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Spatial Mental Models Derived from Survey and Route Descriptions

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In four experiments, subjects read route or survey descriptions of naturalistic environments and then answered verbatim or inference questions from both perspectives and drew maps of the environments. In all studies, subjects were faster and more accurate to verbatim than to inference questions, suggesting that verbatim questions are verified against a representation of the text of the descriptions. Subjects were as fast and accurate to inference questions from the read perspective as from the new perspective, suggesting that inference questions are verified against a representation of the situation described by the text. Map drawings were very accurate for both description types. A separate group of subjects studied maps instead of descriptions, and their performance was comparable to that of description subjects on all tasks. Readers apparently form the same spatial mental models capturing the spatial relations between landmarks from both survey and route descriptions, and from maps.

An informal survey of tourist guide books reveals two styles of description, differing in the perspective taken on the environment. In one, the writer takes the reader on a mental tour or *route:* "As you sail up the Seine from the Place de la Concorde, you first come to the Musee D'Orsay on your right, and then the Louvre on your left. Straight ahead of you, you can see the Ile de la Cite, and the spires of Notre Dame. . . ." Another style of description takes a bird's eye or *survey* perspective: "The Washington Mall is bounded by the Capitol at the east and the Lincoln Memorial at the west. Museums line the southern and northern borders of the middle of the Mall. Along the southern part of the Mall, the most eastern museum is the Air and Space Museum. Just west of it, across the street, is the Hirschorn Museum, and. . . ." The first type of description gives the reader a set of procedures for way-finding in the environment. The second type provides an overview of the spatial layout. Do these two styles of description have different cognitive consequences? In other words, do they induce different mental representations?

Recent research in memory for discourse has demonstrated the existence of multiple representations of discourse: representations of the phonetic or graphemic properties of actual words (e.g., Glanzer, Dorfman, & Kaplan, 1981), of the propositional content or gist of a discourse (e.g., Johnson-Laird, 1983), and of the situation described by the discourse (e.g., Barclay, 1973; Bransford, Barclay, & Franks, 1972; Johnson-Laird, 1983; van Dijk & Kintsch, 1983). Some of these studies have shown that situational representations reflect the spatial properties described in a discourse, for example, the spatial relations among objects (Ehrlich & Johnson-Laird, 1982; Foos, 1980; Franklin & Tversky, 1990; Mani & Johnson-Laird, 1982; Perrig & Kintsch, 1985) and some distance informa-

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tion (Bower & Morrow, 1990; Glenberg, Meyer, & Lindem, 1987; Morrow, Bower, & Greenspan, 1989; Morrow, Greenspan, & Bower, 1987). The question of interest here is whether situational representations maintain features indicative of different text perspectives, in particular, survey and route.

Other research on comprehension and memory for text has demonstrated effects of perspective. Changing perspective apparently takes time and effort (Black, Turner, & Bower, 1979). Perspective affects what aspects of a described scene are foregrounded and recalled. Bly (1989) found readers were faster to respond to probes in the visual field of the character whose perspective they took than probes associated with the character but not visible from the character's perspective. Abelson (1975) instructed readers to imagine a story either as if they were the protagonist or as if they were an observer from a balcony overhead. Readers who took the perspective of the protagonist remembered events close to the character better whereas readers who imagined themselves on the balcony remembered visual details distant from the protagonist better. Other research has shown effects of personal rather than spatial perspective on memory. When biased toward the perspective of a particular character, readers later misremembered perspective neutral sentences as conforming to the perspective that they had taken (Owens, DaFoe, & Bower, reported in Bower, 1978). In recall of a narrative describing a house, readers remembered details relevant to their own perspective, say a burglar, better than details relevant to an alternative perspective, say a potential house buyer (Anderson & Pichert, 1978).

Thus, there is some a priori reason to expect that route and survey perspectives will induce different spatial representations. Further support for that expectation comes from research investigating learning actual environments from different perspectives. Thorndyke and Hayes-Roth (1982) found that subjects who learned an environment by walking through it gave more accurate estimates of route measurements, such as route distances and the degree of change needed to orient to unseen objects, whereas subjects who had studied maps gave more accurate estimates of survey measurements, such as Euclidean distances and the relative positions of locations. Sholl (1987) found that the availability of information in memory differed depending on the way, and consequently from what perspective, it was learned. If learned from a map, all locations were equi-available; but if learned via navigation, locations imagined in the direction of the visual field were more accessible. Streeter, Vitello, and Wonsiewicz (1985) found that subjects presented with a route task, that of navigating unfamiliar roads, performed better with route directions than with a map. Generally, these findings, and others, indicate that the method by which knowledge is acquired influences the type of knowledge stored in memory (Evans & Pezdek, 1980; Thorndyke, 1981).

In studies which served as a model for our own, Perrig and Kintsch (1985) gave subjects survey or route descriptions of a town and tested memory for the actual text, for spatial inferences grounded in the text, and for maps constructed from the information in the text. Perrig and Kintsch found some evidence that female subjects constructed different situation models from survey and route descriptions. However, overall performance was poor, probably because the descriptions were long and detailed, calling into question whether readers actually formed spatial mental models. There was some advantage to route descriptions. Upon closer inspection, this advantage can be attributed to the interplay of the textual organization and the perspective presented resulting in several indeterminate locations for survey descriptions. Perrig and Kintsch's route descriptions were organized serially, where the order of mention of landmarks was determined by a path taken through the environment. This yielded a highly coherent text. Perrig and Kintsch altered their route descriptions to create survey ones by preserving the same linear order of landmarks, but changing the terminology from egocentric terms, such as *left* and *front,* to extrinsic terms such as *north* and *east.* The consequent survey texts were not as well-organized or as coherent. Research has shown that performance diminishes with less coherent text (Denis & Denhiere, 1990; Ehrlich & Johnson-Laird, 1982; Garnharm, Oakhill, & Johnson-Laird, 1982). According to one explanation for this effect, incoherence prevents the immediate integration of new information into a working mental model. Foos (1980) found that construction of a spatial representation was best when new information could be immediately integrated into the representation.

No less important, because Perrig and Kintsch used the same organization for both texts, some spatial relations explicit in the route description were not explicit in the survey description. For example, their route text described Main Street as part of a continuing path, "continue on the highway to Main Street where you can turn either right or left." The direction of motion along the path is explicit. Although the direction of motion for the survey text was the same as for the route text, spatial paths were not always implied in the survey text, rendering the location of Main Street indeterminate: "The town itself consists of little more than the highway and Main Street which crosses the highway." Mani and Johnson-Laird (1982) have shown that readers form mental models from spatially determinate descriptions, but not from indeterminate ones.

Because a survey perspective presents an overview consisting of a more global structure with local substructures (Chase & Chi, 1981), a hierarchical organization is more natural for a survey description, while a linear organization is natural to route descriptions. The cognitive consequences of different textual organizations remains unclear. Studies comparing expressly linear and hierarchical organizations of instructions have sometimes shown one organization to be superior and sometimes the other (Dixon, 1987; Smith & Goodman, 1984; Spoehr, Morris, & Smith, 1983). The two perspectives also differ in the use of different reference frames and spatial terminology. Survey descriptions, where perspective is from above, use an extrinsic frame of reference and canonical terms such as *north, south, east,* and *west* to relate new locations to established locations in the environment. Route descriptions, where perspective is within the environment, use an intrinsic frame of reference and egocentric terms such as *right, left, front,* and *back* to relate locations to the position of a moving observer.

In the present experiments, we developed four fictitious environments—two large-scale, one county-sized and the other a small town, and two small-scale, a zoo and a convention center. Each contained between 11 and 15 landmarks. For each environment, we wrote both a survey and a route description. The survey and route descriptions conveyed perspective appropriate organization, vantage point, spatial terminology, grammatical person, and referent. In addition to the locative information, each description contained nonlocative information giving great elaborative details about the environments. This information was identical for route and survey descriptions.

Because coherence is an important factor in discourse comprehension, we attempted to equate coherence between our descriptions. There is no widely-applicable measure of discourse coherence. Co-reference, that is, linking sentences in sequence by referring to the same thing, has sometimes been suggested (Johnson-Laird, 1983; van Dijk & Kintsch, 1983). However, this measure cannot be applied equally to discourses with different organizations. For route or linear organizations, co-reference is made to the previous sentence, whereas for hierarchical organizations, a new descriptive part will refer back to the overview. Lacking an objective measure, we asked a group of pilot subjects to evaluate the coherence of our texts. Each pilot subject read four descriptions, two route and two survey, and when tested on each with true/false questions, showed no differential performance based on the description perspective. Additional confirmation of coherence came from interviews of the pilot subjects about the descriptions indicating equal coherence for the two description types. The final pretest of these descriptions indicated that the pilot subjects could correctly place all landmarks in sketches. These precautions were apparently successful, as overall performance on survey and route texts was at the same high level.

We modeled our assessments on those of Perrig and Kintsch. After reading each description, readers verified statements related to the text as *true* or *false;* reaction time and errors were recorded. The statements tested both locative and nonlocative information. Locative statements were either verbatim from the text or could be inferred from the information presented in the text. Half of all the locative statements were from a route perspective and half from a survey perspective. Readers read two stories from each perspective and answered all types of questions for each environment. Thus, a verbatim statement from a different perspective was in effect an inference statement for that reader.

If readers represent the gist or exact wording of the text, verbatim questions should have faster and more accurate responses than inference questions. If the situation models readers construct depend on the particular perspective of the narrative, then readers should respond faster to inference statements from the perspective read than to inference and verbatim statements from the other perspective. If, however, the situation models represent spatial relations in a manner not dependent on the perspective learned, then there should be no differences on the inference questions as a result of the perspective read. To check that readers were able to form an integrated and correct spatial model, we had them draw a map of each environment.

Experiment 1

Method

Subjects

Thirty-two undergraduates, 14 female and 18 male, from Stanford University participated individually in partial fulfillment of a course requirement for introductory psychology. The data for two subjects, both male, with scheduling conflicts preventing completion of the procedure, were eliminated from analysis.

Materials

Individual differences. A short preexperimental questionnaire was designed to address several previous cognitive mapping results related to individual differences. First, subjects were asked to designate their gender; some previous research has shown gender differences on spatial cognition tasks (Halpern, 1986; Perrig & Kintsch, 1985). Three more questions addressed previous findings showing correlations between spatial cognition and self-reported sense of direction or actual map use or preference for maps as navigational tools (Kozlowski & Bryant, 1977; Streeter & Vitello, 1986): "How good is your sense of directions?," "How often do you use maps to help you find a new place?," and "Which would you rather use to help you find a new place—maps, verbal directions, or a combination?"

Texts. We prepared four pairs of descriptive texts. Each pair described one of four fictitious environments from one of two perspectives: bird's eye (survey) or mental tour (route). The environments were originally drawn using an Apple Macintosh and the software MacPaint and covered approximately a 6 by 8.5 in. area. The environments differed in both geographic scale and the number of hierarchical levels: the two larger scale areas had three-level hierarchies and the two smaller scale had two-level hierarchies. The environments are depicted in Figs. 1–4. Only subjects in one condition of Experiment 3 actually saw these maps.

The two types of descriptions differed in overall organization. The survey description reflected the hierarchical structure particular to each environment, either depth-first or breadth-first. In contrast, the route texts, designed to lead readers on a mental tour of each environment, had a linear organization. A path through each environment was selected so that all objects within an environment could be mentioned along a continuous path, with as few turns as possible. Additionally, the two perspective texts differed in both spatial terminology and grammatical person. The survey texts used the canonical terms, *north, south, east,* and *west,* along with other spatial terms, such as *across* or *in the center,* to refer to objects with respect to previously mentioned objects. The route texts addressed readers in the second person and described all locations with respect to the reader's suggested position in the environment using egocentric terms such as *on your right* or *in front of you.* Texts exemplifying the features of route and survey descriptions of the town and the convention center appear in Tables 1–4. These specific descriptions were used in Experiments 2–4.

Several factors not related to perspective were equated in the texts. First, each pair of texts was informationally equivalent. By that we mean that all information descriptive of the environments could either be obtained directly or inferred from the texts; there were no indeterminate locations. Within each pair of descriptions, what information was given and what needed to be inferred differed. Second, each pair of texts was written to be equally coherent. This was verified by pilot subjects' judgment of narrative coherence. Third, the texts were roughly equated for length. The average

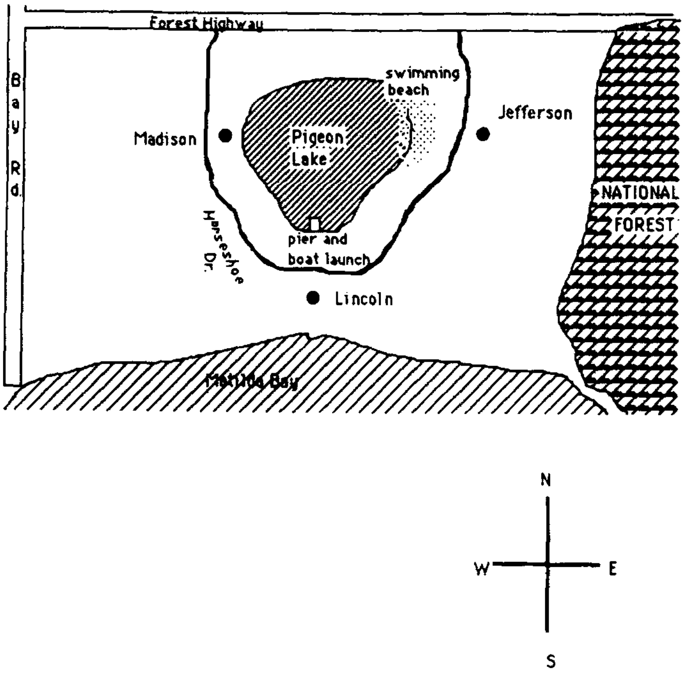

FIG. 1. Map of county-sized resort area.

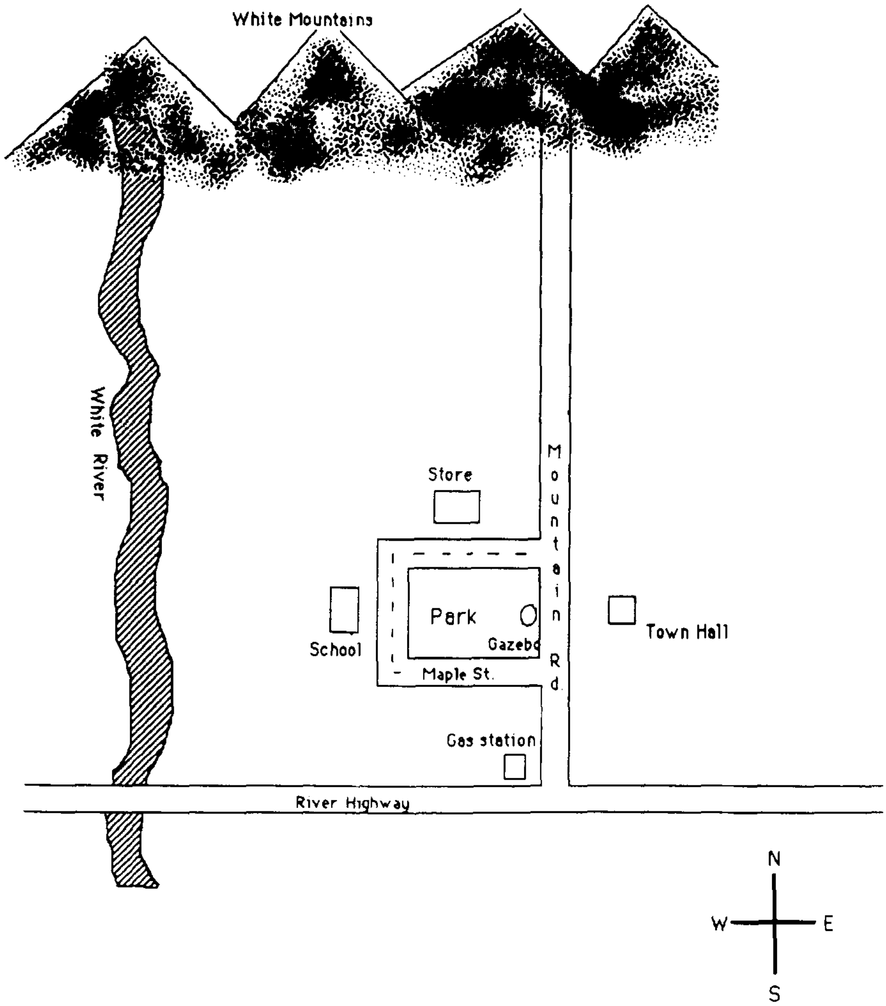

FIG. 2. Map of town.

length was 593 syllables with a range between 483 and 755. A pairwise comparison of text lengths indicated no significant length difference based on perspective. Fourth, information about a new location followed reference to a previously mentioned location. Research has shown that processing time is faster when sentences are arranged in this given/new order (Haviland & Clark, 1974; Yekovich, Walker, & Blackman, 1979).

Test statements. For each pair of descriptions, a set of 28 statements tested knowledge learned from the descriptions. The statements consisted of verbatim sentences from the texts or sentences drawing on information imparted by the texts, but not directly stated. Each set consisted of the following six types of test statements:

Four verbatim nonlocative statements—nonlocative statements found verbatim in both texts in a pair, for example, "Jefferson is the main center for hiking and cycling." or "The Cafeteria is privately run by a family that leases the space on a permanent basis from the Convention Center."

Four paraphrased nonlocative statements—paraphrases of nonlocative statements found in both texts in a pair, for example, "The chimp show includes chimps playing the piano and riding unicycles." or "Boating, water-skiing, and swimming are some of the water sports that are enjoyed on Pigeon Lake."

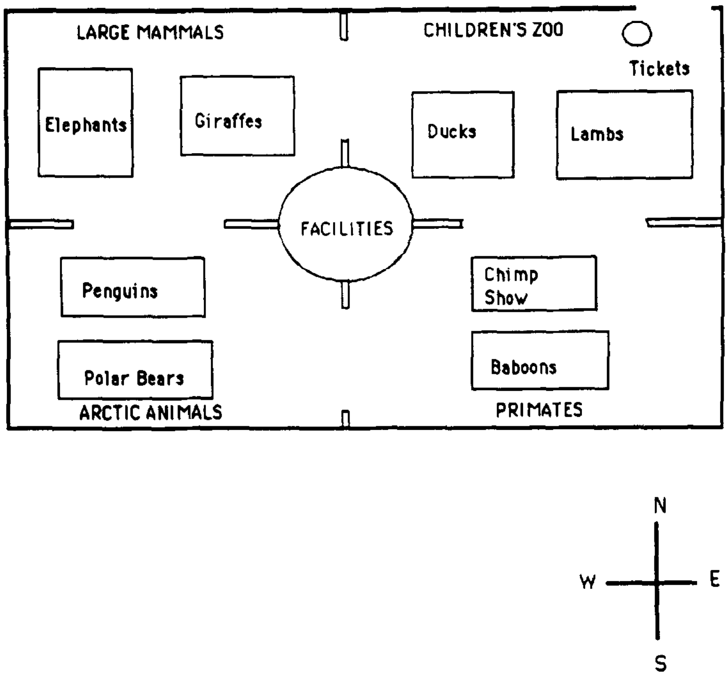

FIG. 3. Map of zoo.

Four verbatim survey statements—locative statements found verbatim in the survey text, for example, "The gas station lies at the northwest corner of River Highway and Mountain Rd." or "Directly south of the Cafeteria, on the west wall, are the Restrooms."

Six survey inference statements—locative statements relating an item in the environment to another item in the environ-

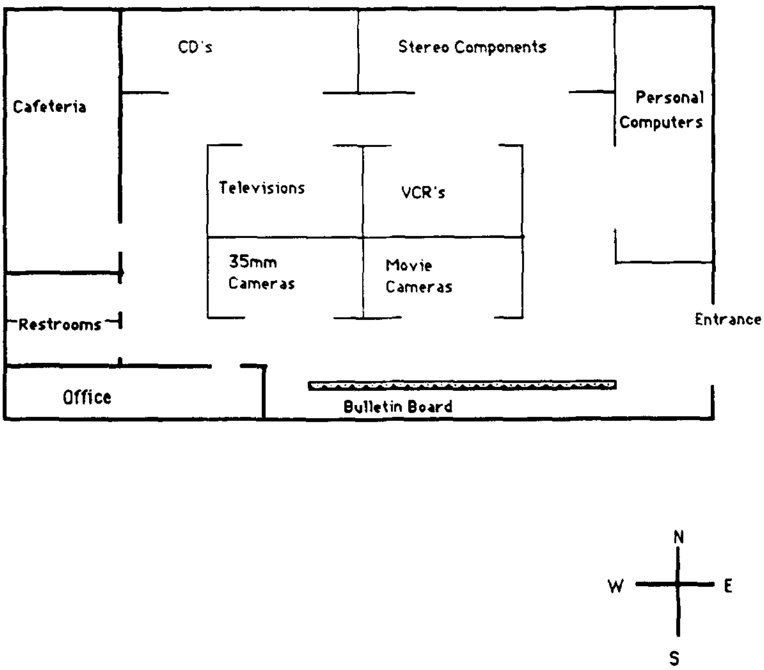

FIG. 4. Map of convention center.

TABLE 1

SURVEY DESCRIPTION OF TOWN. EXPERIMENTS 2–4

One of the largest town fairs and pumpkin festivals in the United States is held each year in the town of Etna. Etna is a typical small New England town. The layout of the town has not changed much since it was founded in the 1700's. Etna and its surrounding areas are bordered by four major landmarks: the White Mountains, the White River, the River Highway, and Mountain Rd. The northern border is made up of the White Mountain Range. Running north–south along the western border of this region is the White River. The southern border is made up of the River Highway. Along the eastern border, connecting the River Highway to the mountains, is Mountain Rd. Most of Etna lies west of Mountain Rd. just north of its intersection with the River Highway. Etna is built around four streets that surround the Town Park. On the eastern edge of the park, there is a white Gazebo. The Gazebo is used to house the town band during afternoon concerts. Along the eastern edge of the Town Park runs Mountain Rd. The other three streets in Etna are each only a block long. Along the southern border of the park runs Maple St. Maple St. is lined with large maple trees. These maples, when they come alive with color in the fall are an attraction for many tourists. Across the street from the park, on separate sides, lie three of the town's main buildings—the Town Hall, the Store, and the School. Across the street from the east side of the park is the Town Hall. The Town Hall is the oldest structure in the town and one of the buildings around which the town was built. Across the street from the north side of the park is the Store. People often gather at the Store to find out the latest town news. Across the street from the west side of the park is the School. The little red, one-roomed schoolhouse is the original school built when the town was founded. At the northwest corner of River Highway and Mountain Rd. is the Gas Station. One of the mechanics from the Gas Station sits in front of the station office and waves to all the cars that drive past.

ment in a way not previously specified in the survey text, for example, "The restrooms are directly south of the Office." or "Horseshoe Dr. runs along the northern shore of Pigeon Lake." These statements maintained the third person and canonical terminology characteristic of the survey text. Three of the statements were true and the other three were false.

Four verbatim route statements—

TABLE 2

ROUTE DESCRIPTION OF TOWN. EXPERIMENTS 2–4

One of the largest town fairs and pumpkin festivals in the United States is held each year in the town of Etna. Etna is a typical small New England town. The layout of the town has not changed much since it was founded in the 1700's. To reach Etna, drive east along the River Highway to where the highway crosses the White River. Continuing on the River Highway, for another half mile past the river you come to, on your left, Mountain Rd. You have reached the town of Etna. As you turn left onto Mountain Rd. from the River Highway, you see, on your immediate left, the Gas Station. One of the mechanics from the Gas Station sits in front of the station office and waves to all the cars that drive past. Straight ahead, you can see the road disappearing into the distant White Mountains. You drive on Mountain Rd. a block past the Gas Station, and come to, on your left, Maple St. Turning left onto Maple St., you see that the street is lined with large maple trees. These maples, when they come alive with color in the fall, are an attraction for many tourists. After turning left onto Maple St. from Mountain Rd., you see, on your right, the Town Park—a central feature of Etna. You travel a block on Maple St. and are forced to make a right turn. On your left, about a half a block after you turn off of Maple St., is the School. The little red, one-roomed schoolhouse is the original school built when the town was founded. Continuing along this street for another half a block, you are again forced to make a right turn. You turn and drive a half a block where you see, on your left, the Store. People often gather at the Store to find out the latest town news. This road continues for another half a block where it dead-ends into Mountain Rd. After you make a right turn onto Mountain Rd., you drive about a half a block to where you see, on your left, the Town Hall. The Town Hall is the oldest structure in the town and one of the buildings around which the town was built. From your position with the Town Hall on your left, you see, on your right, a white Gazebo near the edge of the park. The Gazebo is used to house the town band during afternoon concerts. You return to where Mountain Rd. dead-ends into the River Highway. You turn left from Mountain Rd. and leave the town of Etna by taking the River Highway.

locative statements found verbatim in the route text, for example, "From your position with Lincoln on your right, you see, on your left, the fishing pier and boat launch for Pigeon Lake." or "As soon as you enter

TABLE 3
SURVEY DESCRIPTION OF CONVENTION CENTER. EXPERIMENTS 2–4

Several companies that manufacture electronics have decided to get together for a convention to show their wares. A large convention center was chosen because its large rectangular floor plan can be easily changed to accommodate the needs of various conventions. Temporary wall dividers are used to separate the displays and to form a single entrance to each display. The displays have been grouped according to three categories—Visual Equipment, Personal Computers, and Audio Equipment. The rectangular center section of the building is divided into four displays for the visual equipment. In the northwest corner of the center section, with the entrance facing north, are the Televisions. Like many television displays, the sets are lined up along the walls, all tuned to the same station. In the northeast corner of the center section, with the entrance facing north, are the VCR's. In the southwest corner of the center section, with the entrance facing south, are the 35mm Cameras. In the southeast corner of the center section, with the entrance facing south, are the Movie Cameras. The Movie Cameras are set up to film people as they walk by the display. The remainder of the displays are along the outer, rectangular wall of the Convention Center. The east wall has only one display, the Personal Computers. This display is in the northeast corner and extends for about half of the east wall. There are software samples available for potential customers to test the various computers. Along the north wall are the two Audio Equipment displays—the Stereo Components and the CD Players. Along the north wall, directly west of the Personal Computers, are the Stereo Components. The Stereo Components display includes such items as receivers, turntables, speakers, and tape decks. Directly west of the Stereo Components are the CD Players. In addition to the displays, there are four permanent features of the Convention Center located along the west and south walls—the Cafeteria, the Restrooms, the Office, and the Bulletin Board. Just west of the CD Players, beginning in the northwest corner of the Convention Center and extending for about half of the west wall, is the Cafeteria. The Cafeteria is privately run by a family that leases the space on a permanent basis from the Convention Center. Directly south of the Cafeteria, on the west wall, are the Restrooms. Directly south of the Restrooms, extending from the southwest corner for about a third of the south wall, is the Office. East of the Office, covering about half of the south wall, is the Bulletin Board. The Bulletin Board is used in every convention for the business cards of the participating companies. East of the Bulletin Board, on the east side of the building near the southeast corner, is the entrance.

TABLE 4
ROUTE DESCRIPTION OF CONVENTION CENTER. EXPERIMENTS 2–4

Several companies that manufacture electronics have decided to get together for a convention to show their wares. A large convention center was chosen because its large, rectangular floor plan can be easily changed to accommodate the needs of various conventions. Temporary wall dividers are used to separate the displays and to form a single entrance to each display. The displays have been grouped according to three categories—Visual Equipment, Personal Computers, and Audio Equipment. You go to the east side of the building near the southeast corner where you find the entrance. As you walk into the building, you see, on your left, a Bulletin Board. The Bulletin Board is used in every convention for the business cards of the participating companies. Continuing straight ahead from the entrance, where the Bulletin Board is on your left, you reach, on your right, the Movie Cameras. The Movie Cameras are set up to film people as they walk by the display. Walking past the Movie Cameras on your right, you see, again on your right, the 35mm Cameras. On your left, stretching into the corner of the building, is the Office. From the Office, you are forced to turn right and you see, to your immediate left, the Restrooms. You continue forward from the Restrooms until you see, on your left stretching into the corner of the building, the Cafeteria. The Cafeteria is privately run by a family that leases the space on a permanent basis from the Convention Center. From the Cafeteria, you walk forward, until you are forced to turn right and you see, to your immediate left, the CD Players. On your right are the Televisions. Like many television displays, the sets are lined up along the walls, all tuned to the same station. You walk past the Televisions, on your right, and continue forward until you see, again on your right, the VCR's. On your left are the Stereo Components. This display includes such items as receivers, turntables, speakers, and tape decks. From the Stereo Components you walk forward until you are forced to turn right and you see, to your immediate left, the Personal Computers. There are software samples available for potential customers to test the various computers. From the Personal Computers, you walk until you reach, on your left, the corridor leading to the entrance of the building.

the Zoo, you see, on your right, the ticket booth."

Six route inference statements—locative statements relating an item in the environment to the subject's current suggested position within the environment in a way not previously specified in the route text, for example, "Driving from the Town Hall to the gas station, you pass Maple St. on your right." or "Walking from the Stereo Components to the CD's, you pass, on your right, the 35mm Cameras." These statements maintained the egocentric terminology and second person characteristic of the route text. Three of the statements were true and the other three were false.

In all, there were 22 true and six false statements for each set.

Design and Procedure

First subjects answered the questionnaire. Responses to the three self-report questions were noted on a 1 to 7 scale. Then subjects turned to an IBM PC AT controlled by the Micro Experimental Lab (MEL) software package (Schneider, 1988). Instructions described the remaining procedure. In addition to describing all of the experimental tasks, the instructions provided a bit of additional advice. The instructions told subjects to study a text until they felt they could answer any sort of question about the environment described or until they felt they could describe it to someone else. Additionally, they were told to pay attention to all information in the description. Taking notes or drawing diagrams while studying was not allowed. After an opportunity for clarification of instructions, subjects were reminded that they could study at their own pace, but that they could read each text no more than four times and needed to complete the experiment within an hour.

Subjects read four texts: one survey and one route description for the larger scale areas and one of each for the smaller scale areas. The order of presentation and the assignment of description type to environment were randomized across subjects. The texts appeared on a screen approximately 23 lines at a time. For complete presentation, three of the text pairs required two screens and one pair required three. Subjects scrolled through a text using a designated key. Subjects were allowed, but not required, to read each text four times. The overall reading time for each text was recorded.

After reading a description, subjects verified the corresponding set of 28 test statements by pressing designated keys for *true* or *false*. The statement presentation order was randomized across subjects. Both reaction time and accuracy for each statement were recorded. Finally, for each text, subjects drew a map of the described area from memory. The instructions for this task simply told subjects to draw and label, on a blank sheet of paper, a map of the environment described. For 12 of the subjects, the order that landmarks were drawn was recorded.

Results

Study Time

Study time necessarily combines reading time and time to integrate knowledge into memory. Because the descriptions varied in length, both total study time and study time broken down by syllable were used for analyses. The analyses consisted of repeated measure designs using within-subjects factors of description type and order of presentation.

There were significant main effects for both within-subjects factors. Subjects studied route texts longer (497 s, 0.82 s/syllable), on average, than they studied survey texts (365 s, 0.65 s/syllable), $F(1,29) = 28.12, p < 0.0001$ for study time ($F(1,29) = 21.47, p < 0.0001$ for study time/syllable). The other within-subjects factor, order of presentation, compared the first and second presentation of a particular perspective—route or survey. Subjects studied the first presentation of a description type longer (453 s, 0.77 s/syllable) than the second presentation (409 s, 0.70 s/syllable), $F(1,29) = 5.15, p < 0.05$ ($F(1,29) = 4.49, p < 0.05$).

Test Statements

We collected both accuracy and reaction time (RT) data for the test statements. To control for different test statement lengths, RT per syllable was calculated. RT and RT/syllable analyses gave the same results for all experiments, so in the interest of brevity the total RT results will not be reported here. Repeated measure analyses using within-subjects factors of test statement type and description type were performed using the two dependent measures.

Subjects were faster to respond to true inferences (0.45 s/syllable) than to false inferences (0.5 s/syllable) $t(29) = 3.58$, $p < 0.001$. This is a common finding in reaction time work and held for route and survey inferences individually. The remaining RT analyses were performed using correct RTs to true statements only, but the same pattern of results emerges if correct RTs to false statements are also included. There was no tendency to err more on false than true statements, even though there were more true than false statements.

Both dependent measures showed significant main effects of statement type: for proportion of errors $F(5,145) = 10.91$, $p < 0.0001$ and for RT/syllable $F(5,145) = 137.57$, $p < 0.0001$. Subjects performed better on nonlocative than on locative statements. Neither dependent measure showed a main effect of description type. Performance on route texts was equivalent to that on survey texts. Finally, both dependent measures showed significant interactions between statement type and description type: for proportion of errors $F(5,145) = 10.88$, $p < 0.0001$ and for RT/syllable $F(5,145) = 13.65$, $p < 0.0001$. Errors for each text condition and sentence type are displayed in Fig. 5 and reaction times by syllable in Fig. 6.

Simple effects analyses elucidate the interaction between statement type and description type. First, let us eliminate cases where no differences were found. As was expected, since the nonlocative statements were virtually identical within a pair of texts, no significant differences based on the description studied were found for either type of nonlocative statement. Surprisingly, there were no differences due to text

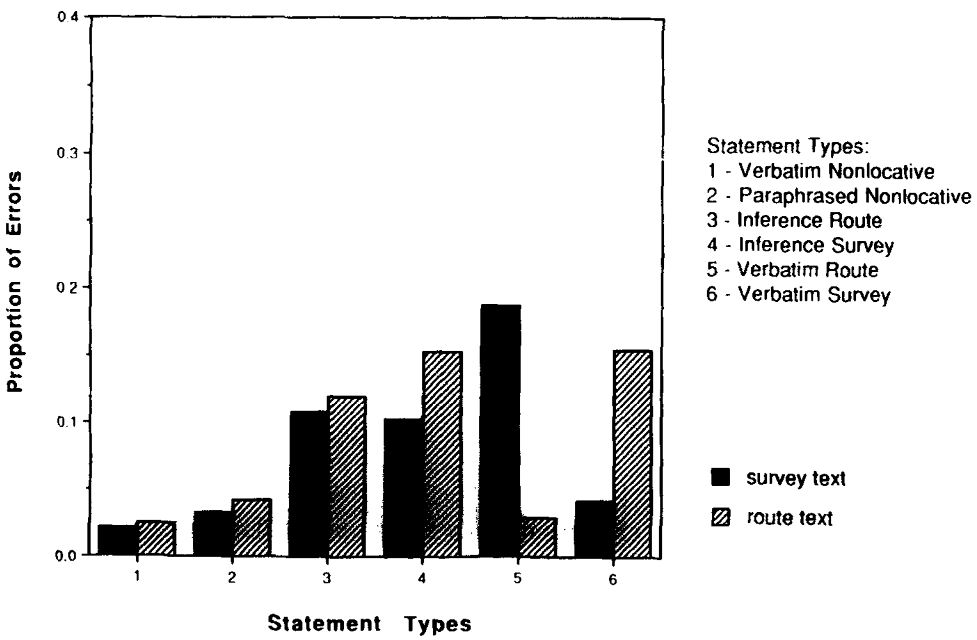

FIG. 5. Proportion of errors for both description types and all test statement types in Experiment 1.

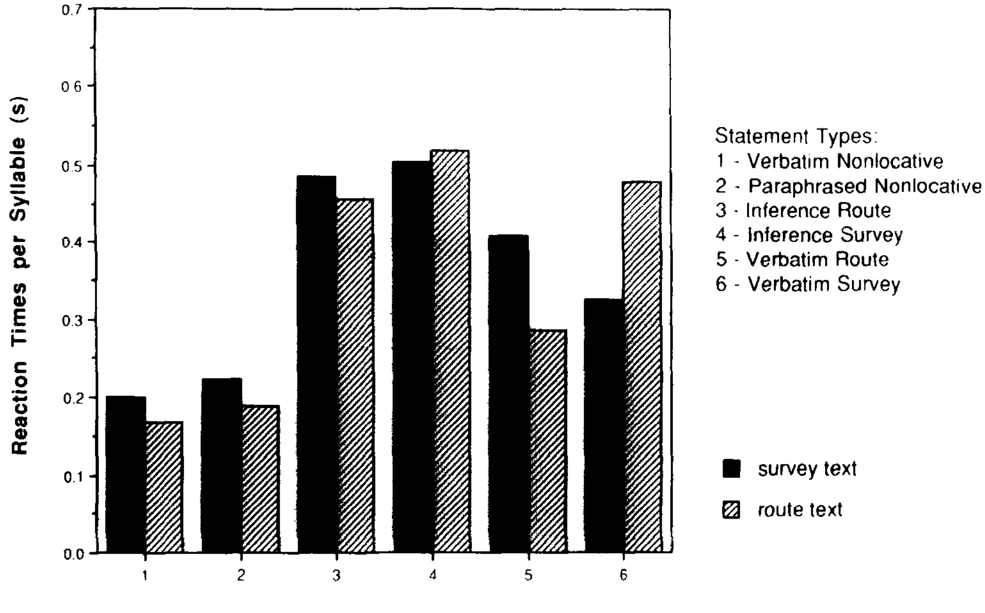

FIG. 6. Reaction times per syllable for both description types and true test statement types in Experiment 1.

perspective on either type of locative inference statement. Survey and route text readers performed equally well on both survey and route inferences.

The verbatim locative statements account for the significant interaction between statement type and description type. Subjects who studied the route text performed significantly better on the verbatim route statements than did subjects who studied the survey text: for proportion of errors $F(1,29) = 21.19$, $p < 0.0001$ and for RT/syllable $F(1,29) = 28.54$, $p < 0.0001$. Likewise, survey subjects performed better on verbatim survey statements: for proportion of errors $F(1,29) = 15.09$, $p < 0.001$ and for RT/syllable $F(1,29) = 46.57$, $p < 0.0001$.

Analyses of statement types within each description type using Tukey's contrasts corroborate the simple effects results for reaction time. There were no differences in performance on verbatim and paraphrased nonlocative statements. For the locative statements, subjects responded faster to verbatim statements than to any form of inference statement. This result was marginally significant for survey subjects, $q = 3.90$, $p < 0.10$, and highly significant for route subjects, $q = 5.09$, $p < 0.01$. Overall, the proportion of errors was too low to yield significant results with the Tukey analysis.

Map Drawings

We scored the subjects' maps for errors, including omissions, misplacements, and indeterminacies. Overall, subjects made few map drawing errors and there was no consistency in the type of error made based on either the description read or the environment described. A repeated measures analysis using within-subject factors of description studied and order of presentation was performed. The analysis yielded significant main effects for both within-subject factors. Subjects who had studied route texts made significantly more map drawing errors (1.31 out of a possible 12.5 errors) than those who had studied survey texts (0.68 errors) $F(1,29) = 6.41$, $p < 0.05$. Also, subjects made significantly more drawing errors on the first map of a given perspective (1.28 errors) than they did on the second map of that same perspective (0.72 errors), $F(1,29) = 4.31$, $p < 0.05$.

While running this experiment, the experimenter noticed a correlation between the order subjects drew the items in their maps and the order the items were mentioned in the description studied. This correspondence was verified by recording the drawing order for 12 of the subjects and is examined more rigorously in Experiments 2 and 3.

Individual Differences

Only one of the individual difference items yielded significant results. The reported frequency of map use when navigating was positively correlated with both RT measures: RT/syllable, $r = 0.41$, $p = 0.03$. Although the individual difference questionnaire was also administered in Experiments 2 and 3, the overall results yielded no significant effects. Therefore, we will not address the issue of individual differences in these experiments. This questionnaire was not used in Experiment 4.

Discussion

Study Time

Readers took more time to study the route descriptions. Several differences between the two description types could account for this: moving vs. fixed spatial referent, deictic vs. extrinsic terminology, and linear vs. hierarchical organization. By spatial referent we mean a known location to which the position of new locations is related. For route descriptions, this was an observer moving in the environment, whereas, for survey texts, this was a previously located landmark. Readers of route texts, therefore, had to keep track of the current location and orientation of the observer as well as the fixed locations of the landmarks; in contrast, readers of survey texts needed to keep track of only the fixed landmark locations. Route descriptions used intrinsic spatial terms, such as *left* and *front,* which change with the changing orientation of the observer. Survey description used extrinsic terms such as *north* and *west,* which are fixed directions in space.

Thus both the moving spatial referent and the egocentric terminology of the route texts may have contributed to an increase in study time for route texts. In addition, the hierarchical organization of the survey texts may have facilitated study time for them. Researchers have argued that the overview given in hierarchically organized texts aids storage and retrieval from memory. Although not always the case, some research has found advantages for hierarchical organizations over serial ones (Dixon, 1987; Smith & Goodman, 1984).

Memory

Although maps were drawn more accurately after reading survey texts than after route texts, in both cases, error rates were very low. Similarly, error rates were very low on the true–false statements. Overall, there were fewer errors and faster response times for nonlocative statements than for locative statements. For the nonlocative statements, performance was equal for verbatim and paraphrased statements. For the locative statements, performance was both faster and more accurate for verbatim than for inference statements for both route and survey descriptions. Because responses to verbatim statements were faster than those to both same and different perspective inference statements, it appears that verbatim statements were verified against a representation of the language of the text. Similarly, nonlocative statements could also be verified against a representation of the text, explaining the better performance on these statements compared to locative statements. The locative inference statements, for which there was no advantage to same versus different perspective, appear to be verified against a representation of the situation described by the text. Thus, this study, like previous ones (e.g., Johnson-

Laird, 1983; Perrig & Kintsch, 1985), suggests that readers form multiple representations of text. That the representation of the language of the text is closer to gist than to exact wording is suggested both by previous findings (e.g., Sachs, 1967; Weaver & Kintsch, 1987) and here by the lack of differences between verbatim and paraphrased nonlocative statements. This question will be explored more directly in the next experiment.

The success subjects had in both verifying statements of spatial relations and drawing maps indicates that they formed spatial mental models of the environments portrayed by both route and survey descriptions. Subjects could accurately infer spatial relations they had not specifically studied. What is surprising is finding no effect of text perspective in responses to inference statements. Both route and survey inference statements had equal response accuracy and response time regardless of the perspective of the text studied. In other words, subjects who read route texts performed equally well on both route and survey inference statements, and subjects who read survey texts performed equally well on both survey and route inference statements. Not only were there no differences between same and different perspective inferences for either errors or reaction times, but the actual number of errors and reaction times were very close. The absence of differences is not easily attributed to weak dependent measures as these measures yielded differences between verbatim and inference statements. Because this finding is surprising, because it is a null effect, and because it contradicts previous findings, it will be replicated in the next three experiments.

Experiment 2: Verbatim versus Paraphrased Questions

In the first experiment, subjects performed better when they could rely directly on memory than when they had to draw inferences from memory. What aspects of previous experience with text produce this advantage of memory? Previous research on memory for discourse has found representation of both the surface form of a sentence and the gist of a sentence. The strength of these two representations has been hypothesized to be associated to differences between short-term and long-term memory; short-term maintains verbatim content and long-term maintains meaning. Sachs (1967) found that with longer retention intervals, subjects confused close paraphrases with original sentences. Paraphrases resulting in a change of meaning, however, were correctly rejected. More recent experiments have demonstrated longer term memory for exact wording (Bates, Masling, & Kintsch, 1978; Hjelmquist, 1984; Keenan, MacWhinney, & Mayhew, 1977; Kintsch, Welsch, Schmalhofer, & Zimny, 1990). Experiment 2 was designed to examine the extent to which subjects maintain a surface trace in addition to a representation of gist by also testing with paraphrases of locative statements. If subjects maintain a representation of the exact surface form of the text, they should be faster and/or more accurate to verbatim than paraphrased statements. If, however, subjects only maintain memory of the gist of the text, performance on verbatim and paraphrased statements should be equal. This experiment also served as a replication of the first experiment.

Another goal of this experiment was to follow up on the serendipitous finding of the first experiment, that readers appeared to draw landmarks in maps in the order they had been mentioned in the descriptions. To make the comparisons clearer, some of the descriptions were rewritten slightly so that route and survey descriptions of the same environments had quite different orders of mentioning landmarks. To make sure that scoring of orders was objective, two naive experimenters collected the data.

Method

Subjects

Nineteen undergraduates, 11 female and eight male, from Stanford University participated individually in partial fulfillment of a course requirement for introductory psychology. The data from two subjects, both male, were eliminated due to problems logging data.

Materials

Materials were taken from Experiment 1. Some modifications were made to the texts. So that we can examine more closely the correlation between drawing order and text presentation order, we changed the order of presentation in some of the texts so that the route and survey descriptions for each environment presented the items in quite different orders. For the test statements, two types of paraphrased locative statements were added to the set, increasing the number of test statements to 36.

Four paraphrased survey statements—paraphrases of locative statements found in the survey text. Paraphrasing mainly involved the rearrangement of phrases. For example, "There is a Swimming Beach on the eastern shore of the lake" was paraphrased from "On the east shore of the lake there is a Swimming Beach."

Four paraphrased route statements—paraphrases of locative statements found in the route text. For example, "You see the Fishing Pier and Boat Launch for Pigeon Lake, on your left, from your position with Lincoln on your right" was paraphrased from "From your position with Lincoln on your right, you see, on your left, the Fishing Pier and Boat Launch for Pigeon Lake."

Paraphrasing mainly consisted of a reordering of the original phrases. Other changes were not possible, in this case, as there are no synonyms for either the place names or the spatial direction terms.

Procedure

Subjects followed the same basic procedure outlined in Experiment 1. The additional test statements increased the time necessary to complete the experiment. To compensate, subjects drew only two of the four possible maps; a map of the first text studied, and a map of the latter of the two texts taking the other perspective. Two experimenters recorded the order that subjects drew items on their maps. These experimenters were unaware of both the drawing order hypothesis and the text that a subject had actually studied.

Results

Study Time

Analyses of variance were performed on total study time and study time per syllable with perspective of description and order of presentation as factors. As before, subjects took longer to study route texts and the first presentation of a description type. Study time averages were 441 s (0.70 s/syllable) for route texts and 367 s (0.62 s/syllable) for survey texts, $F(1,16) = 5.41$, $p < 0.05$ ($F(1,16) = 3.62$, $p < 0.1$). For first presentation, the study time average was 450 s (0.73 s/syllable) and for second presentation, it was 358 s (0.59 s/syllable), $F(1,16) = 5.91$, $p < 0.05$ ($F(1,16) = 4.06$, $p < 0.1$).

Test Statements

Analyses of variance were performed on errors and reaction time per syllable for correct responses using description types and test statements as within-subjects factors. As before, reaction times to true statements were faster (0.41 s/syllable) than reaction times to false statements (0.47 s/syllable), but there was no tendency to err more on false than on true statements. Subsequent reaction time analyses were for true statements only, but the same effects emerge if false statements are included. Both dependent measures yielded significant main effects of statement type: for proportion of errors $F(7,112) = 15.80$, $p < 0.0001$ and for RT/syllable $F(7,112) = 53.43$, $p < 0.0001$. Again subjects performed better on nonlocative statements than on locative statements. No significant main effects for description type were found. There were significant interactions between statement types and descriptions:

for proportion of errors $F(7,112) = 8.59$, $p < 0.0001$ and for RT/syllable $F(7,112) = 9.87$, $p < 0.0001$. The data for errors are displayed in Fig. 7 and for reaction time per syllable in Fig. 8.

Simple effects analyses elucidated the source of the interactions. As before, subjects performed equally well on paraphrased and verbatim nonlocative statements. They also performed equally well on inference statements regardless of the perspective of the statement. Surprisingly, route subjects made significantly more errors on route inference statements than survey subjects, $F(1,16) = 5.76$, $p < 0.05$, though this did not occur for reaction times. As before, subjects were faster and more accurate at verifying verbatim statements than any form of inference statements for both text perspectives. Subjects who studied the route text performed significantly better on verbatim route statements than did subjects who studied the survey text: for proportion of errors $F(1,16) = 11.13$, $p < 0.01$ and for RT/syllable $F(1,16) = 5.04$, $p < 0.05$. Likewise, survey subjects performed better on verbatim survey statements: for proportion of errors $F(1,16) = 9.07$, $p < 0.01$ and for RT/syllable $F(1,16) = 13.88$, $p < 0.005$. This same interaction held for paraphrased statements. Route subjects verified route paraphrases better: for proportion of errors $F(1,16) = 8.73$, $p < 0.01$ and for RT/syllable $F(1,16) = 7.08$, $p < 0.05$; while survey subjects verified survey paraphrases better: for proportion of errors $F(1,16) = 7.54$, $p < 0.05$ and for RT/syllable $F(1,16) = 19.19$, $p < 0.001$.

Further analyses of reaction time within description type mirrored the simple effect results. Nonlocative performance surpassed locative performance. For locative statements, subjects responded more slowly to any form of inference than to non-inference statements, both verbatim and paraphrased. Again, this effect was marginally significant for survey subjects, $q = 3.74$, $p < 0.10$, and significant for route subjects, $q = 4.77$, $p < 0.05$. The proportion of errors was too small to achieve significant results on locative statements with this analysis.

Map Drawings

The maps were scored for errors and subjected to an analysis of variance comparing

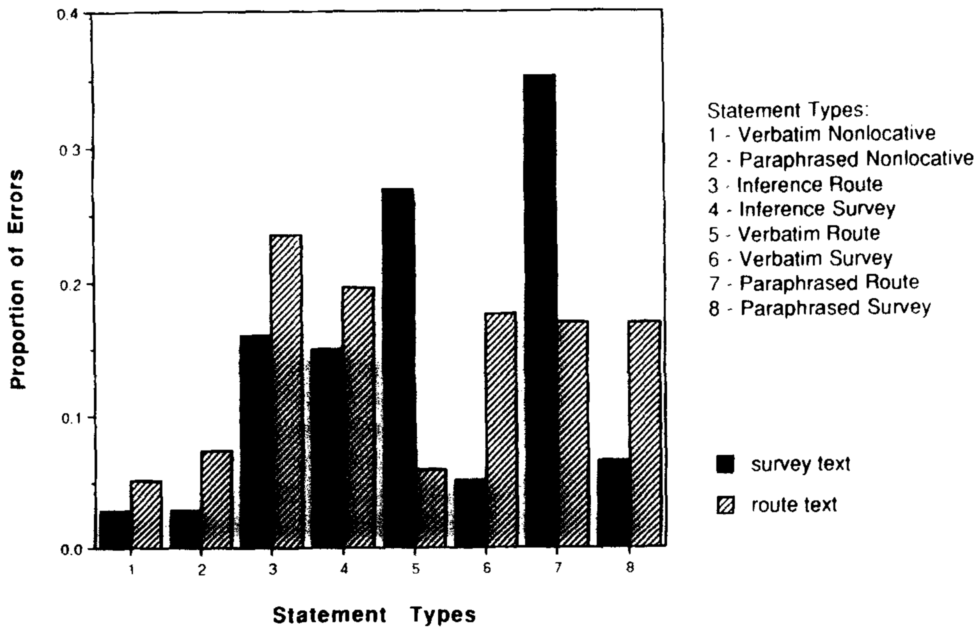

FIG. 7. Proportion of errors for both description types and all test statement types in Experiment 2.

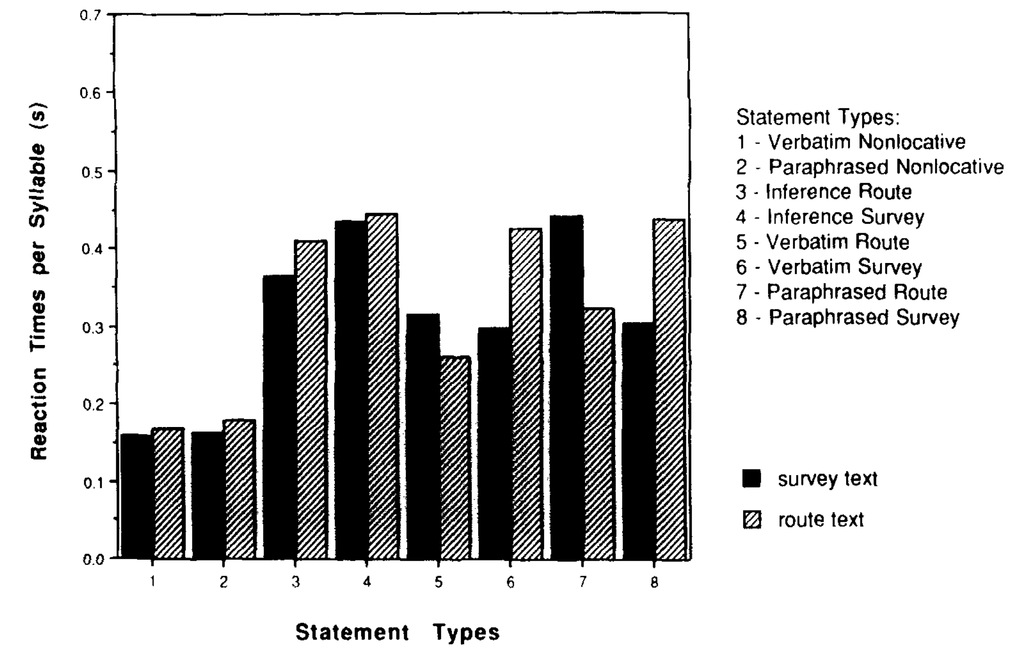

FIG. 8. Reaction times per syllable for both description types and true test statement types in Experiment 2.

description type. Overall, subjects' maps were quite accurate. Although survey subjects made an average of 1.29 errors and route subjects made 2.23, this effect was not significant. Because subjects only drew one relatively accurate map for each description type, this analysis is weaker than the previous one.

We computed Kendall's tau between the drawing order and the text studied and between the drawing order and the other text. The order of mention of items in the text not studied provided another logical way to order the items. The average Kendall's tau between the drawing order and the order in the text studied was 0.58 and 0.18 between the drawing order and the order in the text not studied. Subjects' drawing orders correlated significantly more with the order in the text they studied than with the order in the text they did not study, $t(35) = 5.35$, $p < 0.001$.

Discussion

Most of the effects of Experiment 1 were replicated in this experiment. As before, route texts took longer to study than survey texts. Performance on both verification statements and map drawing was good, the latter was better for survey than for route texts. On the whole, nonlocative information was verified more quickly and accurately than locative.

In the first experiment, subjects were faster verifying verbatim statements than inference statements. Verbatim statements appeared to be verified against a representation of the language of the description. Is that representation closer to the exact wording of the text, or closer to the gist of the text? In this experiment, paraphrases behaved just like verbatim statements, and both differed from inference statements. In addition, there were no differences between verbatim and paraphrased statements on any measure. The lack of any differences between verbatim and paraphrased statements is partly explained by the similarity of the paraphrases to the original statements. Paraphrasing was accomplished by rearranging phrases from the original text statements, because neither landmarks nor locative terms have synonyms. In this case, readers were not sensitive to changes in the order of phrases.

In drawing maps, subjects drew landmarks in the same order as they appeared in the written descriptions. How could such a correspondence arise? It is conceivable that subjects construct maps from representations of the text, rather than from representations of the situation, accounting for the correspondence between drawing and description orders. However, another possibility is that the maps were drawn from representations of the situations, but that in order to draw maps, subjects need to first reconstruct the environment. The most natural way to reconstruct the environment is to follow the order in which it was originally learned, that is, the order of the description.

Experiment 2 replicated the surprising result of Experiment 1, that readers were as fast and accurate to verify inference statements written in the perspective of the text they read as those written in the other perspective. This was taken as evidence that the mental representations constructed while reading the descriptions do not retain the perspective of the description. In the first two experiments, perspective was manipulated by the narratives rather than by actual experience. Because our environments were artificial and streamlined, there is no way to take an actual tour through them. Moreover, descriptions necessarily omit details present in the world, including non-visual detail and temporal experience. Maps, like descriptions, are schematic. The next experiment compares memory performance of subjects who learned environments from descriptions to those who learned environments from maps.

Experiment 3: Texts versus Maps

In the present experiment, perspective was manipulated more strongly by giving some subjects maps instead of verbal descriptions. Maps, such as those in Figs. 1–4, provide a survey perspective, although unlike the survey descriptions, maps make all of the spatial relations explicit. If studying a map induces a different mental representation than reading a description from a route perspective, map subjects should perform exceptionally well on survey questions and relatively poorly on route questions. If, however, studying a map yields a similar mental representation to those produced by the descriptions, map subjects should do as well on route as on survey questions, as was true of readers of the different perspectives.

Method

Subjects

Forty-five undergraduates from Stanford University participated individually in partial fulfillment of a course requirement for introductory psychology. Thirty subjects, 18 female and 12 male, participated in the text condition and 15 subjects, six female and nine male, in the map condition. The data from one of the map subjects, a male, was eliminated from analysis due to trouble logging the data.

Materials

The text condition employed the texts used in Experiment 2 and the sets of test statements from Experiment 1, those not including the paraphrased locative statements. Therefore, the materials consisted of four pairs of descriptions and four sets of 28 test statements. In the map condition, maps replaced descriptions. These maps, described in Experiment 1, were originally used as the bases for the descriptions. The relevant nonlocative statements were printed below each map so as to equate the maps and descriptions for informational content.

Procedure

Subjects in the text condition followed the procedure outlined in Experiment 1. Subjects in the map condition followed the same procedure, only studying the maps with accompanying nonlocative statements, for a maximum of 10 min, instead of the descriptions. For both groups, experimenters recorded map drawing orders.

Results

Study Time

As before, subjects studied route texts longer than survey texts. The average route text study time was 503 s (0.80 s/syllable) and 411 s (0.69 s/syllable) for survey texts, $F(1,29) = 28.78$, $p < 0.0001$ ($F(1,29) = 10.44$, $p < 0.005$). The main effect of order of presentation was not significant.

Test Statements

Text subjects. As before, analyses of variance with statement types and description types as factors were performed on errors and correct reaction times per syllable. True responses were faster (0.45 s/syllable) than false responses (0.50 s/syllable) and subsequent analyses used only true reaction times. The same pattern of results emerged when false reaction times were included. Only map subjects showed a tendency toward more errors on false than true items. If there were a response bias toward true, it might inflate correct responding to nonlocative and verbatim locative statements. As will be evident, however, there were differences in map subjects' responses to verbatim survey and route statements. So, if there were a bias, it did not wipe out all differences. Both dependent measures showed a significant main effect of statement type: for proportion of errors $F(5,145) = 12.83$, $p < 0.0001$ and for RT/syllable $F(5,145) = 166.72$, $p < 0.0001$. Again, subjects performed better on nonlocative than on locative statements. Unlike previous experiments, there was a significant main effect of description type for the RT/syllable measure, with route subjects responding an average of 27 ms/syllable faster, $F(1,29) = 4.34$, $p < 0.05$. The error results did not support this finding. Both dependent measures showed significant interactions between statement types and description: for proportion of errors (displayed in Fig. 9) $F(5,145) = 8.43$, $p < 0.0001$, and for RT/syllable (displayed in Fig. 10) $F(5,145) = 13.17$, $p < 0.0001$.

Again, simple effect analyses revealed the source of the interaction. As before, there were no significant differences for

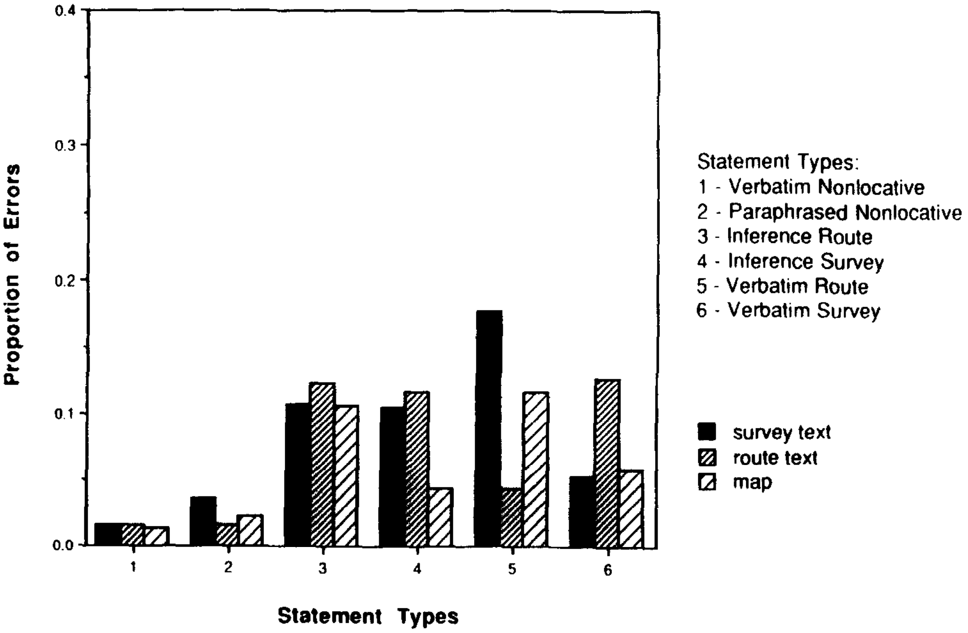

FIG. 9. Proportion of errors for both text and map conditions and all test statement types in Experiment 3.

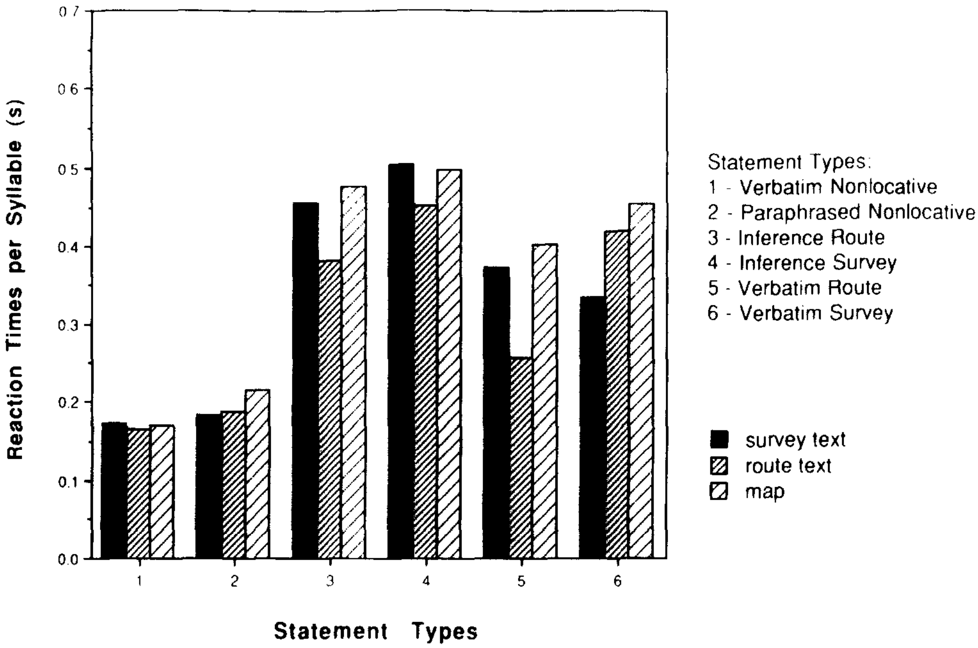

FIG. 10. Reaction times per syllable for both text and map conditions and true test statement types in Experiment 3.

performance on nonlocative statements. Subjects responded with equal speed and accuracy to most locative inference statements, regardless of perspective. One exception emerged: route subjects responded faster than survey subjects to route based inferences, when measured by RT/syllable, $F(1,29) = 7.99, p < 0.01$. However, neither the error rate results nor the within-description type analyses supported this difference.

As before, the verbatim locative statements were the source of the significant interaction. Subjects performed better on verbatim than inference statements. Subjects who studied a route text performed better on verbatim route statements: for proportion of errors $F(1,29) = 15.46, p < 0.001$ and for RT/syllable $F(1,29) = 41.64, p < 0.0001$. Conversely, subjects who studied a survey text performed better on the verbatim survey statements: for proportion of errors $F(1,29) = 11.53, p < 0.05$ and for RT/syllable $F(1,29) = 10.73, p < 0.005$.

Analyses of statement types within description types again yielded significant results for the RT measure, mirroring the results of the simple effects analyses. Performance on nonlocative statements surpassed that on locative statements. For locatives, subjects responded more slowly to inference statements than to verbatim statements. This trend was evident, although not significant for survey subjects ($q = 3.29$, p = n.s.) and significant for route subjects ($q = 5.79, p < 0.01$). The proportion of errors was too small to achieve significant results.

Map subjects. Repeated measure analyses using the within-subject variable of statement type were performed. Both dependent measures showed a significant main effect: for proportion of errors $F(5,65) = 4.34, p < 0.0005$ and for RT/syllable $F(5,65) = 49.45, p < 0.0001$. Subsequent contrast analyses indicated that these differences were due to better performance on nonlocative than locative statements on both dependent measures.

Otherwise, the data of the map subjects were notable for their absence of differences. Because map subjects had no access to the texts, overall performance on verbatim and inference test statements should be identical. This prediction held for both dependent measures. For reaction times, moreover, there were no overall differences in performance for statement perspective.

Performance by subjects in the two conditions, text and map, was quite comparable. There were no overall differences on either reaction time or errors between map and text subjects. Specific comparisons yielded differences between map subjects and text subjects. For reaction times to verbatim statements, map subjects' performance resembled that of readers of the other text perspective. That is, on verbatim route statements map subjects were slower than route subjects ($F(1,42) = 27.24$, $p < 0.001$) but the same as survey subjects, and on verbatim survey statements, map subjects were slower than survey subjects ($F(1,42) = 10.07$, $p < 0.005$) but the same as route subjects. Map subjects were also slower on route inference statements than route subjects ($F(1,42) = 6.25$, $p < 0.05$). Paralleling the results for reaction time, map subjects made more errors on verbatim route statements than route subjects ($F(1,42) = 5.03$, $p < 0.05$). In contrast, for verbatim survey statements, map subjects' performance was comparable in terms of errors to that of survey subjects, and marginally better than that of route subjects ($F(1,42) = 3.38$, $p < 0.07$). On inference survey statements, map subjects were marginally better than both survey ($F(1,42) = 3.27$, $p < 0.08$) and route ($F(1,42) = 3.82$, $p < 0.06$) subjects. Because all of the spatial relations between landmarks are given in a map, the information in survey statements plays the role of verbatim information for map subjects.

Map Drawings

The maps were scored and for text subjects, analyzed for effects of description type and order. Overall, subjects made few map drawing errors. Text subjects made fewer drawing errors when they studied a survey text (0.65) than when they studied a route text (1.25), $F(1,29) = 4.22$, $p < 0.05$. Contrary to Experiment 1, there were no significant differences in the number of errors between the first and second presentation of a given perspective.

Subjects who studied maps made an average of 0.25 errors per map, significantly fewer than subjects reading descriptions, as indicated by contrast analyses, $t(43) = 2.73$, $p < 0.01$. This significant difference held between maps and survey descriptions, the better of the two performances for descriptions, $t(42) = 1.82$, $p < 0.05$.

The analysis of drawing order used in Experiment 2 was implemented again here. The results replicated the Experiment 2 finding. Subjects' map drawing orders correlated significantly better with the text they studied than with the text they did not, $t(116) = 12.63$, $p < 0.001$. The average Kendall's tau between the drawing order and the order in the text studied was 0.647 and 0.154 between the drawing order and the order in the text not studied.

Discussion

In this experiment, one group learned environments by studying descriptions, either route or survey, and another group learned environments from maps. The main results of Experiment 1 were replicated by subjects in the text condition. Subjects took longer to read route descriptions than to read survey descriptions. Subjects performed better on nonlocative statements than on locative. For locative statements, subjects were faster and more accurate to verify verbatim statements than they were to verify inference statements. Finally, subjects accurately represented spatial relations as exhibited by their high performance on both survey and route inferences, as well as on map drawings. This high level of performance did not depend on the perspective studied. The drawing order results of Experiment 2 were replicated. The order subjects drew items on their maps correlated significantly better with the order they learned the items, than with another logical order. Some secondary findings of Experiment 1 were not replicated; in particular, there were no effects of practice which had been exhibited in Experiment 1 by decreases in study time and increases in map drawing accuracy.

Overall, subjects who studied maps performed comparably to subjects who studied text. Map subjects made fewer errors on map drawings than text subjects. This finding is also consistent with the previous experiments' results showing that readers of survey texts made fewer errors on map drawings than readers of route texts. This finding can be attributed to the fact that in a map, all spatial relations are explicit, none need to be inferred. In survey descriptions, spatial relations between landmarks are given directly, rather than with reference to the reader, as in route descriptions. The advantage that survey and especially map subjects had for map drawings is small because all subjects were highly accurate. On test statements, map subjects made marginally fewer errors on survey statements, but did not respond faster to survey statements than to route statements. For map subjects, all survey questions are analogous to verbatim statements in the sense that they refer to spatial relations acquired directly. They are not literally verbatim, and had no advantage in response time, as the literally verbatim statements did for the text subjects. In response time, map subjects, like text subjects, responded equally quickly to statements from both perspectives. Moreover, the advantage map subjects had in accuracy to survey statements was not countered by a disadvantage in accuracy to route statements. Thus, the spatial mental representations established by survey descriptions, route descriptions, and maps are indistinguishable by our measures, save for an advantage to similar linguistic phrasing or specified spatial relations over inferred ones.

Experiment 4: Reduced Task Expectations

Although Experiments 1 through 3 all indicated that the perspective from which an environment is learned does not affect speed or accuracy of making inferences from a different perspective, task expectations may have influenced the way subjects learned the environments. First, subjects in the previous experiments knew that they would be asked to draw maps, and consequently may have been encouraged to represent the text more abstractly. Weaver and Kintsch (1987) found that subjects who drew a map while studying a spatial description constructed accurate situation models, whereas subjects who merely read the descriptions did not. Expecting to draw a map in the future may serve a role analogous to drawing a map while studying. Second, subjects had four trials, and after the first, knew that they would answer questions from both perspectives. We examined first trial data for subjects in this and the other experiments and found performance to be the same as on subsequent trials, namely equally good to both types of inference statements.

In this experiment, subjects participated in only one trial, reading either a route or survey description, but answered both kinds of questions. Moreover, subjects were unaware of the map drawing task until asked to draw. With the elimination of these expectations, subjects have no motivation to construct a mental representation any more impartial than what is needed to comprehend and remember the narrative.

Method

Subjects

Sixty-nine undergraduates from Stanford University participated in partial fulfillment of a course requirement for introductory psychology. Subjects participated either alone or in groups of up to four. The availability of subjects during a particular experimental hour determined group size. Problems logging data eliminated one subject.

Materials

We used two pairs of the texts, one representing a small scale environment (convention center) and the other a large scale environment (town), and the corresponding test statements from Experiments 2 and 3.

Procedure

Subjects read instructions, modified from those used in previous experiments, about the experimental procedure. The modification to the instructions eliminated any mention of the map drawing task. Subjects then read their assigned text. Assignment to texts was random. After studying, they responded to the corresponding set of test statements. Finally, although previously unaware of the task, subjects did draw and label a map representing the described environment.

Results

Study Time

We performed two one-way ANOVAs using study time and study time per syllable as the respective dependent measures. One subject's study time was more than three standard deviations above the median for both study time measures and was eliminated from analysis. When the outlier was eliminated, study times for route and survey descriptions did not differ. The average route text study time was 401 s (0.65 s/syllable), and the average survey text study time was 461 s (0.75 s/syllable). The pattern of performance on verification statements was not affected by removal of the outlier.

Test Statements

The analyses consisted of repeated measure designs using description type as a between-subjects variable and statement type as a within-subjects variable for both dependent measures. Means for errors are displayed in Fig. 11 and for correct reaction time per syllable in Fig. 12. True responses (0.53 s/syllable) were faster than false responses (0.55 s/syllable) and subsequent analyses used only reaction times for true statements. There was no bias to respond "true." There was a significant main effect of statement type: for proportion of errors

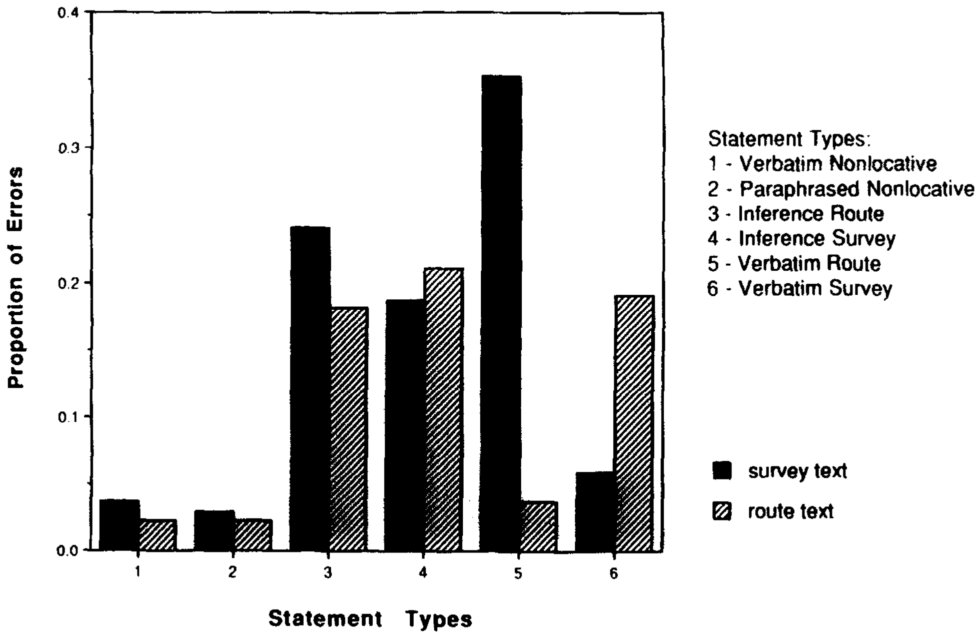

FIG. 11. Proportion of errors for both description types and all test statement types in Experiment 4.

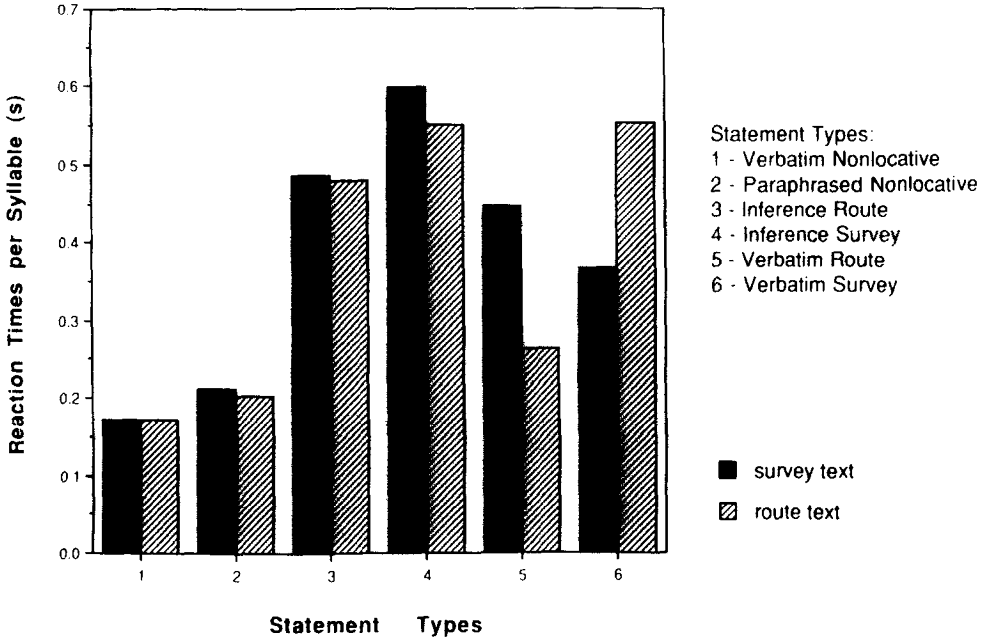

FIG. 12. Reaction times per syllable for both description types and true test statement types in Experiment 4.

$F(5,330) = 20.46$, $p < 0.0001$ and for RT/syllable $F(5,315) = 47.44$, $p < 0.0001$. There was no significant effect of description perspective. There was a significant interaction between statement type and description perspective: for proportion of errors $F(5,330) = 15.75$, $p < 0.0001$ and for RT/syllable $F(5,315) = 6.55$, $p < 0.0001$. Subjects performed better on nonlocative than on locative statements. Within nonlocative statements, performance of verbatim and paraphrased statements did not differ.

Simple effects analyses again showed that subjects who had previously seen a statement responded faster when seeing that statement again. Survey subjects responded faster on verbatim survey statements, $F(1,63) = 8.70$, $p < 0.01$ for RT/syllable. Likewise, route subjects responded faster on verbatim route statements, $F(1,66) = 17.97$, $p < 0.0001$ for RT/syllable. The error rate analyses showed the same pattern of performance, but did not reach significance. For inference statements, description perspective did not interact with statement perspective for either reaction times or errors.

Map Drawing Errors

The maps were scored as in the previous experiments. Figures 13 and 14 show maps drawn by subjects in this experiment. The analysis consisted of a one-way ANOVA with the total number of drawing errors as the dependent measure. There were no differences in the number of errors as a result of the perspective studied. Overall subjects who read a survey description made an average of 1.97 errors, while subjects who read a route description made an average of 1.76 errors. The lack of significance may be attributed to the fact that subjects only drew one map, whereas in the previous studies, each subject drew several maps.

Discussion

Despite their ignorance of the map drawing task, subjects formed accurate spatial

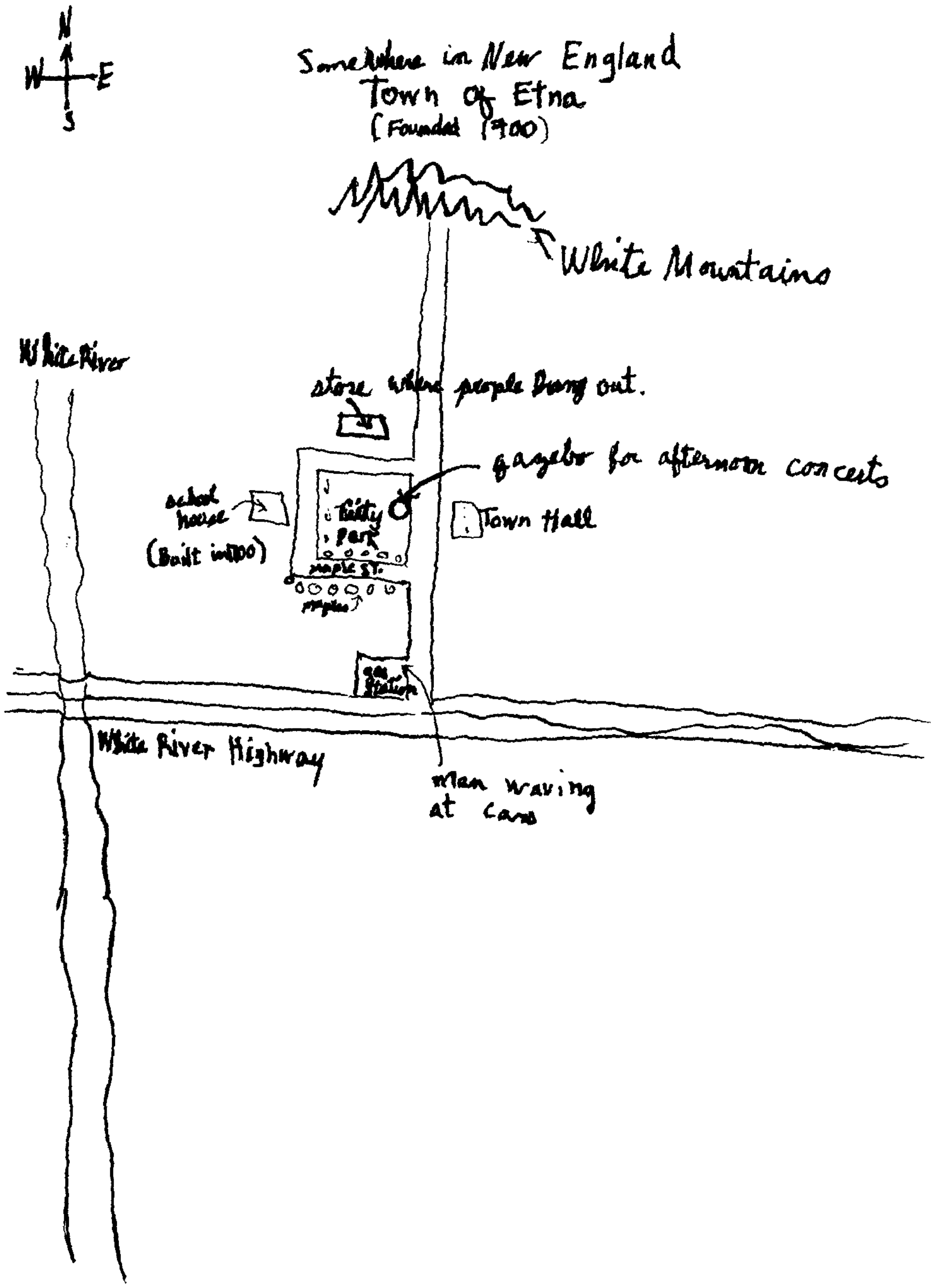

FIG. 13. Subject map drawing of town: Experiment 4.

representations. Their performance on the map drawings was at the same high level as subjects in previous experiments who did expect the task. Similarly, the absence of an expectation to draw a map did not alter performance on the test statements; the overall proportion of errors was still quite low. As before, subjects verified nonlocative statements faster and more accurately than locative statements. They verified verbatim statements faster than inference statements, but were not faster to same

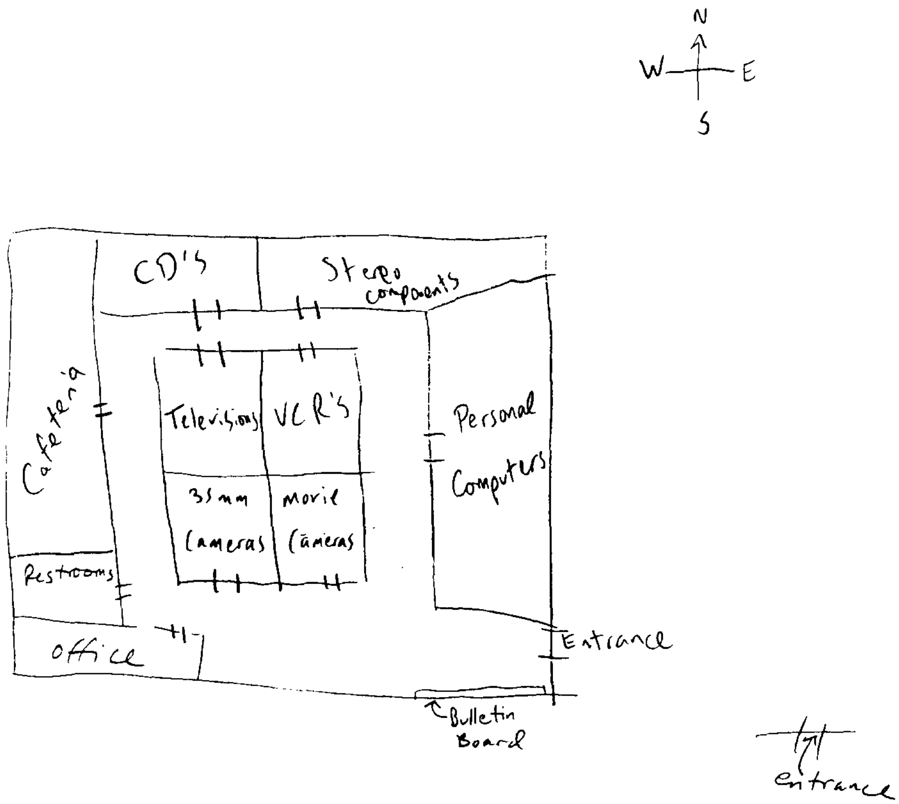

FIG. 14. Subject map drawing of convention center: Experiment 4.

perspective inferences than to different perspective inferences. These results indicate that, even with reduced task expectations, readers, while reading well-formed descriptions, form mental models which reflect general spatial relations, but which remain impartial to perspective.

In this study, unlike the previous ones, subjects did not take longer to study route texts. The reduction in task expectations could have contributed to this. Without the expectation of the map drawing, the criterion for adequate comprehension would correspond to textual comprehension alone. The fact that there were only two environments and that subjects only read one description may also account for the lack of study time difference. In the previous studies, there was a high degree of variance in study time for the individual scenarios.

General Discussion

In four experiments, subjects read narratives describing spatial environments, such as a small town or zoo, from one of two perspectives: a survey perspective looking at the environment from above or a route perspective looking at the environment from within. Subjects' memory for the texts was assessed in two ways: from speed and accuracy to verify the truth of statements about the environments and from maps sketched of the environments. Of the test statements assessing spatial knowledge, some of the statements were taken verbatim from the texts, and others were inferences based on information from the texts, half from a survey perspective and half from a route perspective. Performance on both tasks was quite high. Individual differences, found in other related studies, based on gender, map experience, and preference for maps, were not found. In all experiments, subjects were faster and more accurate when verifying verbatim sentences than when verifying inference statements. In the second experiment, subjects were equally good at verifying verbatim sentences and close paraphrases, and better at both of those than at inferences. This finding adds to the growing body of research supporting multiple representations of memory for text (e.g., Johnson-Laird, 1983; Perrig & Kintsch, 1985), in this case, a representation close to the actual language used in the text in addition to a mental model of the environment described by the text. Memory for the language of the text accounted for superior and faster performance in the verification of both verbatim and paraphrased statements as opposed to inference statements. However, there is yet another reason for increased speed and accuracy for verbatim and paraphrased statements; the spatial relations described in them were explicitly given in the narratives, whereas the other spatial relations had to be inferred.

The second and third experiments revealed an interesting correspondence between descriptions and map drawing. Specifically, subjects drew landmarks in maps in the order in which they had been learned, that is, presented in descriptions. This correspondence can be attributed to mental reconstruction of the environment in order to draw it, where reconstruction recapitulates the original construction. Several experiments have demonstrated correlations between drawing order and order of constructing images or spatial models (e.g., Kosslyn, Cave, & Provost, 1988; Novick & Tversky, 1987).

The accuracy subjects showed both when drawing maps and when making spatial inferences are among the indications that subjects formed models of the environments. The specific question that intrigued us was whether the spatial mental models created by the two perspectives differ, that is, whether perspective is incorporated into the spatial mental models. In some, but not all ways, the two types of descriptions are analogous to studying a map on the one hand and to exploring an environment on the other. Previous experiments comparing knowledge acquired from maps to knowledge acquired from exploration of environments have found that neither perspective has an absolute advantage over the other, but that certain kinds of information are better acquired from maps, such as crow-flies distances and directions between landmarks, and other knowledge is better acquired from traversal, such as route distances (Evans & Pezdek, 1980; Sholl, 1987; Streeter et al., 1985; Thorndyke and Hayes-Roth, 1982). Moreover, Perrig and Kintsch (1985), in studies on which our own were based, found evidence that perspective was represented in situation models, for female, but not for male, subjects.

In contrast to expectations from research comparing maps to traversal, and in contrast to Perrig and Kintsch's findings, we found no evidence for the representation of perspective in mental models of the environments in four experiments. On the contrary, in each experiment, subjects were equally fast and accurate to verify inference statements in the perspective read as in the other perspective. Although overall performance was high, it was not so high as to preclude finding significant differences, such as those between verbatim and inference statements. Not only were there no differences between same and different perspective inference statements, but the absolute levels of speed and accuracy were very close. The same effect, namely no effect of perspective of narrative on verifying same and different perspective inferences, was obtained in Experiment 4 when subjects read only one description and were not informed of the map drawing task ahead of time. So only the requirement to understand and remember the narrative was sufficient to induce readers to construct mental models of the spatial relations among the landmarks, and the mental models constructed from survey texts were indistinguishable from those constructed from route texts. The lack of any interaction between narrative perspective and statement perspective for inference statements provides additional support for the claim that readers verify inference statements against a model of the situation rather than a model of the text. A text model would retain the perspective of the text and lead to an advantage to inference statements in the read perspective.

Of course, not all spatial descriptions induce spatial mental models under instruction to comprehend and remember. The narratives must be well constructed: coherent, organized, and unambiguous. People fail to construct adequate representations when the spatial information comes from indeterminate, poorly organized, or overly difficult descriptions (Denis & Denhiere, 1990; Mani & Johnson-Laird, 1982; Perrig & Kintsch, 1985). In three of the present experiments, subjects studied route texts longer than survey texts, suggesting that route information was integrated more slowly into memory. Once integrated spatial representations had been constructed, however, all information relating landmarks was equally accessible, regardless of the perspective from which it was originally learned. Furthermore, in Experiment 3, a group of subjects who learned the environments from maps rather than texts also responded equally quickly to both route and survey statements, despite the fact that maps distinctly present a survey perspective. The results from the map subjects showed a trend indicating greater accuracy on survey statements than on route statements; this seemed due to the fact that in maps, all spatial relations between landmarks are explicit, and none need be inferred. The absolute levels of errors and reaction times of map subjects were in the same range as those of text subjects. Thus, there was no evidence that the spatial mental models of map subjects favored a survey perspective, nor was there evidence that the spatial mental models of subjects who studied maps were functionally different from those of subjects who read either route or survey descriptions (see also Regian, Shute, & Detweiler, 1986).

In retrospect, these findings do not contradict the earlier results that learning an environment from a map facilitates certain judgments, such as Euclidean distance estimates, and learning an environment from exploration facilitates others, such as route distance estimates. In those cases, the information required by the different judgments was directly obtainable from the respective learning perspectives and not easily derived from the other perspective. When traversing an environment, specific routes are taken, rendering route distance information readily accessible. Similarly, while studying a map, Euclidean distances are readily apparent. In the present experiments, the critical information, namely, the broad categorical spatial relations among landmarks, was obtainable directly from both perspectives. The more refined information about distances and directions probed in previous research comparing acquisition from maps and traversal could not be easily conveyed by narratives and consequently could not be tested. These findings do contradict those of Perrig and Kintsch which provided some evidence that specific perspective information is maintained in spatial mental models. However, an effect of narrative perspective appeared in only one of their two studies, and only for the women in that study. Even then, subjects made so many errors that it is unlikely that they formed complete and accurate situation models of the environment described. These results also contradict others claiming that only when information is learned from different perspectives will the mental representation not be perspective bound (Evans & Pezdek, 1980). The descriptions and maps of these studies presented only one perspective.

The simplest explanation of the finding that readers are as adept at verifying inference statements in a different perspective from the one they read as in the one they did read is that the spatial mental models engendered by the two perspectives are virtually the same. This is not to say that readers do not represent the perspective of the narratives they read; on the contrary, perspective is recoverable from representations of the language of the text, and is evident in faster response times to verbatim and paraphrased statements. Moreover, previous research indicates that while reading descriptions, people do form situation models that include perspective and update them as perspective changes (Black, Bower, & Turner, 1979; Bly, 1989; Bryant, Franklin, & Tversky, 1992; Franklin & Tversky, 1990; Glenberg, Meyer, & Lindem, 1987; Morrow, Bower, & Greenspan, 1989). It appears as though readers use the succession of partial and perspective-laden views to construct a more comprehensive and abstract spatial mental model.

Subjects' spatial mental models, whether acquired by map, route description, or survey description, contained information about the spatial relations among landmarks in a way that did not favor one perspective or another. What might such a spatial mental model look like? We would like to suggest that it may not look like anything that can be visualized. Rather, it may be like an architect's 3D model of a town; it can be viewed or visualized from many different perspectives, but it cannot be viewed or visualized as a whole. Particular spatial perspectives can be derived from a more abstract spatial mental model that is perspective free. In fact, answering the locative questions required taking a particular perspective, either route or survey. To answer a survey question seemed to require taking a view from above to check if the landmarks were in the stated relative locations (north, south, east, or west). To answer a route question seemed to require taking a view facing a specific landmark and checking if the other landmarks were in the stated relations to the viewer (left, right, front, or back). The mental models that the reader constructed from both route and survey descriptions seemed to be abstract enough to allow answering inference questions from both perspectives with equal ease. These conclusions, of course, are limited to the kinds of categorical spatial relations that can be readily conveyed in descriptions.

This is why we have termed the representation a mental model (Johnson-Laird, 1983) rather than an image. This kind of representation differs from the representations proposed in the classic work on imagery (e.g., Finke & Shepard, 1986; Kosslyn, 1980; Pinker, 1984; Shepard & Podgorny, 1978) which are perception-like and from a particular point of view. These spatial mental models, then, are like structural descriptions of objects (see reviews by Pinker, 1984, and Ullman, 1989), which are representations of the parts of an object and their spatial relations that are object-centered, that is, perspective-free, rather than viewer-centered (e.g., Marr & Nishihara, 1978). Such representations were proposed in part to solve the problem of how we are able to recognize objects at many different orientations, that is, from many different perspectives. For spatial descriptions from different perspectives, we encountered a similar problem and proposed a similar solution.

Further support for the position that mental representations of space may not incorporate a uniform perspective, route or survey, comes from a set of studies parallel to these (Taylor & Tversky, 1990) in which subjects studied maps of the environments and then wrote complete descriptions of the environments from memory. The descriptions were fairly accurate; that is, they allowed another group of subjects to correctly place many of the landmarks. What was striking about the descriptions, however, was the lack of a consistent perspective. Some descriptions were wholly route or wholly survey, but about half the descriptions mixed route and survey perspectives. If subjects' mental models of the environments incorporated perspective, that perspective should be consistently expressed in descriptions of the environment (Levelt, 1982). Rather, it seemed as if subjects' representations were of the spatial relations among the landmarks, and different narrative perspectives were used to describe those relations where advantageous. Changes in perspective for spatial descriptions have also been found for less structural spatial arrays in interactive communication settings (Schober, 1990).

Why do people form abstract mental models of spatial relations from descriptions rather than simply remembering the text? After all, constructing such mental models is effortful. Finding one's way in the world is an ancient activity critical to survival. From route experiences in environments, children, adults, and other animals develop more abstract representations of the spatial relations among landmarks in environments. Humans acquire similar representations from maps. Such representations are more flexible and useful than representations of individual routes. They allow for further exploration of an environment from new points of view, recovery from error, coping with changes, and even transfer to new environments. For verbal human beings, descriptions, from either a route or survey perspective, can serve as a surrogate for experience, and also allow the construction of spatial mental models.

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