Behavioral Geography

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Introduction

Behavioral geography is an approach to human geography that attempts to understand human activity in space, place, and environment by studying it at the disaggregate level of analysis—at the level of the individual person. Behavioral geographers analyze data on the behavior of individual people, recognizing that individuals vary from each other. A key tenet of behavioral geography holds that models of human activity and interaction can be improved by incorporating more realistic assumptions about human behavior. For example, behavioral geographers agree with other human geographers that distance (or related factors such as travel time or effort) is an important determinant of human activity, but they maintain that it is subjective rather than objective distance that is typically important. And because different people's beliefs about distances may vary considerably from one another and from objective distance, spatial activities will be more variable and less optimal than nonbehavioral models predict. Thus, the disaggregate study of human geography naturally led behavioral researchers to consider 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, people do what they do because of what they think is true. People evaluate decision alternatives 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 and are often mediated by symbolic representations such as maps and language. Behavioral geography further maintains that human-environment relations are dynamic and bidirectional: The actions and mental states of individuals cause, and are caused by, physical and social environments, within the context of ongoing and changing interactions. Because of these various interests and beliefs, behavioral geography has inherent interdisciplinary connections, particularly with various subfields of psychology, but also with other behavioral and cognitive disciplines, such as linguistics, anthropology, economics, and artificial intelligence, and environmental disciplines, such as planning, architecture, and urban studies. Given this fundamental interdisciplinarity, much of the literature cited here has been published not only within geography and cartography, but also within psychology, linguistics, computer science, and other fields.

General Overviews

More than some other fields of geography, the best overviews of behavioral geography may be found in edited books with chapters by different authors or sets of authors. This reflects the

relative newness of the subfield, its extremely multidisciplinary nature, and its wide relevance to so many disparate problem areas within geography and cartography. At the same time, it has attracted relatively few scholars (few departments specialize in it, for example). The most important and informative edited collections include Downs and Stea 1973 and Gärling and Golledge 1993. There are some valuable books authored by single sets of authors, including Golledge and Stimson 1997, the most authoritative general book on behavioral geography, with the most breadth of coverage; it is the much-expanded second edition of an earlier version by these two authors. Jakle, et al. 1985 is another relevant example. Walmsley and Lewis 1993 is better suited as a textbook for introductory courses. Finally, some journal articles are useful overviews of at least important parts of behavioral geography. Evans 1980, published in a prominent journal of psychology, is perhaps the best example of this.

- Downs, Roger M., and David Stea, eds. *Image and Environment: Cognitive Mapping and Spatial Behavior*. Chicago: Aldine, 1973.

  Save Citation »Export Citation »E-mail Citation »

  Edited collection that is not only very important historically to behavioral geography, but that contains several chapters that are among the most influential sources on their particular topics. Includes chapters by prominent geographers, psychologists, and others. Probably no other single reference in all of behavioral geography is more important.

  Find this resource:

- Evans, Gary W. "Environmental Cognition." *Psychological Bulletin* 88.2 (1980): 259–287.

  DOI: 10.1037/0033-2909.88.2.259Save Citation »Export Citation »E-mail Citation »

  Article from a top journal of research psychology that overviews a major part of behavioral geography—environmental cognition—from the multidisciplinary perspective of environmental psychology, the subfield of psychology most closely parallel to behavioral geography.

  Find this resource:

- Gärling, Tommy, and Reginald G. Golledge, eds. *Behavior and Environment: Psychological and Geographical Approaches*. Amsterdam: North-Holland, 1993.

  Save Citation »Export Citation »E-mail Citation »

  Edited collection of great value because it consists of review chapters covering much of the breadth of behavioral geography, written by top scholars. Uniquely contrasts the perspectives of geography and psychology on each major topic it covers.

  Find this resource:

- Golledge, Reginald G., and Robert J. Stimson. *Spatial Behavior: A Geographic Perspective*. New York: Guilford, 1997.

  Save Citation »Export Citation »E-mail Citation »

  Probably the broadest treatment of behavioral geography found in one source. Does one of the best jobs of connecting the behavioral approach to the general field of human geography. More appropriate for graduate courses than undergraduate.

  Find this resource:

- Jakle, John A., Stanley Brunn, and Curtis C. Roseman. *Human Spatial Behavior: A Social Geography*. Prospect Heights, IL: Waveland, 1985.

  Save Citation »Export Citation »E-mail Citation »

  An interesting early overview of scientific human geography that is essentially a balanced and broad presentation of behavioral concepts and idea. Covers mental, behavioral, social, and cultural use of space by individuals and groups.

  Find this resource:

- Walmsley, D. J., and G. J. Lewis. *People and Environment: Behavioural Approaches in Human Geography*. 2d ed. New York: Wiley, 1993.

  Save Citation »Export Citation »E-mail Citation »

  Rare example of something like an adequate undergraduate text in behavioral geography. Like Golledge and Stimson 1997, it provides a broad coverage that connects the behavioral approach to the rest of human geography, but more concisely and at a more basic level.

  Find this resource:

Historical Background

Early scholarship that links geography and cartography with psychology and other behavioral sciences may be found from as early as the turn of the 20th century, and influential literature appears sporadically throughout that century. Particular research problems within this literature have included spatial orientation and disorientation, geographic education, map design, human aspects of urban planning and landscape design, and models of spatial behavior and interaction, including travel, communication, and economic activity. An important presidential address at the annual meeting of the Association of American Geographers (AAG), published in Wright 1947, was an early and widely disseminated call to geographers to study the subjective. In Tolman 1948, a prominent behavioral psychologist argued for the need to understand behavior in rats and people in relation to mental representations of the world. This would come to greatly influence

geographers and other scholars of space and place. Robinson 1952 laid out the argument to consider maps as tools for communicating ideas and information to people; as such, Robinson argued, maps should be studied with the help of the psychological sciences of perception and cognition. Lynch 1960 made similar arguments for our understanding of the built environments of cities, as did Saarinen 1966 with respect to the study of human responses to natural hazards. Many of these strands coalesced during the 1960s, when behavioral geography became recognized as a distinct approach within human geography, especially with the appearance of Cox and Golledge 1969. Other central publications in the history of the field of behavioral geography include Gould and White 1974, with its emphasis on emotional responses to places, and Tuan 1974, which helped popularize an experiential approach to understanding subjective geography.

- Cox, Kevin R., and Reginald G. Golledge, eds. *Behavioral Problems in Geography: A Symposium*. Evanston, IL: Northwestern University, Department of Geography, 1969.

  Save Citation »Export Citation »E-mail Citation »

  This edited collection can be cited as the origin of the field of behavioral geography, at least by that name. Based on a landmark meeting of scholars from several disciplines, it is the earliest overview and introduction to the field.

  Find this resource:

- Gould, Peter, and Rodney White. *Mental maps*. Harmondsworth, UK: Penguin, 1974.

  DOI: 10.4324/9780203163757Save Citation »Export Citation »E-mail Citation »

  This work demonstrated to geographers that emotion can be studied scientifically. Its name is potentially confusing, as the book focuses on depicting place preferences in the form of exceptionally engaging isoline maps. It is not much concerned with broader issues of place cognition implied by the term "mental map," usually considered a synonym for cognitive map.

  Find this resource:

- Lynch, Kevin. *The Image of the City*. Cambridge, MA: MIT Press, 1960.

  Save Citation »Export Citation »E-mail Citation »

  From an urban planner. No reference work played a more important formative role in the systematic study of the mind-environment interrelation. Important for its concepts of urban "images" (really long-term mental representations) and urban legibility; also provided appealing visualizations of shared mental representations and introduced the method of sketch mapping.

  Find this resource:

- Robinson, Arthur H. *The Look of Maps: An Examination of Cartographic Design*. Madison: University of Wisconsin Press, 1952.

  Save Citation »Export Citation »E-mail Citation »

  Based on the author's dissertation, this work championed the idea of understanding maps as tools for human perception and cognition, not just repositories of objective and consensual geographic knowledge. It paved the way for decades of research on map psychology and stimulated several nonbehavioral approaches to understanding maps and mapping from subjective and contextual perspectives.

  Find this resource:

- Saarinen, Thomas F. *Perception of Drought Hazard on the Great Plains*. Chicago: University of Chicago, 1966.

  Save Citation »Export Citation »E-mail Citation »

  Short book directing researchers to the importance of subjective beliefs in determining how people respond to potential and actual environmental hazards. Builds on earlier groundbreaking work by geographers such as Gilbert White, who persuasively made the case that human activity plays a fundamental role in bringing about so-called natural hazards.

  Find this resource:

- Tolman, Edward C. "Cognitive Maps in Rats and Men." *Psychological Review* 55 (1948): 189–208.

  DOI: 10.1037/h0061626Save Citation »Export Citation »E-mail Citation »

  Influential psychological research positing that animal (including human) behavior is controlled not just by external stimuli but by mental representations of environments, which Tolman termed *cognitive maps*. His observations of rats shortcutting in mazes is still widely taken as key evidence for what is now called survey or configurational knowledge.

  Find this resource:

- Tuan, Yi-Fu. *Topophilia: A Study of Environmental Perception, Attitudes, and Values*. Englewood Cliffs, NJ: Prentice-Hall, 1974.

  Save Citation »Export Citation »E-mail Citation »

  Following John K. Wright, David Lowenthal, and others, this is essential writing on the importance of the experiential, emotional, and contextual in geography. Squarely within

the humanities tradition (particularly humanism and phenomenology), it has been widely read by scientific and humanities scholars alike. Tuan's books offer some of the best belletristic writing in geography.

Find this resource:

- Wright, John K. "Terrae Incognitae: The Place of Imagination in Geography." *Annals of the Association of American Geographers* 37 (1947): 1–15.

   Save Citation »Export Citation »E-mail Citation »

   Perhaps the earliest call from a prominent geographer for the merits of studying the subjective geographic beliefs of lay people as well as experts, whatever their objective validity. He called this *geosophy*. Based on Wright's 1946 presidential address at the annual meeting of the AAG.

   Find this resource:

Metatheory of Behavioral Geography

The 20th and 21st centuries have been characterized by extensive and repeated discussions about the nature of geography as an intellectual endeavor. What is its basic problem domain? What are appropriate geographic concepts and methods? How should geography position itself as a natural science, social science, or branch of humanities or the arts? What are the political implications of geography and how should geographers respond to them? Collectively, these concerns may be referred to as *metatheory*. Behavioral geography has participated in its share of these metatheoretical discussions, if not more than its share. As Golledge 1981 discusses, behavioral geography has typically adopted a scientific approach, which advocates systematic empirical methods and certain other assumptions such as realism that tend to distinguish it rather sharply from other seemingly related approaches that also advocate the study of the subjective in human geography. (Sack 1980 presents a fascinating philosophical discussion of the study of the subjective in geography.) Critical appraisals of behavioral geography have contrasted scientific approaches with those derived from the humanities, including philosophy, history, and literature. Some critics have advocated humanities approaches (e.g., Bunting and Guelke 1979, Tuan 1974) such as humanism, phenomenology, postmodernism, critical theory, and other specific approaches. Behavioral geographers have been criticized for treating humans too individualistically, overlooking the social and cultural context of human activity. Other critiques have focused on the mentalistic nature of much behavioral geography that seemingly leaves a person frozen in daydreams or pondering over alternatives. Such mentalism sometimes confuses cognition with consciousness, lacking nuance in conceptualizing the relationship of mind and behavior (Bunting and Guelke 1979). Like work in the tradition of the quantitative revolution in general within human geography, some behavioral work can be characterized as simplistically and somewhat mindlessly quantitative (e.g., Tuan 1974), too atheoretically empirical, and too intent on listing values of test statistics and probability levels. In part because of these critiques, behavioral geography has lost popularity within human geography since the 1980s (Argent and Walmsley 2009). Conversely, supporters of behavioral geographers have argued for the

plausibility and value of scientifically studying the subjective (see Argent and Walmsley 2009 and Golledge 1981). They have criticized some approaches to human geography for failing to appreciate rigor, or for misunderstanding the claims of behavioral geography. And they have questioned the appropriateness of scholars *qua* scholars mixing their search for understanding with a politicized advocacy of causes such as social justice.

- Argent, N. M., and D. J. Walmsley. "From the Inside Looking Out and the Outside Looking In: Whatever Happened to 'Behavioural Geography'?" *Geographical Research* 47.2 (2009): 192–203.

  DOI: 10.1111/j.1745-5871.2009.00571.xSave Citation »Export Citation »E-mail Citation »

  Recent overview of legacy and current status of behavioral geography. Defends its aims and achievements while observing its decline within mainstream human geography for some decades. Notes several valuable conceptual and methodological contributions of behavioral geography that enrich modern geography, even while much behavioral research has moved to interdisciplinary outlets.

  Find this resource:

- Bunting, Trudi E., and Leonard Guelke. "Behavioral and Perception Geography: A Critical Appraisal." *Annals of the Association of American Geographers* 69.3 (1979): 448–462.

  DOI: 10.1111/j.1467-8306.1979.tb01268.xSave Citation »Export Citation »E-mail Citation »

  Severe and trenchant criticism of behavioral geography. Doubts that perceptual and cognitive research is of much value in explaining actual human activity. Questions the validity with which mental states can be measured and quantified, and expounds on the relatively weak and complex relationship between mind and behavior.

  Find this resource:

- Golledge, Reginald G. "Misconceptions, Misinterpretations, and Misrepresentations of Behavioral Approaches in Human Geography." *Environment and Planning A* 13.11 (1981): 1325–1344.

  DOI: 10.1068/a131325Save Citation »Export Citation »E-mail Citation »

  Wide-ranging defense of behavioral approach by its most productive and vocal proponent. Deals mostly with some of the early criticisms of behavioral geography, such as its confusion with behaviorism in psychology.

  Find this resource:

- Sack, Robert David. *Conceptions of Space in Social Thought: A Geographic Perspective*. Minneapolis: University of Minnesota Press, 1980.

  Save Citation »Export Citation »E-mail Citation »

  Philosophical and conceptual overview of the study of the subjective in geography. Considers both the level of individual minds and that of collective cultural beliefs.

  Find this resource:

- Tuan, Yi-Fu. "Review of *Mental Maps* by Peter Gould and Rodney White." *Annals of the Association of American Geographers* 64.4 (1974): 589–591.

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  Erudite and concise critique of scientific behavioral geography, spurred by criticism of Gould and White 1974 (cited in Historical Background) on preference mapping. Expresses doubts about the value of quantitatively measuring human experience, emotion, and meaning in space and place, from a humanist perspective.

  Find this resource:

Spatial Behavior, Activity Spaces, and Time Geography

The original motivation of behavioral geography when it emerged as a distinct approach during the 1960s was to explain human activity in space and place at the disaggregate level of the individual person. While this led some behavioral geographers to the study of cognition, others continued to focus on measuring and analyzing individual spatial behavior and activity. These include both temporary travel, such as the journey to work, and the relatively permanent mobility involved in migrating to a new home. Hägerstrand 1970 presents several new and widely influential concepts to the study of spatial activity, particularly focusing geographers on the temporal aspects of activity and not just the spatial. Miller 1991 represents some of the best more modern work on time geography, particularly exploiting the tremendous potential of new technologies for automated geographic information collection and processing. Kwan 1999 focuses time geography on gender issues in geography; at the same time, the author furthers a reconciliation of qualitative and quantitative approaches within human geography. Torrens 2012 pushes the envelope to the cutting edge of integrating agent-based computational modeling with virtual-reality simulation in the context of complex and sophisticated modeling of human pedestrian activity in built environments.

- Hägerstrand, Torsten. "What about People in Regional Science?" *Papers in Regional Science* 24.2 (1970): 7–21.

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Groundbreaking work introducing space-time budgets and time geography. Discusses various types of constraints on the locations of spatial activities, dependent on the time available to travel particular distances, as a function of one's transportation mode, the need to collaborate with others, the need to return home at night, and so on.

Find this resource:

- Kwan, Mei-Po. "Gender and Individual Access to Urban Opportunities: A Study Using Space-Time Measures." *Professional Geographer* 51.2 (1999): 210–227.

  Save Citation »Export Citation »E-mail Citation »

Revises the concept of accessibility in light of space-time constraints, especially as experienced by women. Data from travel diaries are analyzed in a network-based geographic information system (GIS). Part of an extended research program combining time geography, GIS, qualitative methods, and gender issues.

Find this resource:

- Miller, Harvey J. "Modelling Accessibility Using Space-Time Prism Concepts within Geographical Information Systems." *International Journal of Geographical Information Systems* 5.3 (1991): 287–301.

  DOI: 10.1080/02693799108927856Save Citation »Export Citation »E-mail Citation »

Takes Hägerstrand's approach to time geography forward, given the explosion of data and data-processing available in the last couple of decades, particularly within a GIS framework.

Find this resource:

- Torrens, Paul M. "Moving Agent Pedestrians through Space and Time." *Annals of the Association of American Geographers* 102.1 (2012): 35–66.

  DOI: 10.1080/00045608.2011.595658Save Citation »Export Citation »E-mail Citation »

Very recent work demonstrating the potential of advanced agent-based simulation in human geography. Attempts to show the power of implementing the disaggregate approach of behavioral geography into a computational model. Argues that such models work better when based on more realistic formalizations of human locomotion and mind, as well as surrounding environments.

Find this resource:

Spatial Knowledge and Cognitive (Mental) Maps

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. Following the lead of Tolman 1948 (cited under Historical Background), but with even earlier precedents, behavioral geographers and other researchers in spatial cognition have studied spatial knowledge of the environment conceptualized as *cognitive maps*. Kitchin 1994 gives a broad overview of this concept and its applicability to geographical problems. McNamara 1992 presents an excellent overview of work on distortions in spatial knowledge and what they suggest about the form and processing of spatial knowledge. Lloyd 1994 promotes the application of prototype theory and neural networks from cognitive science to conceptualizing and measuring cognitive maps.

- Kitchin, Robert M. "Cognitive Maps: What Are They and Why Study Them?" *Journal of Environmental Psychology* 14.1 (1994): 1–19.

  DOI: 10.1016/S0272-4944(05)80194-XSave Citation »Export Citation »E-mail Citation »

  Overviews the concept of cognitive maps and their relationship to a variety of basic and applied research questions in geography and other disciplines.

  Find this resource:

- Lloyd, Robert. "Learning Spatial Prototypes." *Annals of the Association of American Geographers* 84.3 (1994): 418–440.

  DOI: 10.1111/j.1467-8306.1994.tb01868.xSave Citation »Export Citation »E-mail Citation »

  Follows prominent work in cognitive science by applying neural networks to understanding geographic spatial knowledge. These are computational models inspired by the nervous system. They invoke elemental computational units that change by very simple rules, but can nonetheless simulate complex cognition as emerging from the rich interconnections among simple units.

  Find this resource:

- McNamara, Timothy P. "Spatial Representation." *Geoforum* 23 (1992): 139–150.

  DOI: 10.1016/0016-7185(92)90012-SSave Citation »Export Citation »E-mail Citation »

  Concise review by a cognitive psychologist written for a geographic audience. Clearly describes most of the empirical phenomena to date that demonstrate properties of spatial beliefs and reasoning by lay people, as inferred by distorted judgments of distance, direction, and so on.

Find this resource:

Distances, Directions, and Regions

Some of the research on spatial knowledge by behavioral geographers and other behavioral scientists has concentrated on particular elements of knowledge rather than cognitive maps in general. Tversky 1981 demonstrates how the mental processing of spatial knowledge at different scales distorts judgments of directions in certain ways. Golledge 2002 presents an ambitious theory of "primitives" in all kinds of geographic spatial knowledge. Other references deal in detail with the regional organization of spatial knowledge. Regions are spatial categories—pieces of earth surface that capture aspects of similarity among the places within the regions. Cognitive regions are informal region concepts individuals or groups of people use to organize their understanding of the earth surface (culturally shared informal regions are known as *vernacular* regions). Aitken and Prosser 1990 presents interesting methodological approaches to studying neighborhoods as cognitive regions at urban scales. Friedman and Brown 2000 is the first in an ongoing line of studies that investigate the influence of cognitive regions at continental and national scales, particularly how this regional organization influences spatial judgments such as latitude and distance. Stevens and Coupe 1978 and Hirtle and Jonides 1985 extend the study of cognitive regionalization to considering how the hierarchical arrangement of cognitive regions influences the nature of spatial reasoning.

- Aitken, Stuart C., and Rudy Prosser. "Residents' Spatial Knowledge of Neighborhood Continuity and Form." *Geographical Analysis* 22.4 (1990): 301–325.

  DOI: 10.1111/j.1538-4632.1990.tb00213.xSave Citation »Export Citation »E-mail Citation »

  Methodologically innovative empirical study of residents' beliefs about what constitutes their neighborhoods, an important example of an informal cognitive region.

  Find this resource:

- Friedman, Alinda, and Norman R. Brown. "Reasoning about Geography." *Journal of Experimental Psychology: General* 129.2 (2000): 193–219.

  DOI: 10.1037/0096-3445.129.2.193Save Citation »Export Citation »E-mail Citation »

  Initiates major research program on spatial reasoning with cognitive regions at continental and national scales, based on estimated latitudes, longitudes, distances, and more. Shows spatial distortion due to regional reasoning is conceptual and not perceptual, contra Tversky 1981. The most extensive work on "psychological plate tectonics" (p. 218).

  Find this resource:

- Golledge, Reginald G. "The Nature of Geographic Knowledge." *Annals of the Association of American Geographers* 92.1 (2002): 1–14.

  DOI: [10.1111/1467-8306.00276](#)Save Citation »Export Citation »E-mail Citation »

  Based on Golledge's AAG presidential address, this article presents the theory of geographic knowledge in expert geographers and lay people. Golledge discusses spatial thinking in geography in the broadest sense, including thinking about location, distance, network, hierarchy, region, and more.

  Find this resource:

- Hirtle, Stephen C., and Jon Jonides. "Evidence of Hierarchies in Cognitive Maps." *Memory & Cognition* 13.3 (1985): 208–217.

  DOI: [10.3758/BF03197683](#)Save Citation »Export Citation »E-mail Citation »

  Demonstrates regional and hierarchical organization of spatial knowledge on a college campus. Novel use of landmark recall protocols to determine clusters (regions) of landmarks, based in part on functional or semantic associations, not just spatial proximity or regional boundaries. In turn, these clusters influence spatial (distance) judgments about landmarks.

  Find this resource:

- Stevens, Albert, and Patty Coupe. "Distortions in Judged Spatial Relations." *Cognitive Psychology* 10 (1978): 422–437.

  DOI: [10.1016/0010-0285(78)90006-3](#)Save Citation »Export Citation »E-mail Citation »

  Describes four much cited original studies positing hierarchical spatial reasoning as a basis for certain typical distortions in reasoning. Most famously, lay people often say San Diego is west of Reno when it is actually east, purportedly because California is considered to be west of Nevada.

  Find this resource:

- Tversky, Barbara. "Distortions in Memory for Maps." *Cognitive Psychology* 13.3 (1981): 407–433.

  DOI: [10.1016/0010-0285(81)90016-5](#)Save Citation »Export Citation »E-mail Citation »

  Excellent early empirical demonstrations of distortions in spatial recall for features at different scales from local environments, and from cartographic maps, both real and fictional. Phenomena such as alignment in recalling continents and rectilinear distortion

in recalling street directions result from simplifying heuristics in spatial learning and reasoning.

Find this resource:

Learning Environments Directly

At the environmental scale, such as the scale of home territories (whether rural or urban), people have traditionally acquired knowledge of the spatial properties of particular places by direct sensorimotor experience traveling around them. That is, they learn from visually and proprioceptively apprehending the environment around them while standing, walking, biking, driving, sailing, and so on. This knowledge varies in its completeness, accuracy, geometric sophistication, and so on. At a minimum, it may consist of minimally spatial memory traces of the appearance of distinctive features, or "landmarks." More spatially, it may consist of linear sequences of connected features along routes, perhaps with very imprecise quantitative scaling of distances and directions. At its most sophisticated, people may acquire detailed and metrically rich understandings of the two-dimensional layout of the environment. Siegel and White 1975 presents a very influential psychological theory of the cognitive changes that occur over time as one learns a new place, such as a previously unvisited city, a process called spatial *microgenesis*. Couclelis, et al. 1987 provides a different theory of spatial microgenesis, more from the perspective of geography than psychology. Thorndyke and Hayes-Roth 1982 provides a process model of spatial learning and estimation within a large building that specifically contrasts directly experienced environments with those learned from cartographic maps. Kuipers 2000 presents the most detailed theoretical framework available for spatial learning and cognitive-map formation from the perspective of artificial intelligence and robotics. Ishikawa and Montello 2006 empirically investigates theories of directly acquired knowledge, pitting Siegel and White's framework (see Siegel and White 1975) against a more continuous and quantitative alternative theory.

- Couclelis, Helen, Reginald G. Golledge, Nathan Gale, and Waldo Tobler. "Exploring the Anchor-Point Hypothesis of Spatial Cognition." *Journal of Environmental Psychology* 7.2 (1987): 99–122.

  DOI: 10.1016/S0272-4944(87)80020-8Save Citation »Export Citation »E-mail Citation »

  Presents an influential conceptual model of spatial microgenesis, or learning the spatial properties of unfamiliar environments. Initially, key locations ("anchor points") such as one's home serve as points of organization around which new spatial knowledge is referenced. Separate regions acquired this way may eventually be mutually organized over time.

  Find this resource:

- Ishikawa, Toru, and Daniel R. Montello. "Spatial Knowledge Acquisition from Direct Experience in the Environment: Individual Differences in the Development of Metric

Knowledge and the Integration of Separately Learned Places." *Cognitive Psychology* 52 (2006): 93–129.

DOI: 10.1016/j.cogpsych.2005.08.003Save Citation »Export Citation »E-mail Citation »

Longitudinal study of spatial learning after repeated automobile trips through a novel, complex neighborhood. The pattern of spatial knowledge acquisition fits neither the stage-like progression of the "dominant" theory (from Siegel and White 1975) nor the "alternative" continuous theory well, but instead shows strong differences among individuals according to their sense-of-direction (see also Individual, Sex, and Cultural Differences).

Find this resource:

- Kuipers, Benjamin. "The Spatial Semantic Hierarchy." *Artificial Intelligence* 119 (2000): 191–233.

  DOI: 10.1016/S0004-3702(00)00017-5Save Citation »Export Citation »E-mail Citation »

  The most nuanced and developed computational theory of spatial learning of environments in the context of navigation, distinguishing the separate acquisition of various types of topological and metric knowledge. By an artificial-intelligence researcher well versed in behavioral science.

  Find this resource:

- Siegel, Alexander W., and Sheldon H. White. "The Development of Spatial Representations of Large-Scale Environments." In *Advances in Child Development and Behavior*. Vol. 10. Edited by Hayne W. Reese, 9–55. New York: Academic Press, 1975.

  Save Citation »Export Citation »E-mail Citation »

  An exceptionally influential conceptual model of spatial microgenesis. Posits three stages of increasingly sophisticated spatial knowledge structures acquired over time from direct sensorimotor experience during locomotion: landmark, route, and survey or configurational knowledge. So widely accepted through the 1990s, it was dubbed the "dominant" theory (see Ishikawa and Montello 2006).

  Find this resource:

- Thorndyke, Perry W., and Barbara Hayes-Roth. "Differences in Spatial Knowledge Acquired from Maps and Navigation." *Cognitive Psychology* 14.4 (1982): 560–589.

  DOI: 10.1016/0010-0285(82)90019-6Save Citation »Export Citation »E-mail Citation »

Analysis and empirical confirmation of detailed conceptual models of differences in cognitive structures and processes involved in estimating directions and distances, both straight-line and route, based on spatial knowledge learned either directly from walking through a large public building or from studying cartographic map of the building.

Find this resource:

Navigation and Wayfinding

Navigation is coordinated movement of oneself through the environment in order to reach a destination, according to Golledge 1999. It may be conceptualized as consisting of locomotion and wayfinding (Montello 2005). Locomotion is the component of navigation coordinated to the immediate surrounds, allowing people to avoid barriers, walk toward visible beacons, and related tasks. Wayfinding is the component of navigation coordinated to distant features, out of sensory access, allowing people to plan routes, orient to nonperceptible destinations, and related tasks. Both nonconscious information processing, such as feature recognition, and conscious information processing, such as strategic thinking (discussed in Cornell, et al. 1992), play a role in navigation. In many situations, navigation is aided by cartographic maps and other information displays, as discussed in Levine 1982 and Streeter, et al. 1985. (Research focusing on verbal navigational instructions or "route directions" is cited under Spatial/Geographic Language.) In many situations, navigation is a social activity, including the involvement of navigational tools developed over time by cultural accumulation; Hutchins 1995 presents a fascinating discussion of this phenonemon.

- Cornell, Edward H., C. Donald Heth, and Wanda L. Rowat. "Wayfinding by Children and Adults: Response to Instructions to Use Look-Back and Retrace Strategies." *Developmental Psychology* 28.2 (1992): 328–336.

  DOI: 10.1037/0012-1649.28.2.328Save Citation »Export Citation »E-mail Citation »

  Demonstrates the effectiveness of explicitly trained strategies, particularly the look-back strategy, in helping both older children and young adults maintain orientation during a walk through a college campus. Exemplary empirical research combining empirical control with ecological realism.

  Find this resource:

- Golledge, Reginald G., ed. *Wayfinding Behavior: Cognitive Mapping and Other Spatial Processes*. Baltimore: Johns Hopkins University Press, 1999.

  Save Citation »Export Citation »E-mail Citation »

  Authoritative chapters written by geographers, psychologists, biologists, and computer scientists. Sections cover cognitive maps and wayfinding, perceptual and cognitive processing of environmental information, wayfinding and cognitive maps in nonhumans, and the neural and computational bases of wayfinding and cognitive mapping.

Find this resource:

- Hutchins, Edwin. *Cognition in the Wild*. Cambridge, MA: MIT Press, 1995.

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  Novel and influential analysis of human navigation as a socially and culturally situated activity. Extensively analyzes both the nontechnological marine navigation system of traditional Micronesian navigators and the technologically aided marine navigation on US Navy ships.

  Find this resource:

- Levine, Marvin. "You-Are-Here Maps: Psychological Considerations." *Environment and Behavior* 14.2 (1982): 221–237.

  DOI: 10.1177/0013916584142006Save Citation »Export Citation »E-mail Citation »

  Aligned you-are-here maps depict the forward-facing direction of map viewers as up on the map; other map orientations are misaligned. Empirical studies explore the *alignment effect*, the robust phenomenon in which some combination of extra time, error, or subjective difficulty in wayfinding occurs when most people interpret misaligned you-are-here maps.

  Find this resource:

- Montello, Daniel R. "Navigation." In *The Cambridge Handbook of Visuospatial Thinking*. Edited by Priti Shah and Akira Miyake, 257–294. Cambridge, UK: Cambridge University Press, 2005.

  DOI: 10.1017/CBO9780511610448Save Citation »Export Citation »E-mail Citation »

  Overviews mental and behavioral terms and concepts of human navigation as everyday activity of lay people. Distinguishes wayfinding and locomotion as key components of navigation, whether technologically aided or not. Analyzes processes of orientation and disorientation. Considers the role of maps and the layout of physical environments.

  Find this resource:

- Streeter, Lynn A., Diane Vitello, and Susan A. Wonsiewicz. "How to Tell People Where to Go: Comparing Navigational Aids." *International Journal of Man/Machine Studies* 22 (1985): 549–562.

  DOI: 10.1016/S0020-7373(85)80017-1Save Citation »Export Citation »E-mail Citation »

Early empirical study in naturalistic setting, comparing maps and verbal directions as technologies for navigation assistance (see also Human-Computer Interface/Geovisualization).

Find this resource:

Using and Comprehending Maps and Imagery

As discussed in the Introduction, an interest in cartographic map perception and cognition has long been part of the field of behavioral geography, specifically part of the research tradition of cognitive aspects of cartographic communication (details of the communication model for cartography are laid out in Board 1981). Maps are systems of signs and symbols whose interpretation depends in part on a person's prior knowledge and learning experience. MacEachren 1995 provides a comprehensive review of the concepts and findings of research concerning the cognition of cartographic displays. Petchenik 1983 provides an important critique of this approach to cartographic design, although some of Petchenik's most important points have become moot with revisions to the traditional communication paradigm (revisions that her chapter helped to motivate). Hoffman and Markman 2001 looks at cognitive aspects of interpreting imagery from remote sensing.

- Board, Christopher. "Cartographic Communication." *Cartographica* 18.2 (1981): 42–78.

  DOI: 10.3138/8R07-2125-L843-0767Save Citation »Export Citation »E-mail Citation »

  Exposition of the influential communication model in cartography, which argues that maps work by encoding the cartographer's intended meaning into map symbols that are decoded more or less successfully by the map reader to extract the cartographer's message.

  Find this resource:

- Hoffman, Robert R., and Arthur B. Markman, eds. *Interpreting Remote Sensing Imagery: Human Factors*. Boca Raton, FL: Lewis, 2001.

  DOI: 10.1201/9781420032819Save Citation »Export Citation »E-mail Citation »

  Edited collection of research by perceptual, cognitive, and human-factors psychologists on the interpretation of remotely sensed images from optical and satellite remote sensing.

  Find this resource:

- MacEachren, Alan M. *How Maps Work: Representation, Visualization, and Design*. New York: Guilford, 1995.

  Save Citation »Export Citation »E-mail Citation »

Combines comprehensive summary of experimental perceptual and cognitive research on map design and interpretation with philosophical analyses based on map semiotics. Shows that the influential communication model in cartography is misleading because it does not capture the flexible and nondeterministic ways maps actually function cognitively. This is the best single source on cognitive map research.

Find this resource:

- Petchenik, Barbara Bartz. "A Mapmaker's Perspective on Map Design Research 1950–1980." In *Graphic Communication and Design in Contemporary Cartography*. Edited by D. R. Fraser Taylor, 37–68. Progress in Contemporary Cartography 2. Chichester, UK: Wiley, 1983.

  [Save Citation »](#)[Export Citation »](#)[E-mail Citation »](#)

  Tour-de-force critique of cognitive map-design research from a student and colleague of Arthur Robinson. Contrasts analytic goals of scientific research with synthetic goals of mapmakers. Questions the ability of research to accommodate the idiosyncratic nature of map users, map tasks, map designs. Important in its recognition of the limits of the communication model in cartographic research.

  Find this resource:

Spatial/Geographic Language

Besides maps and other forms of imagery, geographic knowledge is also expressed verbally, in the form of written and spoken natural languages, such as English or Chinese. Much of this work examines how spatial, temporal, and thematic knowledge is expressed in different languages, including [Mark, et al. 2011](#) and [Mark 1993](#) (cited under [Geo-ontologies](#)), which inevitably leads one to confront a variety of long-standing philosophical and scientific questions about the relationship of language and thought. Most work on language and geography is concerned with the way spatiality is expressed in language, as seen in [Bloom, et al. 1996](#) and [Mark and Frank 1991](#) (the latter cited under [Behavioral and Cognitive Aspects of Geographic Information Science](#)). Spatiality can be expressed in nearly all grammatical classes, but prepositions in particular mostly convey spatial information. Researchers are also interested in the precision and geometric sophistication of spatiality expressed in language, and the context-dependent nature of many spatial expressions, including deictic expressions such as "here" and "there," discussed by [Klein 1982](#), and terms concerning size or distance ("near," "small"). Spatiality is conveyed in a variety of linguistic forms, including narratives (such as in stories) and verbal signage (see [Passini 1992](#), cited under [Behavior and Cognition in Built Environments](#)). The most common application area for the study of language in geography involves verbal route directions, addressed by [Allen 1997](#) and [Denis, et al. 2007](#).

- Allen, Gary L. "From Knowledge to Words to Wayfinding: Issues in the Production and Comprehension of Route Directions." In *Spatial Information Theory: A Theoretical Basis for GIS; International Conference COSIT '97, Laurel Highlands, Pennsylvania, October*

15–18, 1997. Edited by Stephen C. Hirtle and Andrew U. Frank, 363–372. Lecture Notes in Computer Science 1329. Berlin: Springer, 1997.

Illuminating exposition of behavioral, cognitive, and social interactional issues surrounding one of the most important application areas for the study of language in geography—producing and comprehending navigational route directions.

Find this resource:

- Bloom, Paul, Mary A. Peterson, Lynn Nadel, and Merrill F. Garrett, eds. *Language and Space*. Cambridge, MA: MIT Press, 1996.

Large collection of chapters by several top language researchers from linguistics, psychology, anthropology, and cognitive science. Covers a broad array of topics concerning language and spatiality at several different scales.

Find this resource:

- Denis, Michel, Pierre-Emmanuel Michon, and Ariane Tom. "Assisting Pedestrian Wayfinding in Urban Settings: Why References to Landmarks Are Crucial in Direction-Giving." In *Applied Spatial Cognition: From Research to Cognitive Technology*. Edited by Gary L. Allen, 25–51. Mahwah, NJ: Lawrence Erlbaum, 2007.

Nice summary of an extended research program on the psychology of producing and comprehending route directions, focusing particularly on evidence for the claim that referring to landmarks when providing route directions is very beneficial, even essential.

Find this resource:

- Klein, Wolfgang. "Local Deixis in Route Directions." In *Speech, Place, and Action: Studies in Deixis and Related Topics*. Edited by Robert J. Jarvella and Wolfgang Klein, 161–182. Chichester, UK, and New York: Wiley, 1982.

Organized and thorough exposition of the structure of direction-giving episodes, for both those giving and those receiving route directions. Analyzes deictic references in route directions, linguistic expressions requiring some kind of extra-linguistic context for their interpretation. An example is the spatial context provided by places imagined when routes are orally described.

Find this resource:

- Mark, David M., Andrew G. Turk, Niclas Burenhalt, and David Stea, eds. *Landscape in Language: Transdisciplinary Perspectives*. Amsterdam: John Benjamins, 2011.

  Save Citation »Export Citation »E-mail Citation »

  Chapters by geographers, anthropologists, linguists, and others summarizing research on how speakers of different languages, especially languages of preindustrial and indigenous societies, refer to landscape features, including geomorphological, water, and other features. Emphasizes the variety of linguistic references and their potential relation to conceptual variation across languages.

  Find this resource:

Environmental Attitudes and Decision Making

Behavioral geographers are interested in emotional as well as cognitive and behavioral responses to environments, including both spatial and thematic properties. Cognition and behavior are functionally and experientially intertwined with affect and motivation. Our beliefs and knowledge influence, and are influenced by, what we feel and what we do. When looking at human-environment relations from a behavioral perspective, emotional responses (affect, mood) are considered essential. Examples include aesthetic (beauty, preference) and dysphoric (stress, anxiety) responses to environments and environmental events. A simple analysis identifies two main structural elements of emotional states: hedonic tone (evaluation) and arousal (activity level). A third dimension of potency (control) is sometimes included. For example, happiness and sadness express positive and negative hedonic tone, respectively; anger and sadness express high and low arousal, respectively; anger and fear express high and low potency, respectively. A key concept in this area of study is *attitude*, which is a belief about something coupled with an affective evaluation of the implication of this belief. For instance, one might have an attitude about oil (petroleum) involving belief that burning it as fuel contributes to climate change, and a feeling of worry about this state of affairs. Besides being interesting in and of themselves, emotions and attitudes about environments are thought to have important implications for predicting and explaining many important human behaviors and experiences, such as migration (residential relocation), tourism, shopping, job satisfaction, health, and more.

Environmental Aesthetics and Preference

As discussed in Hartig and Evans 1993 and Kaplan 1992, psychologists and others began to study aesthetics scientifically in the 1950s, focusing on formal properties of visual stimulus properties such as complexity, mystery, novelty, and coherence (so-called *collative properties*); later, these approaches were applied to environmental scenes. Other approaches focused more on the content of environmental scenes rather than just formal visual properties, and tended to interpret the role of content in terms of human biological evolution. That is, it was claimed that preferences for particular environments have evolved to reflect the functional significance of environmental properties for tasks such as hunting and gathering, wayfinding, locating mates,

and avoiding predators. These considerations have been applied to explaining patterns of environmental preference seen universally (across cultures), even when assessed with ratings of photographs, as discussed by Daniel 1990. Some of these widely observed patterns include preference for natural over built environments and scenes with water over scenes without it. The "savannah hypothesis" proposes that tropical savannah landscapes, with trees shaped in particular ways and distributed among partially open grassy areas, are maximally preferred across cultural groups, especially by children. Another important theory is Jay Appleton's "prospect-refuge theory," which attributes aesthetic responses to environments as resulting from the way their layout and form facilitate seeing surrounding areas without oneself being visible. Savannah landscapes generally have good prospect and refuge, in fact.

- Daniel, Terry C. "Measuring the Quality of the Natural Environment." *American Psychologist* 45.5 (1990): 633–637.

  DOI: 10.1037/0003-066X.45.5.633Save Citation »Export Citation »E-mail Citation »

  Overview of methods for systematically assessing aesthetic and other affective responses to natural environments. Traditional psychometric approaches (author calls them "psychophysical") as well as newer alternatives are reviewed. Makes a strong case for the importance of measuring aesthetic responses as part of a valid and complete valuation of natural environments for policymaking.

  Find this resource:

- Hartig, Terry, and Gary W. Evans. "Psychological Foundations of Nature Experience." In *Behavior and Environment: Psychological and Geographical Approaches*. Edited by Tommy Gärling and Reginald G. Golledge, 427–457. Amsterdam: North-Holland, 1993.

  Save Citation »Export Citation »E-mail Citation »

  Excellent review chapter covering basic definitional issues of natural versus built (cultural) environments, the role of nature in informational and affective responses to nature, and the potential benefits of nature experiences of various kinds, such as Outward Bound and viewing landscape paintings from a hospital bed.

  Find this resource:

- Kaplan, Stephen. "Environmental Preference in a Knowledge-Seeking, Knowledge-Using Organism." In *The Adapted Mind: Evolutionary Psychology and the Generation of Culture*. Edited by Jerome H. Barkow, Leda Cosmides, and John Tooby, 581–598. New York: Oxford University Press, 1992.

  Save Citation »Export Citation »E-mail Citation »

  Another excellent review of environmental preference and aesthetics that focuses on affective and information-processing approaches in the light of human biological

evolution. Among other issues, Kaplan carefully reviews the informational model of environmental preference by himself and Rachel Kaplan.

Find this resource:

Behavior and Cognition in Built Environments

Geographers are interested in built (cultural, anthropogenic) as well as natural environments, whether they be cities, agricultural fields, factories, or college campuses. Modern research even includes the geography of indoor places in its purview, overlapping with architecture. Cognitive and behavioral responses to built and natural environments depend partially on the same physical characteristics of the environment, as presented by Weisman 1981, even though there are some typical differences between the way people respond in the two classes of environments, as discussed in Hartig and Evans 1993 (cited under Environmental Aesthetics and Preference). Physical characteristics of environments include their ambient lighting, the appearance of their surfaces (textures, colors, surface reflectivity), the spatial structure of their path networks (considered in Hillier and Hanson 1984), the patterns of occluding structures and consequent open areas (discussed in Benedikt and Burnham 1985), their temperature and humidity, the ruggedness and ground support of their terrain, their flora and fauna, and so on. Variables such as these influence not only aesthetic judgments, but also feelings of privacy, fear, and the ease of orienting within them, as suggested by Passini 1992.

- Benedikt, Michael, and Clarke A. Burnham. "Perceiving Architectural Space: From Optic Arrays to Isovists." In *Persistence and Change: Proceedings of the First International Conference on Event Perception*. Edited by William H. Warren and Robert E. Shaw, 103–114. Hillsdale, NJ: Lawrence Erlbaum, 1985.

  Save Citation »Export Citation »E-mail Citation »

  Presents the powerful idea that many cognitive and behavioral responses, in both indoor and outdoor environments, are influenced by the size and shape of open areas or *isovists*, spatial extents available to direct visual access or lines of sight from a given point. Introduced by planners and architects, this idea is essentially the same as viewshed analysis in geography.

  Find this resource:

- Hillier, Bill, and Julienne Hanson. *The Social Logic of Space*. Cambridge, UK: Cambridge University Press, 1984.

  DOI: 10.1017/CBO9780511597237Save Citation »Export Citation »E-mail Citation »

  Introduced the behavioral theory of development of organic (unplanned) urban spaces. Also proposed the very rich and far-reaching analytic approach known as *space syntax* for analyzing topological patterns of paths, hallways, streets, and so on, with implications for pedestrian behavior, cognitive mapping, public sociality, and much more.

Find this resource:

- Passini, Romedi. *Wayfinding in Architecture*. 2d ed. New York: Van Nostrand Reinhold, 1992.

  Architectural analysis of factors of physical environments, particularly built spaces, that influence wayfinding within the spaces. Especially strong analysis of role of signage. Applied focus on improving orientation in built spaces.

  Find this resource:

- Weisman, Jerry. "Evaluating Architectural Legibility: Way-Finding in the Built Environment." *Environment and Behavior* 13.2 (1981): 189–204.

  DOI:

  Influential typology of four physical characteristics of built environments (that largely apply to natural environments) that are very useful for understanding how physical characteristics affect behavioral and cognitive responses in those environments, especially ease of orientation. Factors are differentiation of appearance, visual access, complexity of layout, and signage systems.

  Find this resource:

Environmental Risks and Hazards

People also respond dysphorically to environments and environmental events—they see them as unattractive or they feel fear, anxiety, or even dread about them. A major component of this is behavioral and cognitive work on natural, social, and technological hazards. (Geographers have traditionally referred to hazard or risk "perception" rather than cognition). Much of the behavioral work has focused on decision-making heuristics, simplified rules-of-thumb for assessing probabilities in complex situations, as seen in Slovic 1993 and Breakwell 2007. One important issue has been a comparison of intuitive judgments about the occurrence and consequences of hazard events with the expert judgments of the formal discipline of risk assessment, which attempts objectively to identify, characterize, and quantify risk from hazard events (Slovic 1993, Breakwell 2007). Also important are social implications of hazards, including the way societal and media responses to the possibility of hazards dampens or amplifies perceived risks, beyond what an objective assessment would predict (Slovic 1993, Breakwell 2007). Research on environmental risks and hazards includes not only work on relatively discrete "events," but also on potentially hazardous conditions or states, especially behavioral and cognitive aspects of environmental change, such as pollution, deforestation, and climate change, represented here by Dunlap, et al. 2000, Nickerson 2003, and Stern 2000.

- Breakwell, Glynis M. *The Psychology of Risk*. Cambridge, UK: Cambridge University Press, 2007.

  DOI: [10.1017/CBO9780511819315](#)Save Citation »Export Citation »E-mail Citation »

  Broad and up-to-date overview of behavioral and cognitive study of risk, particularly related to environmental events and conditions. Covers cognitive, affective, social, technological, and economic aspects.

  Find this resource:

- Dunlap, Riley E., Kent D. van Liere, Angela G. Mertig, and Robert Emmet Jones. "Measuring Endorsement of the New Ecological Paradigm: A Revised NEP Scale." *Journal of Social Issues* 56.3 (2000): 425–442.

  DOI: [10.1111/0022-4537.00176](#)Save Citation »Export Citation »E-mail Citation »

  Revised version of the most widely used survey instrument for assessing pro- and anti-environmental attitudes and values. The internally consistent and validated scale consists of fifteen self-report items, such as "Humans were meant to rule over the rest of nature" and "The balance of nature is very delicate and easily upset."

  Find this resource:

- Nickerson, Raymond S. *Psychology and Environmental Change*. Mahwah, NJ: Lawrence Erlbaum, 2003.

  [Save Citation »Export Citation »E-mail Citation »](#)

  Explores attitude assessment, attitude change, and the relationship between attitudes and behaviors in the context of environmentally relevant behaviors such as resource use, consumer behavior, support for policy, and voting. Explores the potential for behavioral research to contribute to ameliorating problems arising from environmental change.

  Find this resource:

- Slovic, Paul. "Perceptions of Environmental Hazards: Psychological Perspectives." In *Behavior and Environment: Psychological and Geographical Approaches*. Edited by Tommy Gärling and Reginald G. Golledge, 223–248. Amsterdam: North-Holland, 1993.

  [Save Citation »Export Citation »E-mail Citation »](#)

  Reviews research on psychometric paradigm for understanding hazard perception by lay people. Extended discussion of social amplification of risk and stigmatization that can result, presenting author's research on Yucca Mountain nuclear waste repository site in

Nevada (no longer being considered for this, after millions of dollars and decades of research).

Find this resource:

- Stern, Paul C. "Toward a Coherent Theory of Environmentally Significant Behavior." *Journal of Social Issues* 56.3 (2000): 407–424.

  DOI: [10.1111/0022-4537.00175](#)Save Citation »Export Citation »E-mail Citation »

  Develops conceptual framework for understanding environmentally significant behaviors such as consumer choice, resource use, and voting. Focuses on theories involving attitudes, values, and norms, and includes recommendations for the design of programs to promote pro-environmental behavior.

  Find this resource:

Behavioral and Cognitive Aspects of Geographic Information Science

Geographic information science (GIScience) is the interdisciplinary study of research issues surrounding geographic information and the computational systems for storing, processing, analyzing, and displaying it. Behavioral and cognitive aspects of GIScience concern human knowledge and knowing involving geographic information and geographic information systems (GIS). It is practically motivated by the desire to improve the usability, efficiency, equity, and profitability of geographic information and GIS. [Mark and Frank 1991](#) is one of the earliest collections of research papers that explicitly identifies itself as being concerned with cognitive aspects of GIS. [Peuquet 2002](#) provides the broadest overview of research in this area and ties it to noncognitive aspects of GIScience, such as database issues. [Montello and Freundschuh 2005](#) provides a comprehensive and detailed discussion of cognitive research issues in GIScience, including a discussion of behavioral methodological approaches for addressing various research questions. [Raubal 2009](#) presents an up-to-date overview of behavioral issues for GIS, particularly informed by an engineering sensibility.

- Mark, David M., and Andrew U. Frank, eds. *Cognitive and Linguistic Aspects of Geographic Space*. Dordrecht, The Netherlands: Kluwer Academic, 1991.

  DOI: [10.1007/978-94-011-2606-9](#)Save Citation »Export Citation »E-mail Citation »

  Original discussions of cognition, language, and behavior explicitly within the context of GIS. From a NATO workshop at Las Navas, Spain, the first major meeting on these topics within the GIS community. Now recognized as a progenitor of the research domain on cognitive issues in GIScience and the Conference on Spatial Information Theory (COSIT) series.

Find this resource:

- Montello, Daniel R., and Scott M. Freundschuh. "Cognition of Geographic Information." In *A Research Agenda for Geographic Information Science*. Edited by Robert B. McMaster and E. Lynn Usery, 61–91. Boca Raton, FL: CRC Press, 2005.

  Save Citation »Export Citation »E-mail Citation »

  Comprehensive overview of theoretical and empirical issues of cognition and behavior involving GIS in a broad sense. From a strong perspective of basic behavioral and cognitive science, with pointers to relevant applied issues.

  Find this resource:

- Peuquet, Donna J. *Representations of Space and Time*. New York: Guilford, 2002.

  Save Citation »Export Citation »E-mail Citation »

  The most comprehensive review integrating cognitive, philosophical, computational, and database issues in GIScience.

  Find this resource:

- Raubal, Martin. "Cognitive Engineering for Geographic Information Science." *Geography Compass* 3.3 (2009): 1087–1104.

  DOI: 10.1111/j.1749-8198.2009.00224.xSave Citation »Export Citation »E-mail Citation »

  Recent overview of cognitive engineering research applied to improving technologies and tools that incorporate geographic information, especially location-based systems and services. Cognitive engineering is a human factors (ergonomics) approach emphasizing analysis of cognitive processes—such as perception, memory, and reasoning—involved in using systems and technologies.

  Find this resource:

Human-Computer Interface/Geovisualization

The section Using and Comprehending Maps and Imagery contains references on the long tradition of research on map perception and cognition. Within this tradition, a separate and important strand of research on human-computer interfaces and geographic information visualization (*geovisualization*) arose as a major part of the study of behavioral and cognitive aspects of GIScience. This strand of research represents the application of cognitive research within GIScience that is most likely to help improve the usability and accessibility of GIS. It is concerned with the human factors of GIS computer interfaces beyond traditional maps and other

imagery, expanding research efforts to displays that are not just static, two-dimensional, passively displayed graphical maps, but also including displays that are interactive, dynamic, multisensory (notwithstanding the term *visualization*), spatially three-dimensional, and more. Nyerges, et al. 1995 provides an early treatment of research issues on the human factors of GIS interfaces. Slocum, et al. 2001 presents overview research questions for cognitive research on geographic interfaces and geo-visualization. Hirtle 2011 provides a recent summary of these issues that is particularly well informed by spatial cognition research findings. Other literature focuses specifically on especially important visualization topics. MacEachren, et al. 2005 addresses questions surrounding the depiction of data quality and other forms of data uncertainty, including vagueness. Skupin and Fabrikant 2003 reviews technical and behavioral aspects of information *spatializations*, spatial displays such as landscapes used to metaphorically represent the semantic content of large databases of nonspatial content, such as web pages or news stories.

- Hirtle, Stephen C. *Geographical Design: Spatial Cognition and Geographical Information Science*. San Rafael, CA: Morgan & Claypool, 2011.

  Save Citation »Export Citation »E-mail Citation »

  Thorough and up-to-date review of research on behavioral and cognitive issues in GIS design. Best available overview of relevance of spatial cognition for geographic information technologies, and vice versa.

  Find this resource:

- MacEachren, Alan M., Anthony Robinson, Susan Hopper, et al. "Visualizing Geospatial Information Uncertainty: What We Know and What We Need to Know." *Cartography and Geographic Information Science* 32.3 (2005): 139–160.

  DOI: 10.1559/1523040054738936Save Citation »Export Citation »E-mail Citation »

  State-of-the-art overview of important topic of uncertainty in geographic information, incorporating issues of error, data quality, conceptual vagueness, temporal vagueness, and related concepts. Examines uncertainty conceptualization, decision making, computational representation, and visual representation. Considers user issues and studies.

  Find this resource:

- Nyerges, Timothy L., David M. Mark, Robert Laurini, and Max J. Egenhofer, eds. *Cognitive Aspects of Human-Computer Interaction for Geographic Information Systems*. Proceedings of the NATO Advanced Research Workshop on Cognitive Aspects of Human-Computer Interaction for Geographic Information Systems, Palma de Mallorca, Spain, 20–25 March 1994. Dordrecht, The Netherlands: Kluwer Academic, 1995.

  DOI: 10.1007/978-94-011-0103-5Save Citation »Export Citation »E-mail Citation »

Early comprehensive treatment of research issues in applying cognitive human factors to GIS design. Issues include spatial cognition, user behavior, user interfaces, cross-cultural variation, collaborative GIS, and task analysis.

Find this resource:

- Skupin, André, and Sara Irina Fabrikant. "Spatialization Methods: A Cartographic Research Agenda for Non-geographic Information Visualization." *Cartography and Geographic Information Science* 30 (2003): 95–119.

  Save Citation »Export Citation »E-mail Citation »

  Explores extension of geographic and cartographic principles to creating *spatializations*—graphic displays of nonspatial and nongeographic information, such as the semantic content of large databases within any topical domain. In addition to technical issues, considers research issues for designing "cognitively plausible" displays.

  Find this resource:

- Slocum, Terry A., Connie Blok, Bin Jiang, et al. "Cognitive and Usability Issues in Geovisualization." *Cartography and Geographic Information Science* 28 (2001): 61–75.

  DOI: 10.1559/152304001782173998Save Citation »Export Citation »E-mail Citation »

  Research agenda for cognitive and usability issues in geovisualization, organized into six major research themes. Assumes that traditional cognitive theory for static two-dimensional maps may not apply to dynamic, interactive, and immersive three-dimensional representations.

  Find this resource:

Geo-ontologies

Information scientists, including GIScientists, use the term *ontology* as roughly equivalent to *conceptual system*, not as a theory of the ultimate nature of reality, as traditional philosophical metaphysics used the term. Interest in ontologies stems from recognizing that digital representations of geographic information, such as in databases, are models of reality, not reality itself. The study of cognitive geo-ontology further recognizes that human understandings of features and events in the world constitute cognitive models of reality. Because different individuals and groups may have different models of reality, researchers speak of "ontologies" in the plural. Various problems in the study of GIScience involve issues of ontologies, including interoperability between systems, as discussed in Mark 1993, Agarwal 2005, and Kuhn, et al. 2007. A call to focus on ontological issues within GIScience is presented in Egenhofer and Mark 1995, which characterizes the geographic conceptualizations of lay people as "naive" or "commonsense" geography. Concepts can be thought of as rules that define category systems. Much of the research on cognitive geo-ontologies has, in fact, been stimulated by cognitive and

linguistic category theory. Much work in this domain has focused on natural language as an expression of conceptual systems, as seen in [Mark 1993](#) and [Smith and Mark 2003](#) (see also [Spatial/Geographic Language](#)). Other work has included nonverbal approaches to ontologies, such as graphical approaches, demonstrated by [Klippel 2003](#).

- Agarwal, Pragya. 2005. "Ontological Considerations in GIScience." *International Journal of Geographical Information Science* 19:501–536.

  DOI: [10.1080/13658810500032321](#)Save Citation »Export Citation »E-mail Citation »

  Overviews theoretical and practical issues of ontology within GIScience. Clear descriptions of terminology. Considers potential for unified ontology within GIScience.

  Find this resource:

- Egenhofer, Max J., and David M. Mark. "Naive Geography." In *Spatial Information Theory: A Theoretical Basis for GIS; International Conference COSIT '95, Semmering, Austria, September 21–23, 1995*. Edited by Andrew U. Frank and Werner Kuhn, 1–15. Lecture Notes in Computer Science 988. Berlin: Springer, 1995.

  [Save Citation »Export Citation »E-mail Citation »](#)

  Influential theory of "naive" or commonsense geographic understanding, inspired by "Naive Physics Manifesto" of Patrick Hayes (in *Expert Systems in the Microelectronic Age*, edited by Donald Michie, 242–270; Edinburgh: Edinburgh University Press, 1978), which called for artificial intelligence to focus on lay thinking instead of expert thinking about the physical world. Presents fourteen elements of naive geographic thinking, including that the world is flat.

  Find this resource:

- Klippel, Alexander. "Wayfinding Choremes." In *Spatial Information Theory: Foundations of Geographic Information Science; International Conference COSIT 2003, Ittingen, Switzerland, September 24–28, 2003*. Edited by Werner Kuhn, Michael Worboys, and Sabine Timpf, 301–315. Lecture Notes in Computer Science 2825. Berlin: Springer, 2003.

  [Save Citation »Export Citation »E-mail Citation »](#)

  Proposes small set of graphical concepts for cartographic depiction of directions, particularly turns in the context of navigation. Inspired by Roger Brunet's theory of geographic spatial primitives (*choremes*) and by qualitative spatial reasoning in artificial intelligence. Argues that eight turn concepts adequately capture human cognition and language in most situations.

  Find this resource:

- Kuhn, Werner, Martin Raubal, and Peter Gärdenfors, eds. "Cognitive Semantics and Spatio-temporal Ontologies." *Spatial Cognition and Computation* 7.1 (2007): 3–12.

  DOI: 10.1080/13875860701337835Save Citation »Export Citation »E-mail Citation »

  Introduction to a special issue of this journal focusing on ontology and semantics in the context of spatio-temporal information. Useful overview essay by editors of the issue.

  Find this resource:

- Mark, David M. "Toward a Theoretical Framework for Geographic Entity Types." In *Spatial Information Theory: A Theoretical Basis for GIS; International Conference COSIT '03, Marciana Marina, Elba Island, Italy, September 19–22, 1993*. Edited by Andrew U. Frank and Irene Campari, 270–283. Lecture Notes in Computer Science 716. Berlin: Springer-Verlag, 1993.

  Save Citation »Export Citation »E-mail Citation »

  One of the earliest discussions of ontological issues for GIScience, particularly for the prospect of international geographic data standards, from the perspective of cross-linguistic variation in vocabularies for geographic features. Detailed comparison example of "lake," "lagoon," "pond" in English and "lac," "lagune," "etang" in French.

  Find this resource:

- Smith, Barry, and David M. Mark. "Do Mountains Exist? Towards an Ontology of Landforms." *Environment and Planning B: Planning and Design* 30.3 (2003): 411–427.

  DOI: 10.1068/b12821Save Citation »Export Citation »E-mail Citation »

  Do mountains exist? It is very difficult to answer such seemingly straightforward geographic questions, even though mountains clearly play an important role universally in commonsense thought and language. How high does the protuberance have to be? What are its boundaries? "Object-based" ontologies such as mountains are essential to naive understanding, but not for geographic information databases.

  Find this resource:

Child Development and Education

People's geographic knowledge varies as a function of their age, education, and experience. In other words, 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 sensorimotor 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 independent 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.

Spatial Behavior and Cognition in Children

Behavioral geographers are interested in behavior and cognition by children in space and place, both because adults become what they are in part because of their childhood experiences, and because children are people in and of themselves, and therefore of interest to human geographers. The single most influential work in this topical area comes from the Swiss child psychologist Jean Piaget (Piaget and Inhelder 1967), whose broad theory of cognitive development in all domains continues to influence geographers, psychologists, and other behavioral and cognitive scientists, even as alternative theoretical frameworks for understanding development continue to be proposed. For example, Hart and Moore 1973 and Spencer, et al. 1989 discuss Piaget's theory and other ideas and empirical results as they apply to the development of spatial understanding of environments. Newcombe and Huttenlocher 2000 follows in this tradition but contrasts Piagetian work with newer scientific theories and findings. Hart 1979 focuses more on observations of children's behavior in space and place, providing a rich observational study of actual ongoing behavior in naturalistic environments. There has also been quite a bit of work on children's understanding—or lack thereof—of cartographic maps. Blaut, et al. 2003 presents the argument that mapmaking and map interpretation are culturally universal acts that emerge "naturally" in childhood without specific culturally dependent training. Liben and Downs 1989 counters this with an argument in the flavor of Piaget's approach. Uttal 2000 argues that the Western conception of maps is a product of a cultural tradition so pervasive that it even shapes people's way of thinking about space and spatiality in general.

- Blaut, James M., David Stea, Christopher Spencer, and Mark Blades. "Mapping as a Cultural and Cognitive Universal." *Annals of the Association of American Geographers* 93.1 (2003): 165–185.

  DOI: 10.1111/1467-8306.93111Save Citation »Export Citation »E-mail Citation »

  Summarizes logic and evidence for theoretical claim that mapmaking and map interpretation are culturally and historically universal human activities, which emerge "naturally" in childhood without specific cartographic training. Argues against the notion that map skills emerge gradually over childhood and adulthood, especially in stage-like progression, contrary to Piagetian claims.

  Find this resource:

- Hart, Roger. *Children's Experience of Place*. New York: Irvington, 1979.

Rich and extensive multi-method study of children's spatial activity and knowledge, place emotions, and use of space and place. Combines behavioral observation, self-report diaries, and parent and child interviews. Combines scientific and humanistic approaches.

Find this resource:

- Hart, Roger A., and Gary T. Moore. "The Development of Spatial Cognition: A Review." In *Image and Environment*. Edited by Roger M. Downs and David Stea, 246–288. Chicago: Aldine, 1973.

Sophisticated review of past theorizing and research on development of children's spatial thinking. Especially detailed exposition of hypothesized developmental sequence of spatial frames of reference, from egocentric to concrete allocentric to abstract allocentric.

Find this resource:

- Liben, Lynn S., and Roger M. Downs. "Understanding Maps as Symbols: The Development of Map Concepts in Children." In *Advances in Child Development and Behavior*. Vol. 22. Edited by Hayne W. Reese, 145–201. San Diego, CA: Academic Press, 1989.

Detailed theoretical framework explaining the gradual emergence of map interpretation skills over the life span, which involves acquiring particular cognitive skills at different ages. This development is characterized by typical misunderstandings about map symbols. It is consistent with Piaget, not with the "natural" mapping espoused for decades by James Blaut and colleagues (e.g., Blaut, et al. 2003).

Find this resource:

- Newcombe, Nora S., and Janellen Huttenlocher. *Making Space: The Development of Spatial Representation and Reasoning*. Cambridge, MA: MIT Press, 2000.

Excellent review of research on the child development of spatial thinking and reasoning in a variety of contexts, including in environments, with maps, in language, and so on, and from newborn infants to adolescents. Informed by Piagetian theory but updated with information-processing, nativist, and nonhuman animal perspectives.

Find this resource:

- Piaget, Jean, and Bärbel Inhelder. *The Child's Conception of Space*. New York: W. W. Norton, 1967.

  The most influential body of work on spatial cognition and its development in children (originally published in 1948). Presents famous ideas of stage-like progressions dependent on interactions with the physical world, systematically changing schematic knowledge structures, and particular patterns of misunderstandings in spatial reasoning tasks such as overcoming egocentric perspective, understanding metric geometry, and using coordinate systems.

  Find this resource:

- Spencer, Christopher, Mark Blades, and Kim Morsley. *The Child in the Physical Environment: The Development of Spatial Knowledge and Cognition*. Chichester, UK, and New York: Wiley, 1989.

  Overview of research on spatial cognition and behavior at environmental scales with children. Considers both basic and applied issues.

  Find this resource:

- Uttal, David H. "Seeing the Big Picture: Map Use and the Development of Spatial Cognition." *Developmental Science* 3.3 (2000): 247–264.

  DOI: 10.1111/1467-7687.00119

  Argues against map comprehension as culturally universal or "natural," contrary to James Blaut, Barbara Landau, and others. Also opposes Piagetian view that spatial understanding emerges asocially from interacting with the physical world. Looks at the role of culturally specific training and experience as critical, and argues that Western exposure to cartographic products molds a particular way of conceiving of space generally.

  Find this resource:

Geographic Education

An applied reason for the geographer's interest in geographical thought and behavior, and its development over the life span, is that it will help in understanding how best to educate children and adults about spatial and thematic facts, concepts, theories, and methods of geography. An interest in geographic education is shared by many human and physical geographers, as well as educators and education researchers. This interest is part of behavioral geography when it

incorporates systematic behavioral-science concepts and methods. Gersmehl and Gersmehl 2006 and Golledge, et al. 2008 elaborate on the claim that effective geographic education depends on a framework for understanding the basic concepts of geographic thought at various developmental levels (that is, they provide a developmental analysis of geographic ontologies; see Geo-ontologies). Vosniadou and Brewer 1992 exemplifies high-quality empirical research on geographic conceptual change. An important recent publication of the National Research Council (US), Committee on Support for Thinking Spatially 2006, focuses specifically on spatial components of geographic knowledge and the possibility that GIS technologies might be useful tools to promote such spatial understanding.

- Committee on Support for Thinking Spatially: The Incorporation of Geographic Information Science Across the K-12 Curriculum, National Research Council. *Learning to Think Spatially: GIS as a Support System in the K-12 Curriculum*. Washington, DC: National Academies Press, 2006.

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  A far-reaching examination of the value of explicitly incorporating spatial thinking into the educational curriculum at all levels, including the role of geographic information technologies in this effort. Appendix C provides an excellent discussion of individual, sex, and age-related variations in spatial cognition.

  Find this resource:

- Gersmehl, Philip J., and Carol A. Gersmehl. "Wanted: A Concise List of Neurologically Defensible and Assessable Spatial-Thinking Skills." *Research in Geographic Education* 8 (2006): 5–38.

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  A call to base educational curricula on spatial thinking in geography on findings in cognitive neuroscience and the scientific study of mind-brain relations, especially recent advances derived from imaging brain activities with functional magnetic resonance imaging (fMRI).

  Find this resource:

- Golledge, Reginald G., Merideth Marsh, and Sarah Battersby. "A Conceptual Framework for Facilitating Geospatial Thinking." *Annals of the Association of American Geographers* 98.2 (2008): 285–308.

  DOI: 10.1080/00045600701851093Save Citation »Export Citation »E-mail Citation »

  Extensive and empirically based analysis of the basic concepts underlying spatial thinking in geography, from beginning novice to advanced expert levels.

Find this resource:

- Vosniadou, Stella, and William F. Brewer. "Mental Models of the Earth: A Study of Conceptual Change in Childhood." *Cognitive Psychology* 24.4 (1992): 535–585.

  DOI: 10.1016/0010-0285(92)90018-WSave Citation »Export Citation »E-mail Citation »

  Excellent example of sophisticated research on conceptual systems in childhood relevant to geographic understanding.

  Find this resource:

Individual, Sex, and Cultural Differences

One of the important contributions of the behavioral approach to human geography is its recognition that people differ in many ways that have implications for mind and behavior in space and place. Furthermore, behavioral geographers promote the systematic study of these variations. These variations exist most fundamentally at the level of the individual person, but they can be aggregated according to many different variables, such as sex, gender, ethnicity, social class, residential environment, intellectual abilities, educational background, language, and many more. It is critical, however, to recognize that correlations between aggregation variables and geographic behaviors (and beliefs and emotions) are, by themselves, ambiguous with respect to causal explanation. The aggregation variable could cause variations in the behavior, the behavior could cause variations in the aggregation variable, or another factor or set of factors could explain variations in behavior. This ambiguity is sometimes signaled by using terms like "sex-related" or "culture-related" in order to suggest that the explanation for the statistical pattern is uncertain. Allen, et al. 1996; Hegarty, et al. 2002; and Kozlowski and Bryant 1977 focus on individual differences in spatial abilities at environmental scales. Voyer, et al. 1995 focuses on sex-related differences in spatial abilities on traditional paper-and-pencil tests. Golledge 1993 discusses the field of disabilities geography. Gladwin 1970 and Levinson 2003 consider cultural variations in thinking and talking about space and place.

- Allen, Gary L., Kathleen C. Kirasic, Shannon H. Dobson, Richard G. Long, and Sharon Beck. "Predicting Environmental Learning from Spatial Abilities: An Indirect Route." *Intelligence* 22.3 (1996): 327–355.

  DOI: 10.1016/S0160-2896(96)90026-4Save Citation »Export Citation »E-mail Citation »

  Compares individual differences in metric and nonmetric spatial tasks at environmental scales, as in spatial learning during navigation, to scores on traditional psychometric (pictorial) spatial tests. Done within the analytic framework of structural equation modeling, a technique for assessing causal relations with nonmanipulated variables (i.e., from nonexperimental studies).

  Find this resource:

- Gladwin, Thomas. *East Is a Big Bird: Navigation and Logic on Puluwat Atoll*. Cambridge, MA: Harvard University Press, 1970.

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  Fascinating classic in anthropology examining a highly refined expert navigation system from a preindustrial culture in Micronesia. In addition to richly perceiving environmental cues, these navigators employ an intriguing "etak" system, dependent on mentally keeping track of distances traveled over the open ocean by reference to nonvisible or even imaginary islands.

  Find this resource:

- Golledge, Reginald G. "Geography and the Disabled: A Survey with Special Reference to Vision Impaired and Blind Populations." *Transactions of the Institute of British Geographers* 18.1 (1993): 63–85.

  DOI: [10.2307/623069](#)[Save Citation »](#)[Export Citation »](#)[E-mail Citation »](#)

  Considers the spatial behavior and cognition of populations with disabilities, including mental retardation, mobility impairments, and, especially, visual impairments. Helps originate the field of disabilities geography.

  Find this resource:

- Hegarty, Mary, Anthony E. Richardson, Daniel R. Montello, Kristin Lovelace, and Ilavanil Subbiah. "Development of a Self-Report Measure of Environmental Spatial Ability." *Intelligence* 30.5 (2002): 425–447.

  DOI: [10.1016/S0160-2896(02)00116-2](#)[Save Citation »](#)[Export Citation »](#)[E-mail Citation »](#)

  Following up and expanding on [Kozlowski and Bryant 1977](#), these authors developed a valid and reliable self-report scale known as the "Santa Barbara Sense-of-Direction Scale." Sense-of-direction is an environmental spatial ability most strongly related to survey spatial knowledge ability, such as in creative wayfinding.

  Find this resource:

- Kozlowski, Lynn T., and Kendall J. Bryant. "Sense of Direction, Spatial Orientation, and Cognitive Maps." *Journal of Experimental Psychology: Human Perception and Performance* 3.4 (1977): 590–598.

  DOI: [10.1037/0096-1523.3.4.590](#)[Save Citation »](#)[Export Citation »](#)[E-mail Citation »](#)

  Demonstrates the surprising reliability and predictive validity of a simple self-report of sense-of-direction ("How good is your sense-of-direction?") as an efficient measure of

environmental spatial ability, such as that involved in maintaining orientation during travel.

Find this resource:

- Levinson, Stephen C. *Space in Language and Cognition: Explorations in Cognitive Diversity*. Cambridge, UK; New York: Cambridge University Press, 2003.

  DOI: 10.1017/CBO9780511613609Save Citation »Export Citation »E-mail Citation »

  Extensive research program demonstrating cultural variation in spatial language and thought, particularly with respect to the implications of linguistically referring to directions with egocentric (relative) or abstract allocentric (absolute) reference systems (see also Spatial/Geographic Language).

  Find this resource:

- Voyer, Daniel, Susan Voyer, and M. Philip Bryden. "Magnitude of Sex Differences in Spatial Abilities: A Meta-analysis and Consideration of Critical Variables." *Psychological Bulletin* 117.2 (1995): 250–270.

  DOI: 10.1037/0033-2909.117.2.250Save Citation »Export Citation »E-mail Citation »

  Comprehensive review of hundreds of studies on the magnitude, consistency, and stability of sex-related differences in psychometric spatial abilities. Applies quantitative technique of meta-analysis to systematically combine statistical results from the studies. Supports existence of a male advantage in some of these abilities, especially mental rotation, but not all.

LAST MODIFIED: 02/26/2013

DOI: 10.1093/OBO/9780199874002-0069