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## Chapter 12

# Acquiring Spatial and Temporal Knowledge from Language

**Barbara Tversky and Holly A. Taylor**

People love to tell stories. Folk tales were handed down from generation to generation long before the advent of written language. Most often, stories are embedded in a place and time, so that descriptions of space and time are basic to stories. People describe space and time prospectively as well as retrospectively, in making plans for when and where to meet or in giving directions. Linguistic evidence suggests that spatial language developed prior to temporal, for example, spatial terms like "before" and "after" have been extended from spatial to temporal meanings (Clark, 1971; Clark, 1973). Spatial language has been used to convey abstract meanings as well, as in expressions like, "I'm feeling *up* today," or "He's at the *bottom* of the heap," or "That *field* is *wide open*" (for more examples and discussion, see Cooper and Ross, 1975; Clark and Clark, 1979; Lakoff and Johnson, 1980).

Similarly, spatial knowledge is one of the earliest forms of knowledge that people use; they use it daily, and their lives literally depend on it. Given the importance of spatial knowledge and the prevalence of spatial language, it is reasonable to ask how well language conveys space, how adequate a surrogate for experience it is. This is one central goal of research we and our colleagues have been engaged in (summarized in Tversky, 1991). That research divides into two main projects with separate paradigms, one investigating large-scale spaces and the consequences and determinants of different types of spatial descriptions, and the other investigating small-scale spaces and keeping track of the objects surrounding us under simple navigation (e.g., Franklin and Tversky, 1990; Bryant et al., 1992). We will focus on the first project, first summarizing the past results and then relating some new research. Then we describe the beginnings of an analogous project comparing space, time, and character as organizers of events.

Time is inherent in learning about space, as forming a mental representation of a space requires fitting together pieces of the environment that are acquired at different times, for both small-scale and large-scale environments. Perception of the scene in front of our eyes requires construction of the scene from successive eye movements. Conceptions of the neighborhoods we live and work in require construction from successive experiences. The large-scale project we are engaged in investigates this process directly. In the small-scale project, the observer's position changes over time, as the observer turns or moves in the environment. This

## Large-Scale Environments

### *Spatial mental models from route and survey descriptions*

An informal survey of tourist guides reveals two modes of describing tourist sites. The *survey* mode takes a perspective from above, and describes landmarks relative to one another in terms of the canonical direction terms, north, south, east, and west. The *route* mode takes you, the potential traveler, on an imaginary tour of the environment, taking a perspective from within and describing landmarks relative to your current but changing position in terms of your left, right, front, and back. The survey mode is analogous in many ways to learning an environment from a map, and the route mode is analogous in many ways to learning an environment from direct exploration. The survey mode takes what has been called an extrinsic perspective on the environment and the route mode takes what has been called a deictic perspective on the environment (Miller and Johnson-Laird, 1976). Both modes require piecing together parts of a scene acquired sequentially in time into a coherent whole.

We (Taylor and Tversky, 1992b) wondered if these two modes of description led to different mental representations. Previous research suggested that they should. People learning environments from maps perform better on some tasks, and people learning environments from exploration perform better on others (e.g., Evans and Pezdek, 1980; Thorndyke and Hayes-Roth, 1982; Sholl, 1987). People learning from maps seem to form mental representations with a preferred orientation (north up), whereas people learning from exploration seem to form more flexible mental representations. However, certain information is more readily available from maps, such as direct distances, and other information is more readily available from exploration, such as the detailed appearance of a route.

We wanted to test information that is not biased toward one mode or the other, hence, we selected information that can be easily described in language, and easily conveyed from both perspectives, namely, the relative spatial relations among landmarks. We designed four environments—varying in size, a convention center, a zoo, a small town, and a county-sized resort area—with 11–13 landmarks each. For each environment, we wrote one survey and one route description. We pretested the descriptions to make sure that all the relevant spatial information was included in each and that the two types of description were equally coherent. The descriptions also included general information to make them more realistic and engaging.

The primary spatial relation terms for both route and survey perspectives described the directions of landmarks from a referent, the addressee in the case of route perspective, and another landmark in the case of survey perspective. The relations were the four directions defined either by the sides of the human body or by the canonical coordinates of the world (presumably, originally the direction of the path of the sun and the direction perpendicular to it). Some other spatial relation terms were used, such as "next to" or "after that." These terms were used in contexts where the path allowed easy inference of the direction. The spatial relation terms did not convey oblique directions, nor did they convey proximity without direction, as in "near." The descriptions did not use explicit distance information, though they could have. Distance, however, was conveyed implicitly through spatial stereotypes of environments. Approximate distances could be inferred from the implicit distance between city blocks or the implicit size of rooms, corridors, mountains, and rivers.



Subjects studied either a route or a survey description of each of the four environments. They were told that their memories of the environments would be tested and that they could read each description up to four times. After studying a description, subjects responded "true" or "false" to verbatim and inference statements from both perspectives. Verbatim statements were taken directly from the texts. Inference statements had a route or a survey perspective, but tested information not explicitly stated in either of the texts, although inferable from information from the texts. If perspective is included in subjects' mental representations, then they should respond faster to inference statements from the read perspective than to inference statements from the other perspective. Verbatim statements should be faster than inference statements because they can be verified from a representation of the language of the text rather than a representation of the situation described by the text, in this, case, a spatial mental model of the environment. Previous work has shown that subjects are faster to retrieve direct verbal information than to retrieve information from constructed images (Kosslyn, 1976). After responding to the statements, subjects drew maps of the environments.

The results of four experiments indicated that readers formed accurate spatial mental models of environments learned entirely from descriptions. Their maps contained few, if any, errors. Interestingly, although subjects had not seen any of the maps we had used to write the descriptions, subjects' maps resembled our own. We think this is due to shared stereotypes of environments and of map sketches. Responses to the statements were quite accurate. As predicted, subjects were faster and more accurate to verbatim than inference statements. However, on inference statements, subjects performed equally well on statements from the read perspective and from the other perspective. This occurred in four replications, including one in which subjects read only a single description and were not informed either about the other perspective or about the requirement to draw a map. Moreover, a group that learned the environments by studying a map performed similarly to those who learned from descriptions.

Thus, for inference statements, subjects were as fast and as accurate responding to the perspective they had studied as to the other perspective for both perspectives. On these measures, the spatial mental models subjects constructed from reading the survey descriptions are indistinguishable from those constructed from the route descriptions. What might such a representation look like? We suggested that these representations are like architect's models; they include the spatial relations among the landmarks in the environment in a perspective-free manner that allows the taking of many perspectives on them, including perspectives from above (survey) and from within (route). Following Johnson-Laird (1983), we call these representations spatial mental models to distinguish them from images, which have a particular point of view. Similarly, they are like structural descriptions of objects, constructs widely used in discussions of computer vision

and object recognition (e.g., Pinker, 1984). Structural descriptions contain relations of the parts of objects in a perspective-free manner, allowing recognition of the object from many different perspectives. Answering the questions required taking a specific perspective, not just a perspective from within (route) or one from above (survey), but a route perspective from a particular orientation and a survey perspective including a refined set of landmarks.

We do not mean to imply that there are no differences between acquiring environments from exploration and acquiring them from maps. Clearly, there are. We tested knowledge of categorical spatial relations, we did not test the distance and direction judgments that have yielded differences in previous work. The information we tested is easily conveyed in language, using either perspective. It is also information not biased toward one mode of acquisition, as certain distance and direction judgments seem to be. Moreover, we selected small environments, and took steps to insure that they would be well learned. However, it makes sense to us that through interactions with environments, real or described, people construct mental models of the general spatial relations among important landmarks, that is, models that are more general than particular experience and particular perspectives.

### *Producing descriptions of environments*

At this point, it is pertinent to ask whether people spontaneously describe environments the way we have been describing them. Some linguists and psycholinguists have argued that spontaneous spatial descriptions usually take readers or listeners on a mental tour, and that they maintain a consistent perspective (cf. Levelt, 1989). In recent work (Taylor and Tversky, 1992a, 1993), we gave maps of environments varying in scale to subjects to learn, and asked them to write descriptions and draw maps of the environments from memory. Despite the claims of linguists, and without any coaching on our part, subjects produced either route or survey descriptions, or descriptions that mixed the two perspectives. No other description style emerged. Follow-up work systematically varying a number of environmental features indicated that route descriptions are more likely when environments have a single path rather than multiple paths, and when environments have features on a single size scale, rather than multiple size scales. Whether the environment was enclosed or open and whether the environment was itself small scale or large scale did not make a difference.

Irrespective of perspective, descriptions were constructed in the same way. The descriptions were hierarchical on the whole, with the more salient or more functionally significant features described earlier. Environments were described in segments. For each segment, first part of the background environment was described, and then the relevant landmarks were located within it. Perspective was used to locate landmarks within segments and to interconnect segments. Significantly, as indexed by order of drawing landmarks, map sketches of the environments showed the same overall organization as the descriptions. Both route and survey descriptions, then, build up space over time in segments, much as it is experienced.



## Time, Place, and Character as Organizers of Event Descriptions

Most events occur in a particular place at a particular time and involve particular people. Descriptions of events, then, can be organized around any one of these features, or a combination of them. There is something to be said on behalf of each of these factors as perspectives for narrative and organizers of memory. Places are concrete, often imageable, and spatial. Perhaps because of these factors, place has been used to facilitate memory at least since the time the Greek orators invented the Method of Loci to remember their orations. Place serves as the basis of effective mnemonic devices (Bower, 1970) and as the basis of mental models (Radvansky and Zacks, 1991; Franklin et al., 1992). Place is also associated with real-world activities: we swim at beaches and buy food in supermarkets (Tversky and Hemenway, 1983). Such associations form a basis for causal reasoning. Unlike space, which can be revisited, time is fleeting. Though less concrete than space, it is, nevertheless, familiar; after all, we cannot escape it. Like space, time is categorizable in many different ways. Time, too, is associated with activities; breakfast is eaten in the morning, and most people sleep at night, but the depth and breadth of association is less than for place, if only because people are likely to experience a wide variety of distinctive places. In addition to space and time, character may serve as an organizer for events. Character plays an important role in social cognition. People tend to attribute behaviors and consequences to characters rather than to situations. Characters are perceived as active initiators and causes of events (e.g., Ross and Nisbett, 1991). Each of the three organizers is an effective cue in retrieving autobiographical memories (e.g., Williams and Hollan, 1981; Wagenaar, 1986; Barsalou, 1988).

We have begun a project investigating how people naturally organize event descriptions. The first experiment compared organization by time or by character. Subjects read two descriptions, one of a day's activities of residents of a home for senior citizens, and the other of a day's activities of suspects in a murder. The characters were not endowed with personalities, and activities were selected so that they were appropriate for any person, place, or time. Descriptions were organized either by time or by character, and reading time was measured. After reading each description, subjects were tested with true–false statements emphasizing time or character, and then asked to draw a diagram of the events. Together, the measures indicated that subjects preferred to organize the events around characters rather than around time, even when that required reorganization. Although subjects could have organized the events around time and character simultaneously and equally, as in a matrix or schedule, they did not. The preference for character organization can be explained in several ways. People view characters as actors who select activities appropriate for themselves, that is, activities may be seen as causally related to character. Also, characters are concrete. Causal relatedness and concreteness are both known to facilitate memory.

A second study compared place and character as organizers. As before, characters were not given personalities and activities were not related to character or place. Characters were referred to by first names. Places, however, were func-

tional; for example, buildings on a college campus such as library and cafeteria, so they had more substance than the characters. In this study, neither organizer dominated the other; some subjects preferred to organize by character and others by place. Both character and place are concrete, and in life, though not in this study, causally related to activities. Because the places had more substance than the characters, we plan another study where the characters will be professions, more comparable to the places.

If character dominates time but does not dominate place, it is likely that place will dominate time, though we are checking that possibility to make sure. If so, then it will fit with a finding in the problem solving literature, where subjects were more successful finding solutions to a spatial analog of a problem than a temporal analog of the same problem (Carroll et al., 1980). When it was suggested to subjects in the temporal analog condition to use spatial diagrams to facilitate problem solution, their performance rose to the level of subjects in the spatial analog condition.

Mirroring our studies of spatial descriptions, we have also been collecting descriptions of events that occur in various places and times and involve various participants. We expect that for spontaneous descriptions, as for recall, character and place will dominate time as organizers.

## Summary

So far, the first set of experiments investigating learning environments from language has shown that people can establish spatial mental models of environments, large and small scale, from descriptions of them rather than direct experience. In terms of categorical spatial relations among landmarks, mental models established from descriptions are like those established from maps or from actual experience. These mental models are perspective-free, but allow the taking of many perspectives on them. Finally, they are flexible, and are updated and changed as changes in the environment are related, again through language.

A parallel project has been investigating people's descriptions of memorized environments. These descriptions tend to be organized hierarchically, with physically or functionally salient landmarks described earlier. They build up the environments in segments, where each segment first describes a piece of the environment, and then describes the locations of the associated landmarks. Describers use one of two perspectives, or a mixture of both, to relate landmarks to environmental segments and segments to one another. In a route perspective, the addressee is taken on a mental tour of the environment, with a view from within. Landmarks are described with respect to the addressee's front, back, left, and right. In a survey perspective, the view is from above, and landmarks are described with respect to each other in terms of north, south, east, and west.

The final project, investigating time, place, and characters as organizers of events in memory, has shown that place and character dominate time. Place and character are more concrete than time, and more causally associated with events, and both concreteness and causal association are known to promote memory.



Space and time have fascinated people since the beginning of consciousness, whenever that was. Language can convey spatial and temporal information in ways that allow others to construct mental models of space and time. Descriptions of space and time produced by people reveal how we think about space and time. Psychological research may not answer the eternal questions about space and time, but it does give us more to wonder about.

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