Cognitive Geography

D. R. Montello, University of California – Santa Barbara, Santa Barbara, CA, USA

Glossary

Affect Emotional component of psychological states including mood, stress, preference, and attitude.
Cognitive Map Spatial and nonspatial knowledge about places stored in the mind.
Cognitive Regions Regions in the mind, used by people informally to organize their understanding of the Earth surface.
Dead Reckoning Updating orientation by calculating or inferring a new location or heading based on knowledge about movement speed and direction from a known starting point, without recognition of specific features.
Hierarchical Spatial Reasoning Reasoning about spatial relationships on the basis of superordinate relations in a hierarchy of places and regions.
Landmarks Distinct objects or features in the world that can be noticed and remembered, and serve to organize experience and memory, guide action, and provide a basis for communicating about the world.
Route Knowledge Knowledge of linear sequences of landmarks connected by travel patterns, ordered but not necessarily metrically scaled.
Survey Knowledge Knowledge of two-dimensional layout from which spatial relations among places can be determined even if direct travel between them has never occurred.

What Is Cognitive Geography?

Cognitive geography is the study of cognition, primarily human cognition, about space, place, and environment. Cognition is knowledge and knowing by sentient entities, including humans, nonhuman animals, and artificially intelligent machines. Cognitive structures and processes include those of sensation, perception, thinking, learning, memory, attention, imagination, conceptualization, language, and reasoning and problem solving. Some of these structures and processes are consciously accessible, potentially available to awareness; others are nonconscious, outside of awareness. Cognition is functionally and experientially intertwined with affect, motivation, and behavior. Our beliefs and knowledge influence, and are influenced by, what we feel and what we do.

Cognitive geography emerged as an approach within human geography and as an interdisciplinary link with psychology and other fields during the 1960s but reflected strands of inquiry from at least as early as the beginning of the twentieth century. Those strands included an interest in understanding and improving spatial orientation and disorientation, geographic education, map design, urban planning and landscape design, and models of spatial behavior and interaction, including travel, communication, and economic activity. The study of cognition is thus a concern for geographers because it involves the fundamental geographic issues of space, place, and environment. Cognitive research not only holds the promise of improving noncognitive models of human activity but also includes problems that are part of the domain of geography in their own right.

Cognitive geography originated as a component of the behavioral approach in human geography; it thus shares much of the philosophical character of behavioral geography. The behavioral approach is the view that we can understand much about human geography by studying it at the disaggregate level of analysis – at the level of the individual person. As such, behavioral geographers examine data on the behavior of individuals, allowing for the likelihood that individuals vary from one another because of factors such as their intellectual abilities, gender, education, and culture. Behavioral geographers hold that models of human activity and interaction can be improved by incorporating into them more realistic assumptions about human behavior. As a case in point, the assumption of economic rationality holds that economic agents are motivated solely to maximize profit, and have complete and accurate knowledge of profit-relevant information. This assumption is usually quite unrealistic, especially when studying economic agents that are individual people. Behavioral geographers argue that assumptions about human psychology like that of economic rationality can be replaced with assumptions that are more realistic. For example, gravity models hold that spatial interaction declines as a function of increasing distance, raised to the power of some exponent. Behavioral geographers assert that the distance term should properly refer to cognitive distance – distance as believed – rather than actual physical distance (or cognitive travel time rather than actual travel time, and so on).

Although signs of interest in cognition were present in the discipline of geography before the emergence of the behavioral approach (as suggested above), attempts to study human geography at the disaggregate level naturally led behavioral researchers to regard what the individual knows or believes about the world as playing an important role in explaining what the individual does or will do. That is, a key assumption of cognitive geography arising from its genesis within the behavioral approach is that people do what they do, at least to an important degree, because of what they think is true. People evaluate alternative decision options according to their beliefs, in order to make behavioral choices in space and place. What people think, in turn, arises from perceptual knowledge acquired via the senses, as organized and interpreted by existing beliefs and schematic knowledge structures and processes. These, in turn, are products of people's genetic and experiential histories.

Cognitive geography differs from other approaches to human geography, such as environmental geography, social physics, classical economic geography, and various forms of critical geography. It differs in its topical focus, its preferred methodologies and epistemological assumptions, and its basic conceptualization of the human–earth relationship – its version of a human-geographic ontology. Four key tenets of cognitive geography express its topical focus, and its epistemological and ontological assumptions:

1. An appropriate level of analysis is disaggregate. The individual person is an informative unit of analysis (disaggregate or microscopic level) over and above the social or spatial group (aggregate or macroscopic level). Disaggregate analysis allows for – even insists on – possible individual variation based on the genetic and experiential variation of individuals. However, cognitive geography does not assume that this variation is completely random or idiographic; individual variation is assumed to exist within causally patterned networks of interrelatedness. That is, individual variation can systematically explain, and be explained by, other constructs to which it relates. Individual variation is typically studied in terms of constructs that characterize groups of individuals and are potentially causally relevant, including sex, gender, age, education, culture, residential environment, activity patterns, and social class. Thus, cognitive geographers believe it is valid to study individual variation scientifically, that is, according to systematic empirical observation and logically consistent theorizing that is potentially repeatable, accumulable, and generalizable. Of course, patterns of correlations between measures of group constructs and measures of geographic behavior (and cognition) are, by themselves, ambiguous with respect to causal explanation. The group construct could cause variations in the behavior, the behavior could cause variations in the group construct, or another construct or set of constructs that may not even have been measured could cause variations in behavior.
2. Behavior is based on subjective or perceived reality. Affect and behavior are based directly on subjective, or perceived, realities (plural because of individual variation). Behavior is based only indirectly and approximately on objective reality. Much of the indirect effects of objective reality are mediated by subjective reality, because subjective reality itself is directly based on one's experience of objective reality, which varies somewhat across individuals. Cognitive geographers recognize that subjective realities typically deviate from objective reality, sometimes greatly. The internal mental structures and processes believed to mediate observed behavior are not necessarily available to conscious awareness. Much behavior in fact depends on cognitive structures and processes that are not consciously accessible, such as when we respond favorably to a particular place for reasons we do not remember or understand. Furthermore, we sometimes delude ourselves about the reasons for our actions; we may provide explicit explanations for our actions that are actually personal theories or rationalizations, because we sometimes have no direct conscious access to our real motivations and do not feel comfortable accepting this lack of awareness.
3. Human–environment relations are dynamic and bidirectional. Neither environmental determinism nor its opposite, cultural determinism or autonomy, are viable theoretical frameworks for understanding human geography. Human–environment relations are bidirectional, insofar as the actions and cognitions of individuals both cause, and are caused by physical and social environments. Furthermore, these relations are dynamic, constantly emerging and subsiding, though remaining relatively stable over sufficient time periods to justify scientific study. Within the context of cognition, the notion of dynamic and bidirectional human–environment relations is reflected in the notion that humans are active gatherers and processors of information, not simply passive recipients.
4. Mind emerges from brain and nervous system, in a body that is in a physical and social world. Cognitive geographers, like psychologists and other cognitive scientists, recognize that mind depends on the complex organ of the brain and the rest of the nervous system. Following the lead of other cognitive scientists, cognitive geographers in the early twenty-first century are beginning to show interest in cognitive neuroscience, the scientific discipline that studies mind–brain relations. Much recent interest in cognitive neuroscience on the part of geographers and others is fueled by excitement over the relatively new technologies of brain scanning, especially functional magnetic resonance imaging (fMRI). But cognitive geographers do not equate mind with brain; mind does emerge from brain, but it also emerges from the human body, existing in a social and physical world. That is, mind is embodied and situated. Attempting to

understand cognitive geography solely by reducing it to the brain would be like trying to understand glaciers solely by reducing them to hydrogen and oxygen. That is, cognitive geography is not reductionistic, although it accepts that reductionistic analysis contributes to a comprehensive understanding of geography. Although cognitive geographers could once be criticized for treating mind too individualistically, they increasingly recognize that mind emerges and functions within a social and cultural context. Similarly, the critique that cognitive theory leaves a person frozen in daydreams or pondering over alternatives has largely been supplanted by ecological and functional approaches to cognition that reconnect the knowing person to action and the physical world.

Research Topics in Cognitive Geography

As another approach to explaining cognitive geography, this section briefly reviews some of its research topics, including some specific concepts, theories, research questions, and empirical findings. Research in cognitive geography covers a diverse array of topics, as it includes all aspects of human cognition about spatial, temporal, and thematic aspects of the Earth and external representations of the Earth. The rest of this article focuses on research in four topical areas: geographic knowledge and reasoning, navigation and orientation, learning and development, and symbolic sources of geographic information. Other research topics in cognitive geography include spatial choice, artificial intelligence, environmental preference and esthetics, hazard perception, and individual and group differences in geographic cognition.

Geographic Knowledge and Reasoning

Central to cognitive geography is the idea that people acquire geographic knowledge about the spatial and nonspatial properties of the Earth surface, and the natural and human features and processes found there. This knowledge is encoded in the nervous system in the form of patterned internal, or mental, representations. These representations are variously referred to as cognitive (or mental) maps, mental models, memory images, schemas, concepts, and so on. Geographic knowledge also exists as symbolic artifacts – patterned external representations. Examples include cartographic maps, verbal descriptions, numerical equations, and so on. Whether internal or external, geographic knowledge includes knowledge of distances, directions, connectivity, and other spatial properties of varying geometric sophistication; it also includes nonspatial knowledge of temporal and thematic properties, such as storm frequency, soil fertility, city populations, and so on.

The term cognitive map suggests a metaphorical similarity between geographic knowledge and cartographic maps. This metaphor is apt insofar as both cognitive and cartographic maps are representations, contain spatial and nonspatial information, are selective, distort and schematize spatial and nonspatial properties, can encode information via different perspectives, represent on a continuum of abstractness, and have a variety of functions. The metaphor misleads insofar as cognitive maps are not unitary and uniform representations, as is suggested by the spurious idea that they are mental pictures in the mind. Cognitive maps are more like atlases or collages, in that they consist of multiple representations that are not necessarily mutually coordinated or consistent, and do not have constant, or constantly varying, scales. Furthermore, cognitive maps are like multimedia presentations in that they are derived from multiple sources of information and encoded in a variety of formats, not just graphical or pictorial. Cognitive maps do not necessarily encode Euclidean metric spatial relations or any other metric relations. Much research in cognitive geography and related fields has documented various patterns of distorted distances, directions, and other spatial relations that are evident in behavioral data based on cognitive maps.

Cognitive maps are thought to be composed of characteristic elements, including landmarks, paths, regions, and boundaries. Landmarks are distinct objects or features in the world that can be noticed and remembered. They serve to organize experience and memory, guide action such as navigation, and provide a basis for communicating about the world. Although they are often thought of as point-like features, linear and areal features such as paths and regions can also serve as landmarks. Although one often thinks of landmarks as discrete features, such features often act as landmarks only within a context of their location or surrounding environment.

Regions are approximately two-dimensional elements, spatial categories of Earth surface. Just as geographers use regions to organize the Earth surface, and institutions use regions to organize administration of the Earth surface, lay people use regions to organize their cognition of the Earth surface. Cognitive, or perceptual, regions are regions in the mind. People informally regionalize on the basis of physical boundaries and other discontinuities in the structure or appearance of the Earth surface, but they also regionalize on the basis of activities, residential and cultural patterns, past events, and other factors that may not be perceptibly present on the Earth surface. Geographers and others have further noted that people organize regions into full or partial hierarchies; hierarchical structures link regions at different levels of status (size, functional importance) according to relationships of containment or connectivity. For example, countries contain provinces. Hierarchical spatial reasoning occurs when people reason about spatial relationships on the basis of superordinate, rather than direct, relations among regions and places. Regional organization and reasoning, including that which is hierarchical, can be inferred from patterns of judgments people make in recalling places and their relations, and in estimating distances and directions (Figure 1); patterns of times people require to make such judgments are also telling about knowledge organization.

Navigation and Orientation

Navigation is coordinated and goal-directed movement of one's self through the environment, where the goal is a place or location one strives to reach. It is an essential process involved in the temporary and permanent travel behavior that is of great interest to human geographers. A practical reason to study navigation is to understand cognitive aspects of accessibility, such as what information is needed by different classes of travelers, including older adults and those with sensory–motor disabilities.

Navigation may be understood to consist of the two broad components of locomotion and wayfinding. Locomotion is the coordinated movement part of navigation, wherein we walk or drive while maintaining a directional heading, avoiding barriers, and so on. Locomotion is coordinated to the local surrounds – the environment that is directly accessible to one's sensory and motor systems. If a person controls his or her own locomotion, as when driving a car, it is considered active locomotion; otherwise, as when riding in a car, it is considered passive. Wayfinding is the efficient goal-directed planning and decision-making part of navigation; it guides the locomoting person to a destination. It includes planning for travel and decision making during travel, including route choice and orientation to nonperceptible features. Wayfinding is coordinated to the distal environment – the environment that is not directly accessible to one's sensory and motor systems but is accessed via internal or external knowledge, such as that found in cognitive or cartographic maps.

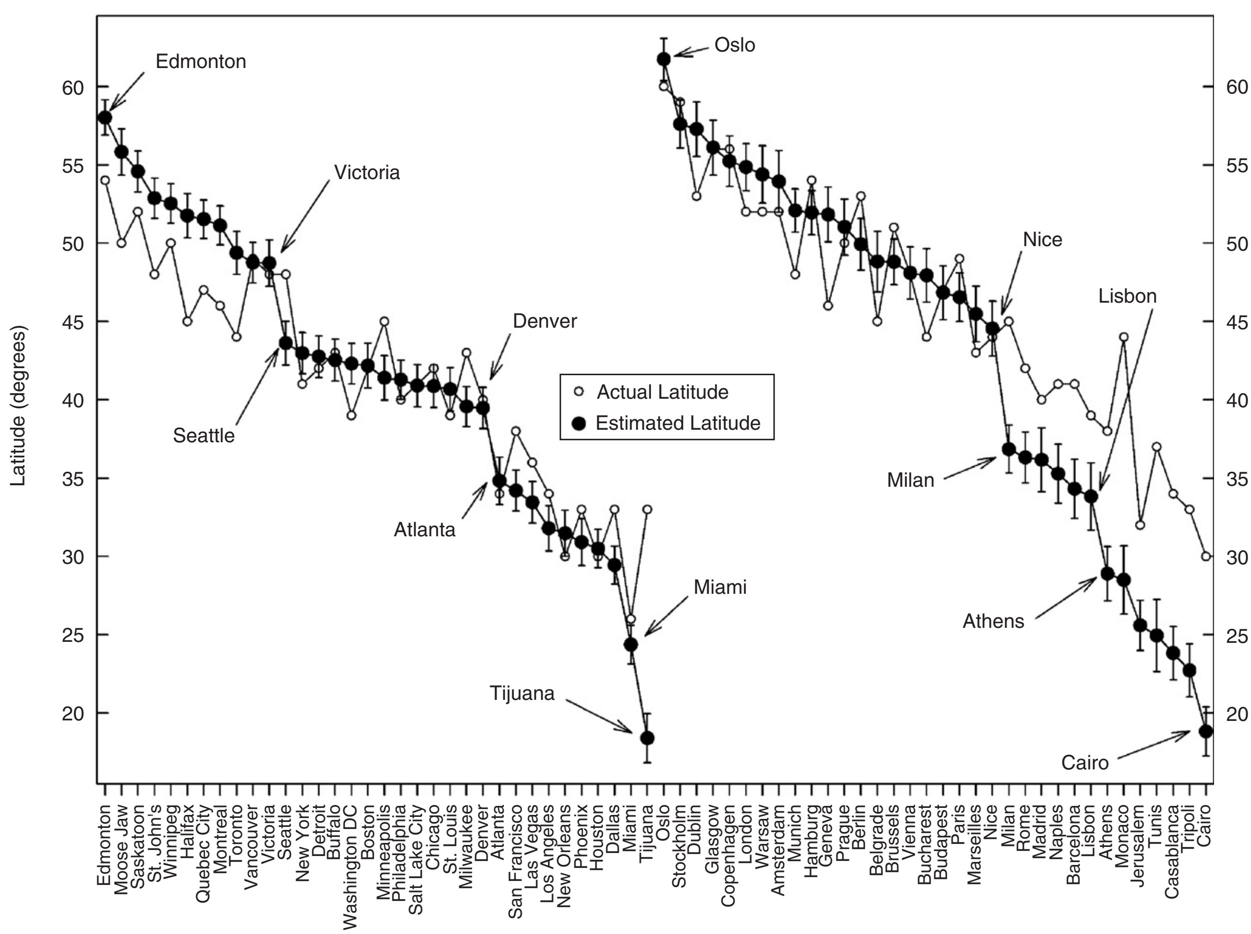

Figure 1 Regional organization and reasoning as reflected in patterns of latitude estimates for world cities. Cities (on the abscissa) are ordered according to estimated latitudes in the Western and Eastern Hemispheres. Adapted from Friedman, A. and Brown, N. R. (2000). Reasoning about geography. *Journal of Experimental Psychology: General* 129, 193–219.

Orientation is an essential component of navigation. Geographic orientation is knowing where you are on the Earth's surface and the heading to your destination. To the degree that people are uncertain about their location and/or heading, they are geographically disoriented. Orientation and disorientation are always relative to some reference system, whether based on one's body, on external landmarks, or on macroscopic properties of the Earth or the surrounding environment, such as magnetic north or the alignment of a visible mountain chain. As people navigate, they typically update their orientation. This can be done according to one of two broad classes of mechanisms, or a combination thereof. Landmark-based updating (piloting, position fixing) is based on recognizing external features like landmarks. Dead reckoning updating (path integration, inertial navigation) involves updating by calculating or inferring a new location/heading based on knowledge about movement speed and direction from a known starting point, without recognition of specific features. Information about movement speed and direction can be based on internal signals, such as vestibular sensing of body acceleration, or external signals, such as optic flow in the visual field.

Learning and Development of Geographic Knowledge

People's geographic knowledge varies, in part, as a function of their age, their education, and their experience. That is, geographic knowledge depends on learning and maturation. Infants are born without specific geographic knowledge, although their nervous system is innately designed to acquire particular types of information (such as depth and directional relations) when exposed to the world through sensory–motor experience. As infants and children age, their geographic knowledge changes, because of changes to the nervous system, new experiences, and reorganizations of cognitive structures and processes that occur over time independently of specific experiences. Different theoretical approaches conceptualize development as occurring in relatively abrupt transitions between qualitatively distinct stages, or in relatively gradual and continuous transitions. These changes are both general, such as acquiring an understanding of spatial relations like hierarchical containment, and specific, such as acquiring an understanding of the layout of a particular neighborhood one has visited. Although these changes are usually thought of in terms of accumulating more knowledge and increasing the complexity or nuance of one's understanding, they also include forgetting and some loss in the ability to hold complex spatial relations in working memory.

Cognitive development over the lifespan of an individual includes changes over relatively short time spans as a function of experience – learning. A widespread theory of special relevance to geographers holds that people moving to a new place acquire an understanding of the layout of that place in a sequence of the three stages of landmark, route, and survey knowledge. Landmark knowledge is knowledge of the identity of landmarks, knowledge that is not intrinsically spatial. Route knowledge is knowledge of linear sequences of landmarks connected by travel patterns; routes are ordered but contain minimal metric scaling. Survey knowledge is knowledge of two-dimensional layout from which spatial relations among places can be determined even if direct travel between them has never occurred; such knowledge is usually thought to be especially useful for formulating shortcuts and other instances of creative navigation. More recent theories question the sequential nature of this progression or even whether such qualitatively distinct stages of knowledge representation exist.

Geographic knowledge is acquired directly during sensory and motor activity in the world and indirectly from symbolic representations (more below). Sensory systems represent the first response of the nervous system to stimulation from the world. Sensory receptors transduce world energy patterned over space and time into patterned nervous system energy. For humans, relevant forms of energy in the world include electromagnetic, chemical, physical pressure and vibration, gravity, and heat; nervous system energy is electrical and chemical. Different types of sensory receptors that respond to different types of world energy lead to qualitatively distinct sensory modalities, including vision, hearing, smell, taste, pressure, texture, temperature, kinesthesis (body limb position and movement), and vestibular sensation (gravity and acceleration). Clearly, humans have more than the five senses commonly believed to exist. All senses contribute to the apprehension of geographic properties, but for humans, vision is especially powerful for apprehending detailed and precise spatial and thematic information at a distance. Knowledge about the world is acquired via motor activity, also. Movements such as turning one's head or walking around a corner provide us with information about the environment. That is, we do not move only to get to new places but to learn about them. Geographers are interested in how different modes of locomotion, whether mechanically aided or not, alter our experience of place as we travel and the information we pick up.

Symbolic Sources of Geographic Information

Indirect symbolic sources of geographic information include static pictorial representations such as maps, photographs, and remotely sensed imagery; static object representations such as physical models; dynamic pictorial representations such as movies and animations; and linguistic representations, including spoken or written natural languages, gestural languages, and formal computational or mathematical languages. The dynamic and actively controlled, first-person computer-graphic representations known as virtual environments (virtual reality) are indirect symbolic sources of knowledge, strictly speaking, but fully immersive systems simulate direct sensory–motor experience in real environments with increasing effectiveness.

From a cognitive perspective, maps and other representations of geographic information serve the purpose of communicating information about space, place, and environment to people, or otherwise inducing ideas or thoughts. Much cognitive research focuses on understanding the power of geographic information displays to support understanding and creative thought, or to support misconceptions and misleading conclusions. Cognitive geographers, including cartographers, study how information is perceived from maps and other information displays, how it is interpreted and stored in memory, how it is used to reason and solve problems, and how it is used to guide behavior. Maps and other displays represent features and other information with graphic symbols. The visibility, legibility, and semantic interpretation of these symbols are important, as is the sheer amount of information possible to display effectively at one time. Some symbols are relatively iconic, resembling or at least suggesting graphically what they mean; using blue to represent water may be easy to interpret but may also suggest that most water bodies are a particular shade of blue when they are actually green, brown, or black. Other symbols are relatively abstract and may therefore require more training for their interpretation; representing elevation by means of contour lines is an example. Computer technologies offer the possibility of tailoring information displays to the cognitive characteristics of individual users; research must determine the best way to measure these variations and help evaluate how displays should be modified to take account of them.

Cognitive geographers and others conduct research on the characteristics of spatial and environmental information as communicated via natural language, both spoken and written. This research will help us improve human interaction with digital geographic information systems, including navigation systems, digital libraries, and information systems for tourists and those with disabilities. Spatial information is to be found in most grammatical classes of words; nearly all prepositions refer to spatiality or temporality. Spatiality expressed in prepositions and other elements of language is almost always relatively imprecise and nonmetric, not expressing quantitative distances and directions. Many spatial terms depend on various aspects of context for their interpretation; 'near the barn' and 'near Beijing' surely refer to rather different proximities.

Linguistic descriptions of spatial layout designed to aid navigation are called verbal route directions. Cognitive geographers are interested in describing how people construct route directions and how people interpret them. For example, it has been observed that, as in other cases of linguistic communication, a speaker will attempt to assess what a listener knows in order to judge what level of complexity the listener can likely comprehend. Cognitive geographers are also interested in characterizing how people should deliver route directions so as to communicate optimally about navigation. Should directions focus on landmarks, or should they include survey layout information? How important is it to provide corrective or overshoot statements?

See also: Affect; Artificial Intelligence and Expert Systems; Behavioral Geography; Children and Mapping; Choice Modeling; Color, Mapping; Embodied Knowing; Experimental Design; Fuzzy Set and Fuzzy Logic; Geovisualization; Golledge, R.; Haptic or Touch-Based Knowledge; Landscape Perception; Language and Research; Lowenthal, D.; Map Perception and Cognition; Memory; Mental Maps; Neural Networks; Semiotics; Sense of Place; Subjectivity; Transport and Accessibility.

Further Reading

Downs, R. M., Liben, L. S. and Daggs, D. G. (1988). On education and geographers: The role of cognitive-developmental theory in geographic education. *Annals of the Association of American Geographers* 78, 680–700.

Downs, R. M. and Stea, D. (1973). *Image and Environment*. Chicago, IL: Aldine Publishing.

Friedman, A. and Brown, N. R. (2000). Reasoning about geography. *Journal of Experimental Psychology: General* 129, 193–219.

Gärling, T. and Golledge, R. G. (eds.) (1993). *Behavior and Environment: Psychological and Geographical Approaches*. Amsterdam: North-Holland.

Golledge, R. G. (ed.) (1999). *Wayfinding Behavior: Cognitive Mapping and Other Spatial Processes*. Baltimore, MD: Johns Hopkins Press.

Gould, P. and White, R. (1986). *Mental Maps* (2nd edn.). Winchester, MA: Allen and Unwin.

Kitchin, R. and Blades, M. (2002). *The Cognition of Geographic Space*. London: IB Tauris Publishers.

Lloyd, R. (1997). *Spatial Cognition: Geographic Environments*. Dordrecht: Kluwer.

Lynch, K. (1960). *The Image of the City*. Cambridge, MA: MIT Press.

Mark, D. M., Freksa, C., Hirtle, S. C., Lloyd, R. and Tversky, B. (1999). Cognitive models of geographical space. *International Journal of Geographical Information Science* 13, 747–774.

Montello, D. R. (2002). Cognitive map-design research in the twentieth century: Theoretical and empirical approaches. *Cartography and Geographic Information Science* 29, 283–304.

Moore, G. T. and Golledge, R. G. (eds.) (1976). *Environmental Knowing*. Stroudsburg: Dowden, Hutchinson & Ross.

Portugali, J. (ed.) (1996). *The Construction of Cognitive Maps*. Dordrecht, The Netherlands: Kluwer Academic.

Tversky, B. (1992). Distortions in cognitive maps. *Geoforum* 23, 131–138.

Relevant Websites

http://cognitivesciencesociety.org/index.html
Cognitive Science Society
This professional society brings together researchers from many fields who hold the common goal of understanding the nature of the human mind.

http://www.edra.org/
EDRA–The Environmental Design Research Association
This professional society is the home for researchers from several disciplines, including geography, psychology, and architecture, who study human behavior and environmental design, including cognitive research on relationships between people and their environments.

http://epbg.blogspot.com/
Environmental Perception and Behavioral Geography, Specialty Group of the AAG.
This specialty group is the home for cognitive and behavioral researchers in the Association of American Geographers.

http://cognet.mit.edu/
MIT CogNet
This site provides access to ten major reference works on cognitive science and neuroscience, including the "The MIT Encyclopedia of the Cognitive Sciences," edited by Wilson and Keil.