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23

Remembering Spaces

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From the moment we enter the world, we are engaged in spatial cognition, in interacting with the world around us and in constructing mental representations of that world and our own place in it. Yet we do not conceive of the world as a geometer might, as space with three extrinsic orthogonal coordinates that specify the locations of points, objects, or regions. Rather, we adopt different frames of reference and incorporate different elements in constructing mental spaces for the real spaces important in our lives. Two milestones of the first year of life illustrate two of these functional spaces. Around the third month of life, babies begin to reach for and later manipulate objects in their environments. At the end of the first year, they begin to walk on their own. The space around the body and the space of navigation constitute natural breaks in our perception and our behavior, and in our consequent conceptions of space.

Historical Roots

Geography and Architecture

The study of spatial cognition has two separate origins that have merged, one outside psychology and applied, and the other inside psychology and theoretical. Outside psychology, spatial cognition began as the human side of architecture and geography. A seminal book was Lynch's *The Image of the City* (1960). There he observed that people's images of cities differ from reality depending on their personal experiences. He proposed that images of cities are constructed from point elements (that is, landmarks and nodes), from linear elements (that is, paths and edges), and from area elements (that is, regions). This view inspired geographers and later psychologists to investigate people's images of their environments, how they are acquired, and how they deviate from reality (see, for example, early edited books by Downs & Stea, 1973 and Moore & Golledge, 1976; review chapters by Chase (1986) and Evans (1980); more recently, a special issue of *Geoforum* in 1992 on cognitive maps, the COSIT (Conference on Spatial Information Theory) proceedings published by Springer-Verlag in 1993, 1995, 1997, and 1999, and books edited by Egenhofer & Golledge, 1998; Garling & Golledge, 1993; and Portugali, 1996.)

Psychology

Within psychology, the controversial notion of a cognitive map came to us from Tolman's paper, "Cognitive Maps in Rats and Men" (1948). Although accused by his adversaries of leaving the rat buried in thought, Tolman's point was that in solving mazes to find food, rats learned the lay of the land, not just to make left and right turns. That insight, however, did not directly stimulate research on human spatial cognition, though it left its impact on animal work (e.g., Gallistel, 1990; O'Keefe & Nadel, 1978) and thereby on current neurocognitive work. Investigations into the cognitive maps of humans was held back by two related preconceptions. One was a bias to think of memory and thought as based in language, and to regard knowledge about the visual and spatial world as reducible to language, be it labels or verbal codes or propositions. The other deterrent was a remnant of behaviorism, that mental representations of the visual and spatial were suspect; they were vague, subject to interpretation, not open to public inspection.

The view that memory for the visual/spatial world was reducible to words or propositions was first challenged by work of Paivio (1971) and others showing that words for vivid things were remembered better than other words, controlling for everything conceivable, and that pictures were remembered better than their names, and work by Shepard (1967) and others showing remarkable memory for pictures. If pictures are reduced to words in memory, how is it that pictures are remembered better than words? The view that mental representations of a visual/spatial nature are not open to scientific investigation was challenged by striking demonstrations of mental transformations, such as mental rotation and mental scanning, (e.g. Finke & Shepard, 1986; Shepard & Cooper, 1982) and mental imagery (e.g., revealed in systematic patterns of reaction times; Kosslyn, 1980).

More recently, other traditions within psychology have contributed to spatial memory. Not surprisingly, researchers in perception have been interested in people's memory for distance and direction in actual environments, with or without vision, with or without actual navigation, with imagined or actual experience (e.g., Berthoz, Israel, Georges-Francois, Grasso, & Tsuzuku, 1995; Creem & Proffitt, 1998; Loomis, Klatzky, Golledge, Cicinelli, Pellegrino, & Fry, 1993). More surprising is the interest of researchers of language use, who have studied descriptions of space because space is universal to human experience, has an objective reality for comparison to mental representation, and forms a basis for more abstract thought (e.g., in language, Lakoff & Johnson, 1980; in depiction, Tversky, 1995). These disparate traditions illustrate the broad range of inputs to spatial memory, from the lower level perceptual inputs that may be implicit to the higher level linguistic and depictive inputs that are cognitive and explicit.

From the beginning, research on memory for space and spaces has been driven more by what is special about space than by the traditional concerns of memory research, such as factors promoting encoding and retrieval of information. There is one factor that promotes memory and that makes space special—namely the way space is mentally structured, organized or schematized. Revealing the ways different spaces are schematized has been the aim of much of the research on memory for space, blurring the boundaries between spatial memory and spatial cognition.

Mental Spaces

The evidence to be surveyed supports the view that mental spaces are mental constructions, consisting of elements and the spatial relations among them. Elements may be objects, people, landmarks, regions, cities, and so forth. Elements are coded and remembered relative to each other and relative to reference frames. The spatial relations among them range from the more typical schematic or categorical to metric. To some extent, elements correspond to the "what" system and spatial relations to the "where" system distinguished in neuropsychology (e.g., Ungerleider & Mishkin, 1982).

The choices of elements, spatial relations, and reference frames depend on the space of interest, its function, and the task at hand. In the environmental psychology tradition, it has been common to distinguish between egocentric and allocentric reference frames—that is, those based on one's own perspective in contrast to those based on an external set of coordinates, such as the cardinal directions (e.g., Pick & Lockman, 1981). In the psycholinguistic tradition, a three-way distinction has been common: one based on a person, called deictic or relative or egocentric; one based on an object, usually called intrinsic, and one based on an environment, usually called extrinsic or environmental. Within this tradition, there has been debate concerning the distinction between person-based and object-based reference frames (see Levinson, 1996, for a reformulation or Taylor & Tversky, 1996, for an application and critical commentary). Spatial relation terms appropriate to person- or object-based frames include "next to," "near," "right," "in front of," and "between." Spatial relation terms appropriate to extrinsic or allocentric reference frames include "north" and "seaward."

The various perspectives provide a view or way of organizing spatial elements. More than one perspective may be used to encode even a single situation. Research on parietal patients suggests that both egocentric and allocentric reference frames are disturbed in hemineglect (Behrmann & Tipper, 1999; Bisiach, 1993), suggesting that locations are initially encoded in multiple reference frames. In language, multiple perspectives abound. Here's an example, from Taylor and Tversky (1996), "Following the loop around westwardly, you will arrive at the blizzard roller coaster, extending north as you enter the Blizzard area" (see also Carlson-Radvansky & Irwin, 1993; Schober, 1993). In addition, mental spaces may be incomplete or inconsistent, and more than one mental space may affect behavior. These properties of organization and memory of mental spaces are reflected in reaction times, errors, inferences, language, and other measures.

Places

The emphasis in this chapter is on space rather than place, on relations rather than elements. Nevertheless, a word on memory for places is appropriate. Places serve as landmarks, important in memory for space. And it appears that memory for places has special qualities not shared by memory for other, even other visual, stimuli. The first hint came from the prevalence of places among those pictures that were highly memorable (e.g., Shepard, 1967; Standing, 1973). Like other stimuli, organized scenes are remembered better than unorganized (Mandler, Seegmiller, & Day, 1977). That organization is primarily vertical, constrained by gravity. Like objects, scenes fall into natural categories. At the first level is indoors and outdoors, with house, school, and restaurant as subcategories of the former and beach, mountains, and city as subcategories of the latter (Tversky & Hemenway, 1983). Extraordinary memory for places was recognized millennia before scientific psychology became a discipline. The ancient Greeks capitalized on memory for places to facilitate memory for other information in the Method of Loci (Yates, 1966), the only European invention of interest to the late sixteenth-century Chinese court (Spence, 1985). Although remembering locations of places may not be completely effortless or perfect, it is certainly relatively easy (cf. Hasher & Zacks, 1979; Huttenlocher, Hedges, & Duncan, 1991; Lansdale, 1998; Naveh-Benjamin, 1987). In memory for sentences, places, unlike other concepts such as people and objects, do not suffer from decreased retrieval time (fan effect) when serving as a cue for many other concepts (Radvansky, Spieler, & Zacks, 1993; Radvansky & Zacks, 1991). This is presumably because the sentences invoke mental models and mental models of places can support associations to multiple objects. The special status of places is reinforced by evidence implicating a region of the parahippocampal cortex dedicated to recognition of them (Brewer, Zhao, Desmond, Glover, & Gabrieli, 1998; Epstein & Kanwisher, 1998).

The Space of Navigation

The space of navigation is generally regarded as the space that is too large to be seen from a single vantage point. Thus, any mental representation of the space of navigation has to be put together from different views or experiences. Nevertheless, people form mental representations of these spaces, whether from navigation or from maps or from descriptions or from a combination, that allow them to arrive at their destinations and to give directions to others with some success. This is not to say that people's mental representations of the space of navigation are holistic or complete or accurate. In spite of successful navigation and direction giving, people's memories for the space of navigation differ systematically from the actual spaces. Moreover, people's memories are not simply two-dimensional simplifications, as the term "cognitive map" would imply, though they are that, too. They are in addition distorted in ways that reveal how they are constructed and organized. The evidence for these systematic distortions comes from a variety of tasks, some semantic, some episodic, some using reaction times, some using errors, some using memory, some using judgment (for reviews, see Chase, 1986; Tversky, 1992, 1993, 1997, 1998). Systematic errors and biases in reaction times have been especially informative. Errors and biases are easy to overlook as random noise unless researchers are prepared by theoretical intuitions to seek them out. Errors and biases can be interpreted as consequences of the way