2.74$, $p < .05$; $F_2(3,141) = 2.39$, $p < .10$), so the interaction of reshifting with distance was not significant (both $F(3,141) < 1$). Therefore, we tentatively attribute the effect in the following sentences to spill-over of processing from the target sentences (see de Vega, 1991): If an anaphoric reference in the target sentence was difficult to understand, some additional processing of the anaphor continued as the following sentence was read, thus slowing its reading speed. This spill-over would also explain why the distance effect was weaker with the following sentences than with the target sentences. Since most processing of the anaphoric reference occurs while reading the target sentence, differences in the ease of processing will have a greater effect on the reading times of target sentences.

## Experiment 2

So far, all experiments on the shifting focus of attention in situation models and its effect on narrative comprehension (Morrow et al., 1987, 1989, 1992; Wilson et al., 1993) have used actor movement sentences such as "He walked from the repair shop into the experiment room." These sentences explicitly mention the rooms where the motion event begins and ends. Even though the path room remains unmentioned, it is strongly implied and seems to be activated during comprehension of the motion sentence, as shown by the results of Experiment 1 and several others (Morrow et al., 1989; Wilson et al., 1993). Writers of narratives, however, often use a different stylistic means to indicate a character's spatial movement; specifically they sometimes mention only the final location and leave it to the reader to infer the complete motion event, as in "His next stop was the experiment room." We may ask whether in such cases readers will infer the protagonist's movement from the source room through the path room into the goal room. Such inferences would not be necessary to construct a text model and a propositional text base of the narrative (van Dijk & Kintsch, 1983; Johnson-Laird, 1983), nor to answer the comprehension questions used in our experiments. However, if subjects simulate movements of the character in a situation model of the narrative, they should infer the path, since characters do not simply disappear from one room and suddenly reappear in another.

Experiment 2 was designed to find out

whether readers fill in the protagonist's movement from the source room through the path room into the goal room, even when the motion sentence mentions only the goal room as the protagonist's final location. If they do this filling in, then the same gradual distance effect should arise in the comprehension of anaphoric references: References to objects in the goal room should be easier to understand than references to objects on the path room. In turn, these path room anaphors should be easier than references to objects in the source room, which should be easier than references to objects in an other room. If, on the other hand, subjects do not fill in the movement in their model, an *all-or-none* location effect should be observed: References to objects in the goal room should be easier than references to objects in the path, source, and other room, but the last three referent solutions should not differ in speed.

*Method*

*Subjects.* Forty Stanford University undergraduates participated in the experiment to fulfill a service requirement for an Introductory Psychology course. The data of one additional subject were excluded from all analyses due to a high error rate (38%) to the questions following each narrative. The remaining 40 subjects had an average error rate of 15% to these questions.

*Layout and procedure.* These were identical to the ones used in Experiment 1.

*Narratives.* The same narratives as in Experiment 1 were used. The four practice narratives were identical to the ones used before, whereas the 16 experimental narratives differed in the motion and target sentences. Only the four types of target sentences with the room name were used (see the upper half of Table 2). Target sentences without the room name were replaced. Instead, two different types of motion sentences were used. The "walk sentences" are the ones used previously that state that the protagonist walked from the source room (through the unmentioned path room) into the goal room (see Table 1). Additionally, for each walk sentence a corresponding "jump sentence" was composed that mentioned only the goal room as the protagonist's final location. For instance, the jump sentences corresponding to the three motion sentences in Table 1 are "In the wash room, he looked around for signs of disorder," "So his next stop was the experiment room," and "Next he sat down in the conference room."

*Design.* Both factors, "target room type" (goal, path, source, other room) and "motion sentence type" (walk, jump), were varied within subjects. Each subject read six different target sentences in each of the eight experimental conditions. Each object appeared equally often in each condition, and each of the 48 motion sentences was presented equally often in the "walk" and the "jump" version. Again, reading times of target sentences and following sentences served as dependent variables.

*Results*

*Target sentences.* Figure 3 shows the mean reading times per syllable for target sentences following walk and jump sentences, according to type of target room. Table 3 contains the corresponding standard deviations as well. The ANOVAs of these reading times revealed a significant effect of target room type ($F_1(3,117) = 19.58, p < .001$; $F_2(3,141) = 15.6, p < .001$; $f = .28$): RTs increased with increasing distance between the protagonist and the referent. Figure 3 also suggests longer RTs after walk than after jump sentences; however, the effect of motion sentence type did not reach statistical significance ($F_1(1,39) = 2.19$, n.s.; $F_2(1,47) = 2.92, p < .10; f = .05$). There was also no trace of an interaction between distance and motion type (both $F < 1$, $f = .03$). Target sentences showed comparable distance effects after jump sentences ($F_1(3,117) = 9.78, p < .001$; $F_2(3,141) = 7.33$, $p < .001$; $f = .24$) and after walk sentences ($F_1(3,117) = 11.33$, $p$

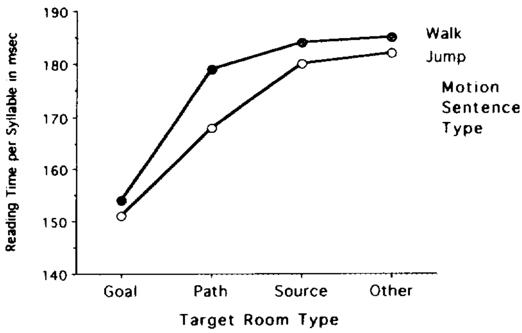


FIG. 3. Experiment 2: Mean reading times per syllable (in milliseconds) of target sentences following "walk" or "jump" motion sentences, categorized by target room type.

$< .001$; $F_2(3,141) = 11.01$, $p < .001$; $f = .24$). Target sentences after jump sentences did not reveal an all-or-none location effect, but a spatial gradient with significant differences between goal room and path room ($t_1(39) = 2.39$, $p < .03$; $t_2(47) = 2.47$, $p < .01$) and between path room and source room ($t_1(39) = 1.7$, $p < .10$; $t_2(47) = 1.73$, $p < .05$). In fact, the distance effect seemed even more "gradual" after jump sentences than after walk sentences. After the latter, only the difference between path room and source room was significant ($t_1(39) = 5.07$, $p < .001$; $t_2(47) = 3.36$, $p < .01$).

*Following sentences.* Spill-over effects were observed again in the reading times of the sentences that followed the target sentences (see Table 3). Like the target sentence RTs, the following sentence RTs revealed an effect of target room type ($F_1(3,117) = 8.35$, $p < .001$; $F_2(3,141) = 6.94$, $p < .001$; $f = .15$), with increasing RTs with distance. The type of motion sentence produced no reliable differences ($F_1(1,39) = 1.13$, n.s.; $F_2(1,47) < 1$, $f = .03$), nor did the interaction (both $F$s $< 1$, $f = .05$). As in Experiment 1, the distance effect observed with the reshifting following sentences was not stronger than the effect with the other following sentences, so the interaction of reshifting with target room type was not significant ($F_1(3,117) = 1.46$, n.s.; $F_2(3,141) = 1.01$, n.s.).

*Discussion*

The results of Experiment 2 indicate that, while reading the motion sentences, subjects inferred the protagonist's movement from the source room through the path room into the goal room. Such inferences occurred even for *jump* sentences that mentioned only the goal room. Reading times of these sentences revealed the same gradual increase with increasing distance as observed with the *walk* sentences in Experiments 1 and 2. The results indicate that when readers have a situation model of the spatial relations described in the narrative, they will use this knowledge to infer movements that are not explicitly stated. In this manner, they can incorporate the events described in the narrative into the situation model and update the model when necessary.

## EXPERIMENT 3

A possible objection to Experiments 1 and 2 is that the anaphoric references do not reveal effects of spatial distance in situation models, but rather effects due to the reader's surprise and confusion. According to this objection, our alleged distance effects only arose because subjects were confused by our target sentences that always referred to objects that were out of the focus of attention: Coherent narratives usually do not include many instances in which the protagonist suddenly remembers or thinks about a remote object. Indeed, our target sentences were presented directly after the motion sentences without any explicit motivation for the protagonist's thought which contained the anaphoric reference. Moreover, in the questionnaire completed at the end of the experiment, many subjects answered the question "Did you notice any sentences or other things in the stories that seemed strange to you?" by mentioning the target sentences. A prototypical answer of this kind was "The main characters were always reflecting back on objects in other rooms." Thirty-four of the

48 subjects in Experiment 1 and 25 of the 40 subjects in Experiment 2 mentioned the target sentences in their answers to this question. Subsequent analyses of the data from both experiments showed, however, that subjects who mentioned the strangeness of the target sentences showed the same pattern of results as subjects who did not mention this. Nonetheless, the high percentage of subjects who mentioned the target sentences indicates that these sentences were striking, possibly because they interrupted the smooth flow of the narrative and confused the subjects.

For interpreting our results, this confusion argument has several versions. The most extreme version states that the observed distance effects were completely caused by confusion: Only references to objects in the focus of attention (the goal room) are easily understood, whereas all other references are unmotivated and surprising. Moreover, the amount of surprise varies with distance from the focus of attention, i.e., the further away an object is, the more awkward is an anaphoric reference to it. A slightly weaker version of the confusion argument does not assume the distance relation, but rather predicts only an all-or-none location effect caused by confusion: References to objects in the goal room should be easily understood, whereas all other references should be equally surprising and confusing. The weakest version of the confusion argument merely assumes that sudden mention of the character's thoughts (described in the target sentences) amidst his many actions could be surprising. According to this hypothesis, the degree of surprise would be comparable in all different conditions, thereby causing an increase in reading times of all target sentences. All three versions of this confusion argument are compatible with the observed spill-over of processing to the following sentences: If a target sentence is confusing, subjects might plausibly continue processing it as they read the following sentence, hoping that it might provide helpful information.

Experiment 3 was designed to check whether the results observed so far could be explained by surprise or confusion instead of spatial distance in the situation model. We aimed to eliminate all possible surprises by motivating the thoughts and recollections mentioned in the target sentences. This was achieved by inserting a motivating sentence between each motion sentence and target "thought" sentence. For instance, after the motion sentence "He walked from the laboratory into the wash room," we inserted the sentence "In order to devise a list of necessary tasks, he tried to think of everything that looked dirty or messy in the building" just before the target sentence "He thought that *the shelves in the library* still looked like an awful mess" (see Tables 1 and 2). These inserted motivators should prepare subjects for the mental event described in the target sentence, e.g., they should expect the protagonist to think about a dirty or messy object somewhere in the building. Therefore, since the following target sentences should no longer be surprising or confusing, any remaining differences in comprehension time should be due to differences in accessibility of the referent objects. In addition, we reduced the likelihood that the target sentences might attract subjects' attention by using only 32 instead of the original 48 target sentences.

### *Method*

*Subjects.* Forty Stanford University undergraduates were paid for their participation in the experiment. The data of one additional subject were excluded from all analyses due to his making 30% errors on the questions following each narrative. The remaining 40 subjects had an average error rate of 12%.

*Layout and procedure.* These were identical to the ones used in Experiments 1 and 2.

*Narratives.* The same narratives as before were used. The 16 experimental narratives differed only in the motion and target sentences, and the new motivating sentences. To ensure comparability with Experiments 1 and 2, we used only the four types of target sentences with the room name (see the upper half of Table 2) and the "walk" type of motion sentences (see Table 1). For each of the 48 target sentences, we composed a sentence that motivated the mental event described in the target sentence. These motivating sentences were inserted between the corresponding motion and target sentences. Four independent judges rated the quality of each motivating sentence and the amount of remaining interruption in the flow of the narrative. We used only the 32 motivating sentences that were unanimously judged to clearly motivate the target sentence without leaving any interruption. The remaining 16 motivating sentences together with the corresponding target sentences were removed from the experimental materials. Table 4 shows the motivating sentences that were used with the example narrative, together with the goal room and other room target sentences. Table 4 should convey the impression that both types of target sentences are equally well motivated and "smooth," even though one refers to an object close to the protagonist and the other one to a distant object.

*Design.* The experiment involved only the factor of "target room type" (goal, path, source, other room), which was varied within subjects. Each subject read eight different target sentences in each of the four experimental conditions. As before, each object appeared equally often in each condition, and reading times of target sentences and following sentences served as dependent variables.

### *Results*

*Target sentences.* Figure 4 shows the mean reading times per syllable of target sentences, according to target room type. Table 3 contains the corresponding standard deviations as well. As Fig. 4 indicates, RTs increased with increasing distance between the protagonist and the object referred to. Accordingly, the ANOVAs of these RTs revealed a strong effect of target room type ($F_1(3,117) = 12.15$, $p < .001$, $F_2(3,93) = 10.88$, $p < .001$; $f = .30$).

TABLE 4

MOTION, MOTIVATING, AND TARGET SENTENCES FROM EXPERIMENT 3

| | |
|---|---|
| Motion sentence: | He walked from the laboratory into the wash room. |
| Motivating sentence: | In order to devise a list of necessary tasks, he tried to think of everything that looked dirty or messy in the building. |
| Goal room target: | He thought that the toilet in the wash room still looked like an awful mess. |
| Other room target: | He thought that the shelves in the library still looked like an awful mess. |
| Motion sentence: | So he walked from the repair shop into the experiment room. |
| Motivating sentence: | He re-checked his list of tasks to see what else needed to be done to make the research center decent-looking. |
| Goal room target: | He remembered that the blackboard in the experiment room should not be so dirty tomorrow. |
| Other room target: | He remembered that the sink in the wash room should not be so very dirty tomorrow. |
| Motion sentence: | Next he walked from the reception room into the conference room. |
| Motivating sentence: | He didn't want to let any uncleanliness distract the directors from his presentation, so he checked his list for things that needed to be cleaned. |
| Goal room target: | He decided that the coffee machine in the conference room needed cleaning as soon as possible. |
| Other room target: | He decided that the booths in the experiment room needed thorough cleaning as soon as possible. |

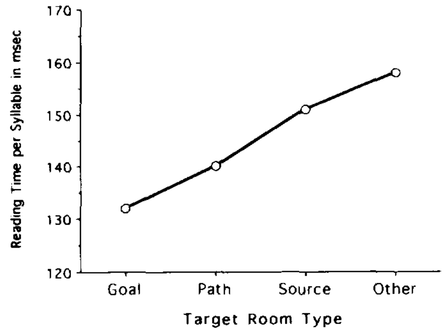


FIG. 4. Experiment 3: Mean reading times per syllable (in milliseconds) of target sentences categorized by target room type.

Planned comparisons revealed significant RT increases from goal to path room ($t_1(39) = 2.07, p < .05; t_2(31) = 1.89, p < .05$), and from path to source room ($t_1(39) = 2.78, p < .01; t_2(31) = 2.9, p < .05$). The difference between the source and the other room fell short of statistical significance ($t_1(39) = 1.42, p < .17; t_2(31) = 1.59, p < .10$).

We also conducted joint analyses of those target sentence RTs that were comparable over Experiments 1, 2, and 3, i.e., RTs of target sentences with the room name that followed a "walk" motion sentence (see the first, fifth, and ninth line of mean RTs in Table 3). The analyses revealed a significant main effect of "experiment" ($F_1(2,125) = 10.77, p < .001; F_2(2,125) = 6.02, p < .01; f = .35$). Post-hoc contrasts using Scheffé tests indicated that RTs in the current experiment (3) were shorter than in the first two experiments (both $p$s $< .01$).

*Following sentences.* The ANOVAs of the following sentence RTs revealed a weak effect of target room type ($F_1(3,117) = 2.88, p < .05; F_2(3,93) = 2.75, p < .05; f = .11$). As with target sentences, RTs of following sentences increased with distance between the protagonist and the object. However, only the increase from goal room to path room reached statistical significance ($t_1(39) = 2.42, p < .05; t_2(31) = 2.91, p < .01$).

*Discussion*

The results of the third experiment suggest that our materials are producing effects of spatial distance in situation models, and not effects of surprise or confusion caused by the unmotivated target sentences. The inclusion of the motivating sentences was apparently successful in reducing some modest infelicity and surprise created by the target sentences. With the preceding motivating sentences, the characters' thoughts and recollections mentioned in the target sentences seemed neither sudden nor strange to our readers (see the comparison of all four experiments below). Nevertheless, reading times of the target sentences still showed a spatial gradient similar to that observed in the first two experiments. Although the motivating sentences did not change the shape of the spatial gradient, they did reduce the overall reading time of the target sentences compared to the earlier experiments. This reduction might indeed reflect an increase in the smooth coherence of the text, but by an equal amount in all experimental conditions. Thus, the results support the weakest version of the confusion argument outlined above: Providing a reason for the mental events described in the target sentences helped subjects to understand the target sentences more easily.

## EXPERIMENT 4

An alternative explanation of the results obtained so far states that the anaphoric references do not reveal effects of *spatial* distance in situation models, but rather effects of the *temporal order* during learning. According to this explanation, our alleged distance effects arose because the rooms were learned in a temporal order that approximated their spatial distance. Indeed, closer inspection of the blank diagrams filled in by the subjects of the first three experiments revealed that most of them learned the building layout by starting with one room (often the reception room in the upper-left corner, compare Fig. 1) and proceeding through the building by studying one room after the other in a clockwise or counterclockwise order. In this manner, spatial distance between rooms in the layout and temporal distance during learning would be highly confounded: Except for the first and the last room studied, rooms close together in space would also have been learned close in time. Therefore, the memory representation of the rooms and objects would be rather like that of a temporally ordered list of rooms (with objects) without any necessity to assume the representation of spatial relations.

This "temporal distance" account cannot be ruled out as an explanation for the effects observed in the experiments reported here. Furthermore, the plausibility of this account was strengthened by results reported by Clayton and Habibi (1991). They demonstrated that an apparent spatial priming effect observed in a city-recognition task following map learning disappeared if spatial contiguous cities were not learned in a temporally contiguous fashion. Sherman and Lim (1991) observed similar results in a recognition task after subjects learned the locations of objects in a real environment. In a follow-up study, McNamara, Halpin, and Hardy (1992) found significant priming in a location judgment task for items learned in either spatial or temporal contiguity, but found significant priming in a city-recognition task only when an item was both spatially and temporally close to its prime during learning. In light of these findings, we may question whether our "spatial distance" effects in anaphora resolution times are due to a confound of spatial and temporal distance during learning.

To test this temporal distance explanation, we changed the way subjects learned the building layout. Instead of seeing the complete layout, subjects were forced to study one room after the other presented in a random temporal order. In this way, spatially close rooms were not learned any closer in time than spatially distant rooms. In all other respects, Experiment 4 was identical to Experiment 3. If temporal distance during learning is responsible for the effects observed in the first three experiments, no effect should be observed in Experiment 4. If the effects are caused by spatial distance in the situation model, a comparable spatial gradient should be observed again.

The temporal order of learning a collection of rooms (and their objects) might influence anaphora resolution times in several ways. While it would eliminate any spatial gradient of RTs plotted around the current focus of attention, the temporal hypothesis expects that anaphora resolution times will increase with increasing temporal distance during learning: The further apart two rooms were studied in the temporally ordered learning series, the longer it should take subjects to access an object in one of the rooms when their focus is on the protagonist located in the other room. Moreover, the temporal hypothesis would expect something resembling a temporal "serial position effect" in subjects' access to objects in different rooms. Specifically, objects in whatever rooms were presented and learned first or last in the temporally ordered learning series should be more accessible than objects learned in the middle of the temporal series. In order to check this possibility, each subject studied the rooms in a constant (random) order during learning. To counterbalance which rooms and objects were in different serial positions during learning, different subjects studied different random orders that were fixed over trials.

### *Method*

*Subjects.* Fifty subjects participated in the experiment. They were Stanford University students, 7 of whom were enrolled in summer courses. They were paid for their participation. The data of 10 subjects were excluded from all analyses because one subject failed to learn the building layout and 9 subjects gave incorrect answers to more than 30% of the questions following the narratives. The remaining 40 subjects had an average error rate of 14%.

*Layout, narratives, and design.* These were identical to the ones used in Experiment 3.

*Procedure.* In the first part of the experiment, subjects studied the building layout. In contrast to the other experiments, they never saw all the room names and object names in a complete layout but rather studied one room at a time, going through the rooms in a random order. First, they were handed a learning booklet and several blank diagrams of the whole building. Each page of the booklet showed the building layout with nine rooms being blank and one room being complete with its room name and the objects contained in it. Each room was learned in the following manner: Subjects studied it for about a minute, put the booklet aside, wrote down the room and object names in a blank diagram, compared this to the booklet page just studied, put the used diagram away, and turned the booklet page over to study the next room. After finishing the learning booklet, they were handed a practice booklet to check and improve their knowledge of the rooms and objects. Each room was practiced in the following way: The first page of the booklet contained a request to fill in one of the rooms and its objects in a new blank diagram of the whole building. After doing this, subjects turned the page over and compared their version to the correct version shown on the next page. Turning the page over again brought them to a test on the next room being learned. Subjects went through the practice booklet as often as necessary until they could perfectly reproduce all room and object names in their correct locations. For each subject, the order of the rooms was random, but identical in both booklets. The experimenter took care that subjects did not depart from the order specified by their booklets. Afterwards, subjects answered the same six questions about the location of objects in the building as in the other experiments. Subjects required about 35 min to learn the layout and answer the questions perfectly. The second part of the experiment—including reading of the narratives, answering the three questions following each narrative, and completing the questionnaire about reading strategies—was identical to that of Experiment 3, which had the motivating sentences preceding the target sentences.

### *Results*

*Target sentences.* Figure 5 shows the mean reading times per syllable of target sentences, according to target room type. Table 3 contains the corresponding standard deviations as well. As Fig. 5 indicates, RTs increased with increasing distance between the protagonist and the object referred to. Accordingly, the ANOVAs of these RTs showed a significant effect of target room type ($F_1(3,117) = 9.44, p < .001$; $F_2(3,93) = 4.89, p < .01; f = .13$). Planned comparisons revealed a significant RT increase from goal to path room ($t_1(39) = 2.13, p < .05$; $t_2(31) = 2.32, p < .05$). The differences between path and source room and between source and other room fell short of statistical significance (all $ps > .10$). The difference between path and other room was significant, however ($t_1(39) = 2.75, p < .01$; $t_2(31) = 2.83, p < .01$). These

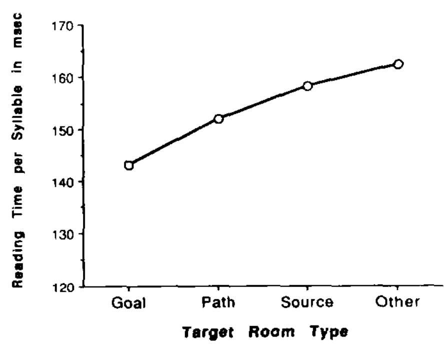


FIG. 5. Experiment 4: Mean reading times per syllable (in milliseconds) of target sentences categorized by target room type.

data indicate that an effect of spatial distance can be observed, even if spatial distance in the situation model is not confounded with temporal distance during learning.

To check for possible effects of temporal distance, we determined how far apart the goal room and the target room of each target sentence were learned. Naturally, this temporal distance is always zero for target sentences referring to an object in the goal room, since goal room and target room are identical in this case. Therefore, only sentences referring to an object in the path, source, or other room were used in this analysis. For instance, the two rooms involved in a path room target sentence always have a spatial distance of one room, whereas their temporal distance could be any number between one and nine positions, e.g., five positions if the target room was learned as the second room and the path room as the seventh room. However, ANOVAs of the target sentence RTs revealed no effect of temporal distance during learning (both $F$s $< 1$).

A second implication of the temporal hypothesis is that rooms studied at the beginning or end of the 10-room series should be more accessible than other rooms (a primacy or recency effect). Unfortunately, since each subject received a random order of rooms during learning, the 10 rooms did not distribute evenly over the 10 possible positions. But by pooling data from adjoining positions, we obtained an even distribution of rooms over these 5 pooled positions (1-2, 3-4, 5-6, 7-8, 9-10). All four types of target sentences could be used in this analysis. However, ANOVAs of the target sentence RTs including this five-level factor of "temporal learning position" revealed that it did not affect reading time of target sentences (both $F$s $< 1$).

*Following sentences.* ANOVAs of the following sentence RTs revealed an effect of target room type ($F_1(3,117) = 7.13$, $p < .001$; $F_2(3,93) = 7.00$, $p < .001$; $f = .13$). As with target sentences, RTs of following sentences increased with distance between the protagonist and the object, but only the increase from goal room to path room reached statistical significance ($t_1(39) = 3.07$, $p < .01$; $t_2(31) = 2.27$, $p < .05$). Also in accordance with the results observed for target sentences, neither temporal distance between rooms nor their absolute position during learning had a reliable effect on the RTs of following sentences (all $F$s $< 1.27$, n.s.).

*Comparison of the four experiments.* Since Experiments 3 and 4 were identical except for the learning procedure, we also computed joint analyses of the data from both experiments. As expected, joint analyses of target sentence RTs showed no indication of an interaction between experiment and target room type (both $F$s $< 1$, $f = .04$). The same was true for the joint analyses of following sentence RTs (both $F$s $< 1$, $f = .04$), indicating that our change of the learning procedure did not affect the spatial gradient observed before.

Compared to Experiments 1 and 2, subjects in Experiment 3 and 4 (who had the motivating sentences) read the syllables of the target sentences about 30 ms faster. To determine the significance of this finding, joint analyses were computed for those target sentence RTs that were comparable over all four experiments (see the 1st, 5th, 9th and 11th line of mean RTs in Table 3). As expected, the joint ANOVAs of these RTs revealed a strong main effect of "experiment" ($F_1(3,164) = 7.27$, $p < .001$; $F_2(3,156) = 4.31$, $p < .01$; $f = .32$). Post-hoc contrasts using Scheffé tests revealed that RTs in Experiments 3 and 4 were indeed shorter than in the first two experiments (all $p$s $< .05$). RTs in Experiments 3 and 4 did not differ significantly from another, neither did the RTs in Experiments 1 and 2 (all $p$s $> .10$). The ANOVAs also showed an effect of target room type ($F_1(3,492) = 46.13$, $p < .001$; $F_2(3,468) = 33.54$, $p < .001$; $f = .24$), and subsequent planned comparisons revealed significant RT increases from goal room to path room

($t_1(167) = 5.6, p < .001; t_2(159) = 5.51, p < .001$), from path room to source room ($t_1(167) = 3.68, p < .001; t_2(159) = 2.6, p < .01$), and from source room to other room ($t_1(167) = 2.84, p < .01; t_2(159) = 1.87, p < .05$). Furthermore, the interaction of experiment and target room type was significant in the by-subjects analysis ($F_1(9,492) = 2.80$, $p < .01$; $f = .10$) and marginally significant in the by-materials analysis ($F_2(9,468) = 1.82$, $p < .10$), indicating that the RT increase was less linear in Experiment 2 than in the other experiments.

Joint analyses of the sentences following comparable target sentences (see the third, seventh, tenth, and twelfth line of mean RTs in Table 3) revealed only one significant effect, namely, spatial distance or target room type ($F_1(3,492) = 17.53, p < .001$; $F_2(3,468) = 12.04$, $p < .001$; $f = .16$). Again, planned comparisons showed that only the RT difference between goal room and path room was significant ($t_1(167) = 4.92$, $p < .001$; $t_2(159) = 3.13$, $p < .01$). Neither the main effect of experiment nor the interaction reached statistical significance (all $F$s $< 1.77$). In the post-experiment questionnaire, only 5% of the subjects in Experiment 3 and 20% of the subjects in Experiment 4 mentioned the target sentences as "strange," significantly less than in Experiment 1 (5% vs 69%, $p < .01$; 20% vs 69%, $p < .01$) and Experiment 2 (5% vs 63%, $p < .01$; 20% vs 63%, $p < .01$).

### *Discussion*

The results of the fourth experiment suggest that the effects observed before were indeed caused by spatial distance in situation models, and did not arise because the rooms were learned in a temporal order that paralleled their spatial distance. In Experiment 4, temporal distance during learning and spatial distance in the layout were explicitly uncorrelated. Nevertheless, reading times of the target sentences still showed a spatial gradient comparable to that observed in the first three experiments. In particular, the results are very similar to those of Experiment 3 that differed only in the way the spatial knowledge was acquired. Somewhat surprisingly, we did not observe any effect of temporal position or distance during learning on reading times of target sentences and following sentences. However, the present experiment was not designed as a strong test of these effects because we were primarily interested in the spatial distance effect. Therefore, we used random orders of rooms during learning instead of carefully balanced orders, which might have been more powerful. Furthermore, the results of Experiment 4 further support the conclusion from Experiment 3: Again, a spatial gradient was found that cannot be attributed to confusion or surprise during reading of the target sentences.

## General Discussion

Taken together, the four experiments reported here provide evidence for the claim that spatial distance in the reader's situation model of a narrative influences the accessibility of referents for anaphoric expressions. Reading times of sentences containing anaphoric references to learned objects increased with spatial distance between the object and the reader's focus of attention, i.e., the protagonist of the narrative. In contrast to the earlier study by Glenberg et al. (1987), the distance effect here was shown with definite noun phrases as anaphors instead of pronouns. Since noun phrases can be used to refer to both foregrounded and backgrounded referents, the observed distance effect provides stronger evidence for the situation model assumption. Moreover, by having four different levels of spatial distance, our results showed that the accessibility of referents gradually decreases with increasing distance from the reader's focus of attention. All four experiments revealed monotonic increases in reading time with increasing distance between the object referent and the protagonist. The fact that references to objects in the unmentioned path room were consistently easier to understand than references to objects in the explicitly mentioned source room is especially important. It shows that the observed effects are due to characteristics of the reader's situation model (Morrow et al., 1989), not to characteristics of the text base, i.e., recency of mention.

Moreover, the results provide evidence against the "salience" explanation of spatial distance effects put forth by McKoon and Ratcliff (1992). McKoon and Ratcliff claimed that the results observed by Glenberg et al. (1987) were not produced by spatial distance, but by the fact that objects that the protagonist carried with him were more salient than objects that the protagonist left behind. This explanation cannot account for the data reported here: Target objects were never mentioned in a narrative before they were referred to in a target sentence, and the motivating sentences used in Experiments 3 and 4 made all objects equally salient as potential referents for the anaphor contained in the following target sentence. Therefore, it would be quite difficult to argue that the spatial gradient observed in the present experiments should be caused by differential salience that does not arise from a spatial situation model.

In addition to the conclusions specific to anaphora resolution, the results provide converging evidence for the general influence of situation models on narrative comprehension: Our results obtained with reading times of anaphoric sentences agree with and extend the probe reaction time results of Morrow et al. (1987, 1989) and Wilson et al. (1993). Presumably, longer reading times in the present experiments reflect the same pattern of accessibility of objects in memory as found in earlier studies. Converging evidence from the present experiments is particularly valuable because the paradigm used here resembles "natural reading" more closely than does the object probe paradigm used heretofore. Subjects have only one task, namely, reading carefully, and they do not need to switch between the two unrelated tasks of reading narratives and answering probe questions. In this manner, the anaphora method avoids the problems associated with the probe paradigm that were reported by Wilson et al. (1993).

These general conclusions are supplemented by specific results of single experiments. Experiment 1 revealed that more information contained in the anaphoric sentence quickened resolution of the anaphor: Sentences that contained the name of the target room were easier to understand than sentences without the room name. Moreover, this effect spilled over to influence reading times of the sentences following the target sentence. Presumably the room name helped readers either to focus their attention on the correct room immediately or to retrieve the referent object more quickly. Experiment 2 demonstrated some of the inferences that subjects draw from their situation models. Subjects used their situation models to infer movements that were only implicitly stated in the text: They inferred the protagonist's movement from the source room through the path room into the goal room, even when the described motion involved a "jump" to the protagonist's final location, i.e., the goal room. Finally, Experiments 3 and 4 indicated that the observed effects were not due to the text causing confusion in the reader or to confounding spatial and temporal contiguity during learning, but were due to spatial distance of the referent in the situation model. The same spatial gradient was observed as in the first two experiments, even with target sentences that were made smoothly coherent by preceding motivating sentences and with a randomized order in which the rooms of the layout had been learned.

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