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Descriptions and depictions of environments

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Subjects studied maps with the expectation that they would draw or describe them from memory. In fact, subjects did both. Order of drawing or describing landmarks revealed the mental organization of environments. Organization was quite similar across maps and descriptions of the same environments, revealing hierarchical structures based on spatial and functional features of the environments and on conventions for sequencing the landmarks.

Before there was written language, there were pictures: cave drawings, petroglyphs, maps, tallies, and picture languages (Gelb, 1963). These various communicative inventions of the human mind are remarkably similar across cultures that have had no known contact. The resemblance of the petroglyphs left by North American Indians to those of other cultures was enough to convince early observers that America had been invaded by Chinese, or Egyptians, or the Ten Lost Tribes (Gelb, 1963). The rock paintings of the Bushmen in South Africa create depth in much the same way as those left in caves in southern France and northern Spain (Boas, 1927/1955). The geometric patterns in weavings in basketry from many different parts of the world resemble each other, though their symbolic interpretations may differ (Boas, 1927/1955).

Not only do the depictions and designs of unrelated cultures resemble each other, they also resemble the spontaneous productions of children. Children's drawings spontaneously use, albeit crudely, many of the conventions of representing perspective used by artists in various cultures (Hagen, 1986). The maps of early explorers and even modern tourist maps bear similarities to the maps of children and adults (for examples, see Brown, 1949/1977; Noble, 1981; Southworth & Southworth, 1982). Unlike "veridical" maps, they often incorporate several scales and several perspectives. Like veridical maps, they often include symbolic elements as well as the strictly visual.

The presence of widespread similarities in pictorial representations and their underlying systematicity suggests that they reflect universal cognitive predilections, in conjunction with constraints of the media. Despite these compelling similarities, not just of form, but of meaning, pictorial productions are rarely used as psychological data.

One of the hesitations in using pictures as cognitive data is that adults rarely draw them, so that their naturalness or ecological validity as data may have questionable. However, one situation in which adults quite commonly draw sketches is when they draw maps to communicate spatial information. Depictions of maps served as one of the dependent variables of the present experiment. Constrained map productions have been used as data, primarily to indicate systematic distortions (e.g., Chase & Chi, 1981; Stevens & Coupe, 1978; Tversky, 1981; Tversky & Schiano, 1989). Another difficulty in using pictures as data is scoring them. In this case, depictions were scored for organization, with the index of organization being the order in which the elements of the map were drawn. Order of output has been used as an index of organization at least since Tulving (1962) used order of free recall of unrelated words as an index of clustering or chunking. The assumption underlying that work, and the many subsequent techniques developed, is that items that are more related are more likely to be remembered together, an assumption basic to all conceptions of associative memory.

In addition to depictions of maps, descriptions of maps served as a dependent variable. Descriptions can also be scored for organization on the basis of recall order of the landmarks. Therefore, there is an added convenience that the same measure was used for both drawings and descriptions. Subjects learned one of three environments, which varied in scale. Two of these environments were adapted from previous research (Taylor & Tversky, 1992), a small-scale Convention Center and a large-scale Town, and one environment, an Amusement Park midway in scale, was new. These were meant to be representative of the sorts of environments that people spontaneously draw map sketches of. Subjects studied a map with the expectation that they would either draw the map or describe the environment. In actuality, they performed both tasks, in counterbalanced order. Our interest was in how people organized these spatial environments. Several factors could influence organization, including (1) expectations, to draw or to describe; (2) task constraints, for either drawing or describing; and (3) characteristics of the environments. In the last case, similarities will emerge between the organization revealed by the descriptions and that revealed by the depictions.

There are several reasons to expect that organization of depictions may differ from that of descriptions. For

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one thing, there may be constraints imposed by the media themselves. Discourse, it has been observed (e.g., Levelt, 1982), is linear. Of course, pictures must be drawn sequentially, too; but in discourse the order must make sense to both sender and receiver as the discourse progresses. A drawing does not need to be comprehended until it is completed, so that the order in which elements are drawn is not part of the communicative act. There are other factors that may affect drawing. First, it may be easier to draw nearby elements together, a principle of least effort or manual economy. Next, drawing is known to be affected by writing habits (e.g., Goodnow, 1977; Kugelmass & Lieblich, 1979; Tversky, Kugelmass, & Winter, 1991), so the left-right, top-bottom directions governing written English may be evident in the drawings of English speakers. On the other hand, the order for both discourse and drawing may be driven more by expectations subjects have about the task they will perform. These expectations might be influenced by issues such as constraints of the media, linearization, manual economy, or writing habits.

There are reasons to expect that the anticipated task either drawing or describing, may lead to differential learning and therefore differential organization of the original map. The exact spatial relations among elements are more critical for maps than for descriptions. Similarly, the translation of the spatial to the verbal and the sequencing of elements are more critical for describing than for drawing. The task of constructing a description from a depiction seems to require more transformations than does the task of constructing a depiction from a depiction. In previous work, learners encoded the same pictorial stimuli quite differently in anticipation of picture recognition than in anticipation of verbal recall (Tversky, 1973). Learners may attempt to form a mental image of the map when expecting to draw a map and may attempt to form an implicit description of the map when expecting to describe it. On the other hand, aspects of the natural spatial structure of the environments may determine the organization and override considerations of anticipated response mode.

There is evidence from many studies using a variety of memory measures that environments, like linguistic stimuli, are grouped and organized in memory (e.g., Chase & Chi, 1981; Hirtle & Jonides, 1985; McNamara, 1986; Stevens & Coupe, 1978; Tversky, 1992). Spatial and visual features, as well as semantic ones, serve as bases for organization. In mental representations of maps, larger regions can be divided into smaller ones. Map landmarks are often remembered with respect to the smaller regions encompassing them, and the smaller regions are remembered relative to the larger ones. This is a hierarchy based on containment or part-whole relations and may lead to systematic distortions in direction estimates (Stevens & Coupe, 1978). Regional boundaries, significant highways, rivers, and other salient natural features of environments may be used to subdivide environments. More salient environmental features may have precedence over less salient ones. Nonspatial organizations may also be used—for example, remembering items together that are related by function rather than by spatial proximity. In research on students' mental representations of Ann Arbor, Hirtle and Jonides found that commercial buildings tended to be grouped with other commercial buildings, and university buildings with other university buildings, despite the fact that the buildings were spatially interspersed. The groupings affected distance estimates, with between-group estimates overestimated relative to within-group estimates.

METHOD

Subjects

Seventy undergraduates from Stanford University participated individually, either for pay or in partial fulfillment of a course requirement for introductory psychology. Approximately equal numbers of male and female subjects were recruited. All subjects recruited were native English speakers. The data from 3 subjects, 2 subjects who turned out to be non-native English speakers and 1 subject who did not follow instructions, were eliminated from analysis.

Materials

Three fictitious environments were drawn using an Apple Macintosh and the software MacPaint and were printed on standard 8.5 × 11 in. paper. The environments differed in scale, ranging from a single building to an enclosed Amusement Park with several buildings to a small Town. The building, a Convention Center, contained 13 landmarks. The Amusement Park contained 17 landmarks, and the Town contained 13 landmarks. The Town and the Convention Center were adapted from previous research (Taylor & Tversky, 1992). The maps appear in Figures 1-3. A compass rose appeared on each map, indicating that the maps were oriented with North at the top.

Design and Procedure

The subjects received one of two instruction sheets. Both instructions informed the subjects that they would study a map for 5 min in order to later recall the information. The instructions described different recall tasks, one telling the subjects they would draw the map from memory and the other telling the subjects they would write a verbal description of the map. The instructions for the description told the subjects to write their description so that someone who was unfamiliar with the environment and had never seen the map could read the description and know where all the landmarks were. The experimenter then clarified any questions about the procedure.

The subjects received one of the three maps to study. Overall, 24 subjects received the map of the Town, 24 received the Convention Center map, and 22 received the Amusement Park map. Of the subjects eliminated from analysis, 2 received the Town map and 1 received the Convention Center map. The subjects could study the map for as long as 5 min, but they could move on to the recall task whenever ready. After the study phase, the experimenter told the subjects that instead of the single task described on the instruction sheet, they would actually be asked to do two memory tasks, draw a map and write a description. Order of tasks was counterbalanced across subjects so that half the subjects performed the ex-

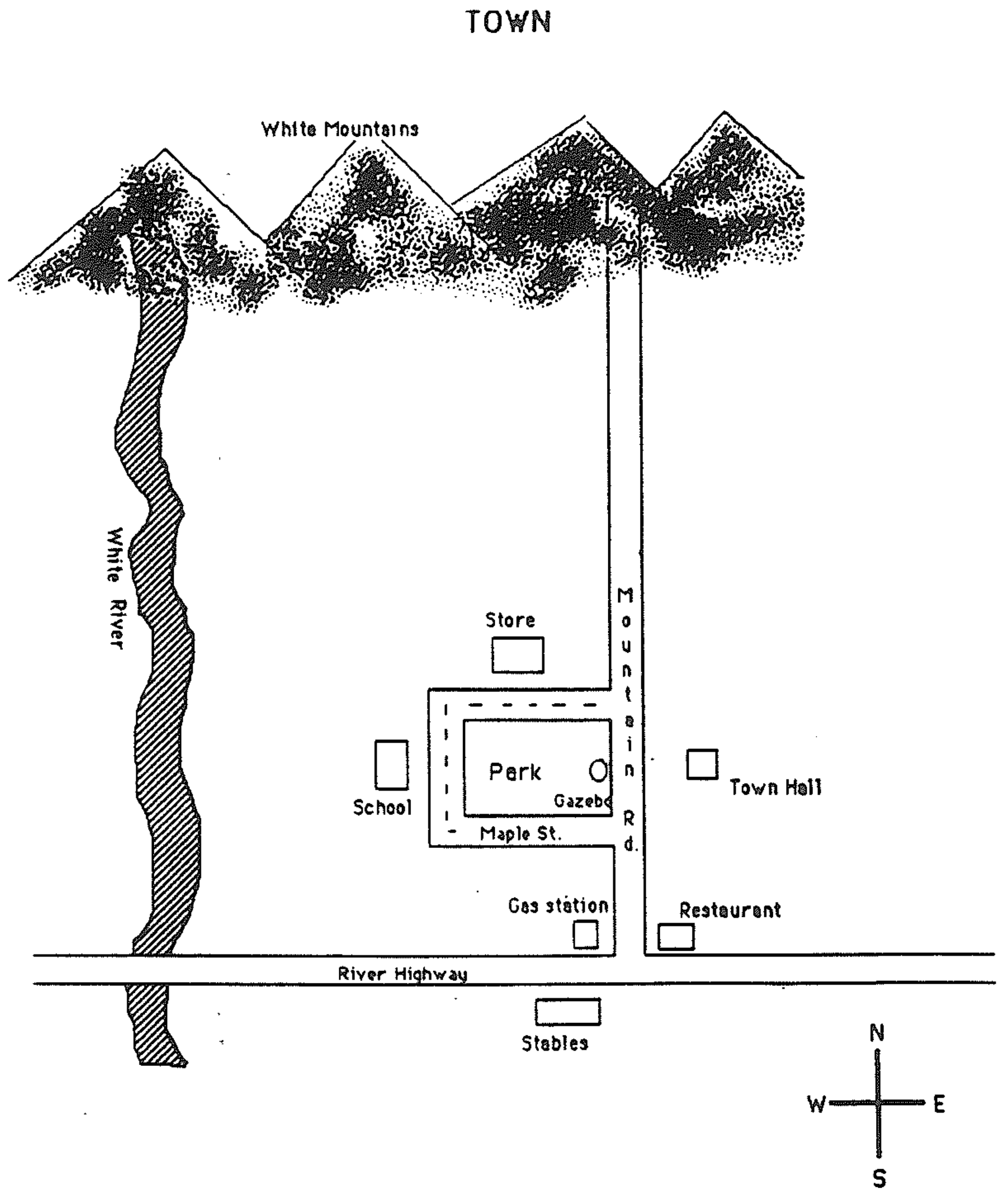

Figure 1. Map of Town. Adapted from Taylor and Tversky (1992) with permission.

pected task first and half performed the surprise task first. While subjects drew their maps, the experimenter recorded the order in which each item was drawn. The subjects completed the tasks at their own pace, but within 30 min.

RESULTS

Memory Results

Landmarks. Overall, the subjects' memory was excellent. Table 1 shows the total number of landmarks in each environment and the mean number of landmarks recalled on each memory task. Neither the task expectation, the first task performed, nor the match between these variables affected memory. For maps and descriptions combined, the subjects recalled 94.6% of the landmarks. Although performance on both memory tasks was high, a paired t test showed that the subjects remembered significantly more landmarks when drawing maps (98.2%) than when writing descriptions (94.6%) [$t(66) = 3.58$, $p < .001$]. The memory difference between maps and descriptions held up, with at least marginal significance, regardless of the expected task or the first task performed, for

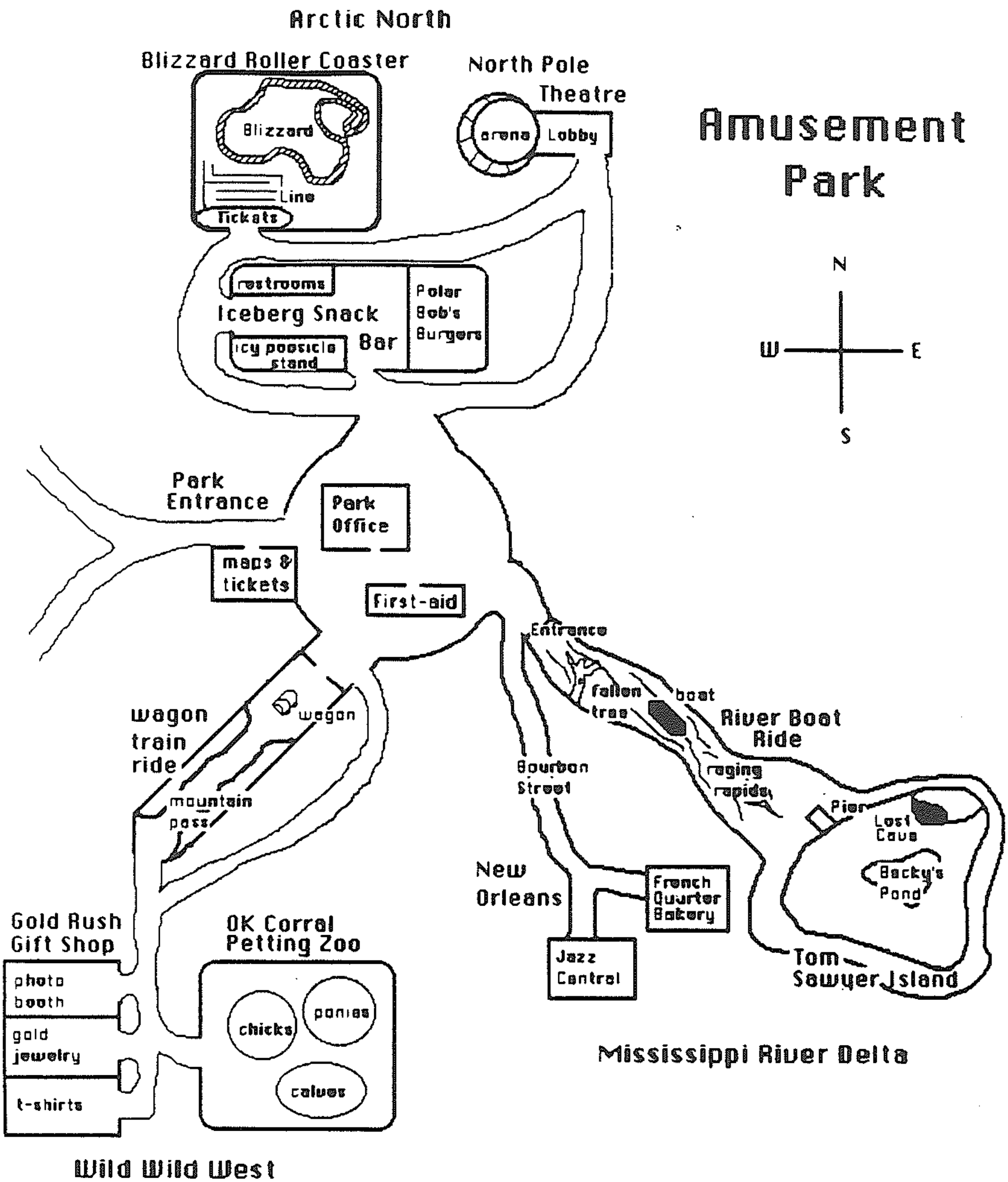

Figure 2. Map of Amusement Park.

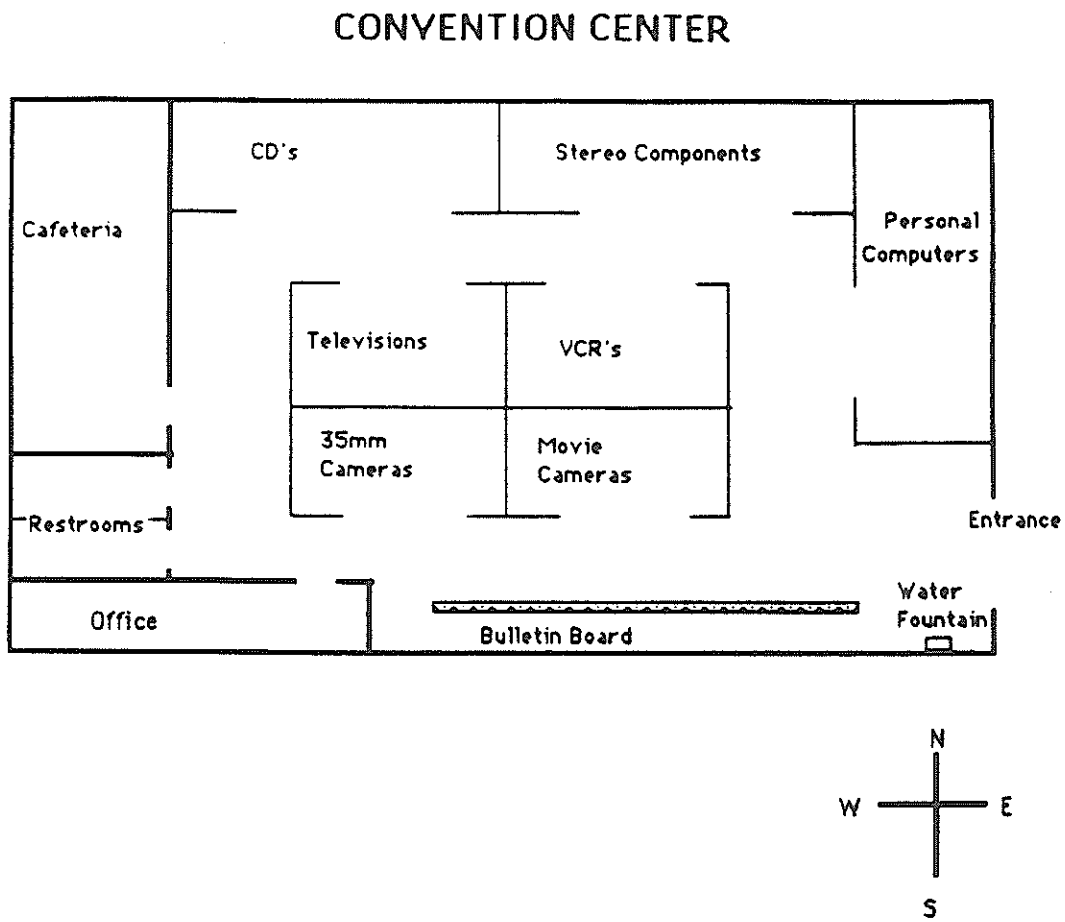

Figure 3. Map of Convention Center. Adapted from Taylor and Tversky (1992) with permission.

subjects expecting to draw a map [$t(32) = 3.09$, $p < .01$], for those expecting to write a description [$t(33) = 1.96, p < .1$], for those who first drew the map [$t(32) = 2.08, p < .05$], and for those who first wrote a description [$t(33) = 2.95, p < .01$]. Examples of descriptions of the three environments are shown in the Appendix.

Spatial information: Maps. Inclusion of landmarks in both descriptions and depictions was only one part of the task. The other part was to accurately convey the spatial information relating the landmarks to one another. The maps the subjects drew were scored for omissions and for location errors. There were three types of location errors: global errors, local errors, and indeterminate locations. Global errors occurred when entire sections were misplaced but spatial relations between landmarks within a section were correct. Local errors occurred when individual landmarks were misplaced within their section. Indeterminate location errors occurred when the subjects provided a label for a landmark but did not provide an icon signifying the location. On average, the subjects made fewer than one error of any type per map, so that errors were not broken down by type. Error rates did not differ significantly for the individual environments.

Spatial information: Descriptions. The descriptions made obvious the fact that the subjects treated the maps as environments and not simply as spatial arrays. Therefore, the subjects followed the description instructions by conveying the spatial layout of the *environment* to an unknown reader. Determining whether the descriptions accurately conveyed spatial information was more difficult. To do so, we recruited a new group of subjects. We gave each description to 2 subjects who had never seen the associated map. They were asked to construct a map from the description. Errors on these maps could come from two sources: errors and ambiguities in the descriptions, or misinterpretations and drawing errors by the new subjects. Because we were interested in how well the descriptions could communicate, we scored the map with the lower number of errors for each description. These maps were scored as described above. On average, the subjects included 90.8% of landmarks in their maps, compared with 94.6% of landmarks included in the descrip-

Table 1
Mean Landmarks Recalled

		Memory Task	
	N	Map	Description
Town	13	12.7	11.9
Amusement Park	17	16.8	16.5
Convention Center	13	12.7	12.4

tions. The subjects included 91.3% of the landmarks for the Town map and 90.5% for both the Amusement Park and the Convention Center. On each map, it was possible to have more location errors than locations, since there were different types of location errors. However, the subjects made relatively few location errors. Overall, the subjects made very few global errors; there were 0.28 global errors on average, with 0.23 errors on the Town map, 0.24 errors on the Amusement Park map, and 0.36 errors on the Convention Center map. They also did not leave many locations indeterminate; there were 0.35 indeterminate locations on average, with 0.18 for the Town map, 0.29 for the Amusement Park map, and 0.56 for the Convention Center map. There were more local errors, 1.51 local errors on average, with 1.32 errors for the Town map, 1.81 errors for the Amusement Park map, and 1.44 errors for the Convention Center map. These low error rates show that the descriptions conveyed spatial information quite accurately.

Order Results

For each subject, recall order on both memory tasks was listed. In descriptions, recall order was based on first mention of a landmark. In drawings, order was based on placement of an icon representing a landmark rather than on the order that the items were labeled. Comparing recall order both within and across subjects and tasks required the same map elements. However, the subjects sometimes forgot landmarks in one or both of the memory tasks. To yield the greatest number of usable recall orders for analysis, we determined the landmarks most often forgotten for each environment and eliminated those from the lists. In all, 3 of 13 landmarks were eliminated from the Town orderings, 2 of 17 from the Amusement Park orderings, and 3 of 13 from the Convention Center orderings. Recall orders that still had missing landmarks were eliminated from the analysis. The analyses used these remaining recall orders to examine three issues: (1) the degree of agreement on recall order across subjects on the two tasks, (2) the degree of agreement on recall order within subjects on the two tasks, and (3) tendencies for landmarks to cluster together in recall.

Order agreement across subjects. To determine the degree of agreement across subjects for each memory task, we calculated Kendall's coefficient of concordance across subjects for the map orders, the description orders, and the orders of the two tasks together. Kendall's coefficient of concordance shows the extent to which distinct rank orderings are similar. With a sizable number of subjects, significance can be tested using a chi-square distribution. For all three environments, analysis of each task separately and both tasks combined yielded significant agreement. This point will be addressed further in the next section. Table 2 displays Kendall's coefficients of concordance by environment and task. All chi-squares were significant. For the Town, map-drawing agreement yielded $\chi^2(9, N=20) = 145.30$, $p < .001$; description-order agreement yielded $\chi^2(9, N=17) = 90.85$, $p < .001$; and combined-task-order agreement yielded $\chi^2(9, N=37) = 229.37$, $p < .001$. For the Amusement Park, map-drawing agreement yielded $\chi^2(14, N=21) = 95.02$, $p < .001$; description-order agreement yielded $\chi^2(14, N=20) = 184.77$, $p < .001$; and combined-task-order agreement yielded $\chi^2(14, N=41) = 225.93$, $p < .001$. For the Convention Center, map-drawing agreement yielded $\chi^2(9, N=22) = 75.08$, $p < .001$; description-order agreement yielded $\chi^2(9, N=20) = 85.54$, $p < .001$; and combined-task-order agreement yielded $\chi^2(9, N=42) = 156.64$, $p < .001$.

We also calculated agreement of orders depending on the task expected and on the first task performed. Both expectations and both first tasks resulted in significant agreement for all environments. The chi-square values showing significant concordance for these four conditions ranged between 71.65 and 157.11, with degrees of freedom equal to the number of landmarks in the environment minus one, and *p*s < .01. Expecting a description seemed to lead to greater concordance than expecting a map, for all three environments. To test this hypothesis, we calculated the average r value associated with each coefficient of concordance. This resulted in six r values, one for each expectation in each of the three environments. For each of these, we calculated the Fisher's r-to-z transformation, which resulted in six z scores. A paired t test on these values did not result in a significant difference in concordance. However, since the coefficient of concordance is a summary statistic, little power was left for comparison of the expectations. Overall, expectation of a map resulted in an average z score of the concordance coefficient of 0.45, and expectation of a description resulted in an average z score of 0.66. The task performed first did not influence the degree of agreement.

Order agreement within subjects between tasks. As shown in the previous section, when the recall order for both tasks was combined across subjects, the results showed significant agreement on order. This combined measure indicates that the subjects tended to recall landmarks in the same order for both tasks. To further

Table 2
Order Agreement Across and Within Subjects

	Kendall's Coefficient of Concordance			Tau: Map and Description
	Maps	Descriptions	Both	
Town	.81	.59	.69	.68
Amusement Park	.32	.66	.39	.48
Convention Center	.38	.48	.41	.37

determine the degree of agreement between tasks, we calculated Kendall's tau for the two memory-task recall orders for each subject and then averaged these for each environment. Kendall's tau indicates the agreement between two rank orderings by computing the number of order inversions for pairs of items in the two rankings. The average taus were 0.63, 0.48, and 0.37 for the Town, Amusement Park, and Convention Center, respectively. For comparison with the concordance coefficients, the tau values are also displayed in Table 2. For 10 or more items, the significance of Kendall's tau can be tested using a normal distribution. The subjects showed highly significant agreement between tasks for both the Town ($z = 2.54$, $p < 01$) and the Amusement Park ($z = 2.49$, $p < .01$) and marginally significant agreement for the Convention Center ($z = 1.49$, $p < .10$).

Overall, the correspondences within and across tasks and within and across subjects were strong but variable and by no means perfect. One reason for the imperfect correspondences was that each environment, especially the Amusement Park and the Convention Center, elicited more than one popular order. For example, for the Amusement Park, some subjects began at the entrance and others at the northern section. For the Convention Center, some subjects first recalled the outer core of exhibits and then the inner core, whereas others alternated between outer and inner corridors. The alternatives for each environment will be documented in the section on specific features of orders.

Clustering of landmarks. To better understand the bases of the strong recall-order concordance, the next step involved a closer look at the orders by examining the clustering of landmarks in recall. For each subject, we calculated the *recall distance* for every pairwise combination of landmarks in the environment, specifically, the number of landmarks recalled between the two items in the pair. Note that distance depends on recall order and not on map distance. From each recall order, the average recall distance for each pair of landmarks was calculated and represented in a half matrix. This was done separately for each environment and for descriptions and maps. The average distance matrix was then used as input for ADDTREE (Sattath & Tversky, 1977). This program produces a tree, with landmarks represented by the external nodes, where the distance between landmarks is given by the length of the horizontal part of the path that joins them (the vertical part is added for graphic convenience). ADDTREE is less restrictive than the standard hierarchical clustering scheme, which requires that all external nodes be equidistant from the root.

The ADDTREE solutions yielded interpretable representations. These solutions accounted for 93.6% of the variance for descriptions and 93.1% of the variance for maps. The fit of the ADDTREE solutions did not differ for the two memory tasks or for the different environments. Figures 4–9 show the ADDTREE solution trees of the three environments.

A visual comparison of ADDTREE solutions obtained for maps and descriptions reveals that the maps yielded more clusters, whereas the descriptions are more chainlike. For example, in the Amusement Park, the map solution gave rise to three distinct clusters corresponding to the entrance, the North, and the South, whereas the description solution gave a chain of landmarks. Despite these apparent detailed differences between solutions for maps and descriptions, in each case the larger groupings tended to contain the same set of landmarks. For the Town, the large-scale environmental features constituted one cluster, the landmarks at the intersection constituted a second cluster, and the landmarks around the square constituted a third cluster. For the Amusement Park, the clusters were geographic and functional. For the Convention Center, the groupings corresponded to the walls of the Center and the inner core. These similarities of structure are consis-

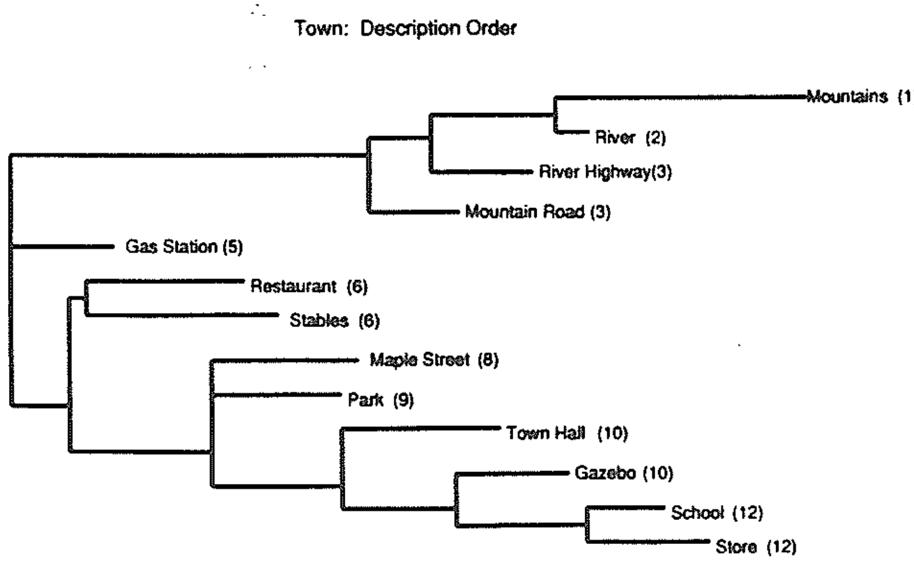

Figure 4. ADDTREE solution of description order for Town. Parenthetical numbers indicate median order of recall.

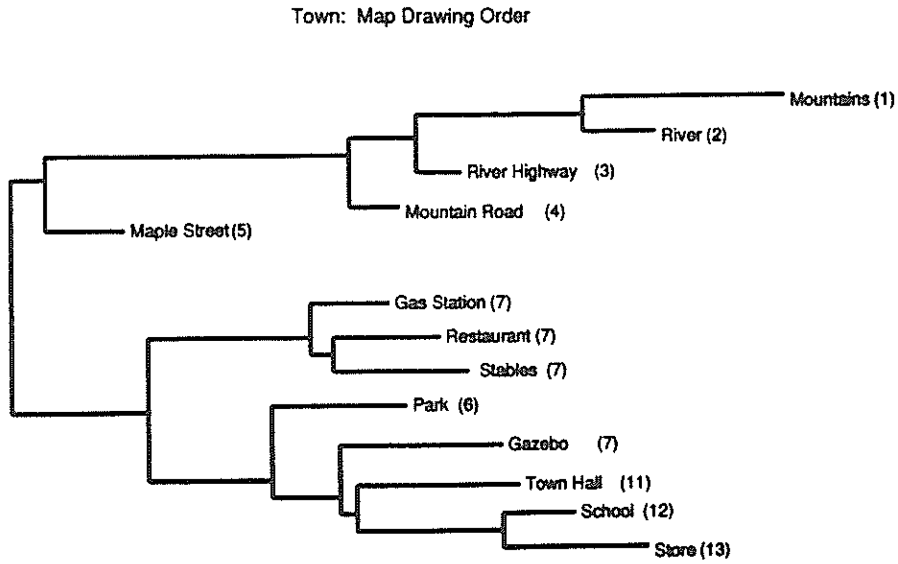

Figure 5. ADDTREE solution of drawing order for Town. Parenthetical numbers indicate median order of recall.

tent with the concordance of recall order between maps and descriptions, both across and between subjects, and will be examined in more detail in the next section.

Specific features of orders. In addition to the ADDTREE analysis, we examined specific features of the drawing and description orders, including starting point, clusters, hierarchical structures, and direction of tour. The groupings for the hierarchical structures corresponded to the major clusters in the ADDTREE solutions. Given the different features of each environment, these microanalyses depended on the individual environment. Because these analyses did not require equal numbers of landmarks between and within tasks, the data eliminated from the overall ordering analyses were again included.

For the Town, we looked at the starting point, the location of the first mentioned road, the location of the first mentioned details, and the complete or partial use of the hierarchy established by the size of the environment's features. The results of these analyses for both map-drawing orders and description orders are shown in Table 3. The predominant starting point was the White Mountains, the northern border. The only other starting points were

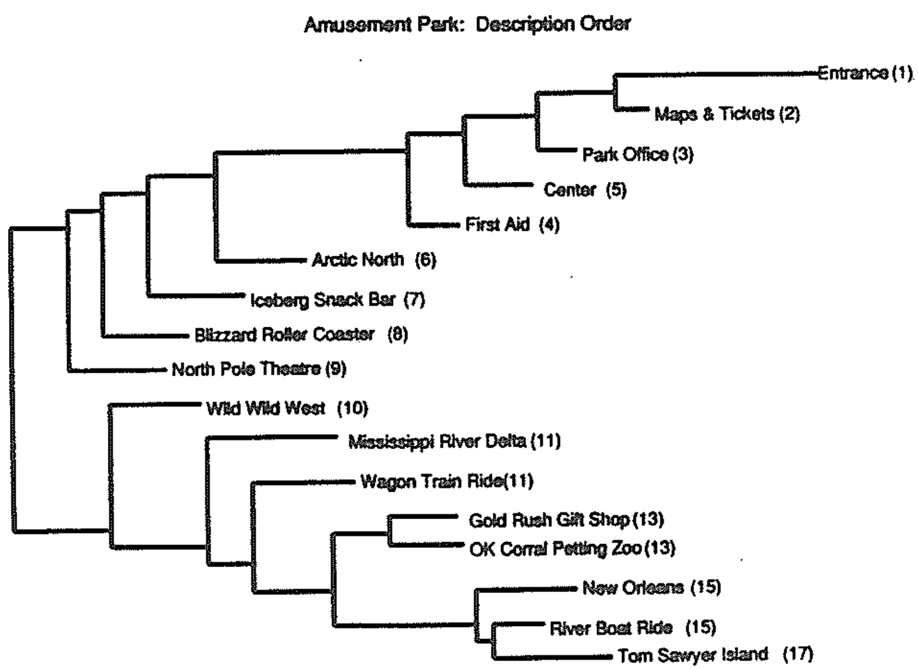

Figure 6. ADDTREE solution of description order for Amusement Park. Parenthetical numbers indicate median order of recall.