1 Cognitive mapping

Rob Kitchin and Scott Freundschuh

> Cognitive mapping is a process composed of a series of psychological transformations by which an individual acquires, stores, recalls, and decodes information about the relative locations and attributes of the phenomena in his everyday spatial environment.
>
> (Downs and Stea, 1973: 7)

Introducing cognitive mapping

Cognitive mapping concerns how we think about space, and how those thoughts are used and reflected in human spatial behaviour (Downs and Stea, 1973). Like all animals, humans move in and through space: from toddling around the house to negotiating the playground and the neighbourhood; from travelling to work, planning a shopping excursion, to visiting relatives in a distant city. Spatial behaviour is thus central to our everyday lives. In order to traverse space we make hundreds of complex spatial choices and decisions, in most cases without any reference to sources such as maps, instead relying on our knowledge of where places are. The necessity of understanding space is reflected in human activities that attempt to communicate spatial information effectively to people in spaces with which they are unfamiliar. For example, over thousands of years, humans have employed cave paintings, three-dimensional models, maps constructed of various natural materials (sticks, shells, rocks, sand) and man-made materials (paper, mylar, ink), satellite images, computer-generated worlds, and virtual environments to communicate spatial relations (Jacobson, 1999; Blaut, 1999).

Cognitive mapping research seeks to comprehend how we come to understand spatial relations gained through both primary experience and secondary media (e.g., maps). In other words, how people learn, process and use spatial information that relates to the environment that surrounds them. There are a number of research questions of practical importance that are of interest to explorations of cognitive mapping. Some of the more obvious questions include 'how are new routes learned?', 'how are routes between two locations remembered?', 'how are distance and direction estimates made?', 'how

are relative locations between places learned?', 'how are maps interpreted and used for location and navigation tasks?', and 'how is spatial knowledge related to spatial behaviour?'. Cognitive mapping, then, is a component of the broader field of spatial cognition research – research that concerns the understanding of spatial thought *per se*. Spatial cognition, in turn, is an important sub-part of cognition *per se*, and its understanding is thought to be central to understanding 'learning and knowing' in general (Johnson, 1987; Lakoff, 1987).

As detailed in the literature (for example, see Kitchin 1994), the terms 'cognitive mapping' and 'cognitive map' are not without their problems. The term 'cognitive mapping' has been used in three different ways. First as a descriptive title for the field of study that investigates how people learn, remember and process spatial information about an environment. Second, it has been used as a descriptive phrase for the process of thinking about spatial relations. Third, it has been used as a descriptive name for a methodological approach to understanding cognition in general, consisting of the construction of 'maps' of cognitive processes (e.g., Swan and Newell, 1994). Similarly, the term 'cognitive map' has been used in a variety ways, nearly all relating to a person's knowledge of spatial relations. Tolman (1948), the originator of the term 'cognitive map', hypothesized that we construct a map-like representation (i.e., a cognitive map) within the 'black box' of the nervous system, which is then used to guide our everyday movements. In this instance, the representation is structured in the same way as a cartographic map. The implication, then, is that the cognitive map acquires Euclidean properties with repeated environmental experience. So, 'cognitive' map was used by Tolman as an *explicit statement*, with spatial knowledge functionally and representationally equivalent to a map (also see O'Keefe and Nadel, 1978). The term has also been used as an *analogical device* where spatial knowledge is assumed to be like a cartographic map (Levine *et al.*, 1982, Kuipers, 1982); and as a *metaphorical device* to label spatial knowledge as functionally equivalent to a map – we act as if we have a map-like representation in our minds, although it is acknowledged that here 'map' is a hypothetical construct (Moore and Golledge, 1976; Newcombe, 1985; Siegel and Cousins, 1985). Finally, in some cases the term 'cognitive map' has been used as a descriptive term for a conceptual drawing of an individual's cognitive processes and is the outcome of the methodological process of cognitive mapping (third definition above). In this book, we use the term 'cognitive mapping' as a descriptive title for the field of study concerned with understanding spatial thought and 'cognitive map' to denote a person's spatial knowledge of the environment regardless of form.

Surprisingly, cognitive mapping research is a relatively recent endeavour. Whilst there were isolated studies such as Trowbridge (1913) and Hardy (1939), the vast majority of research has taken place over the course of the past forty years. This research, initiated by the seminal work of Kevin Lynch

(1960), is unusual in that it has always been multidisciplinary (although not always interdisciplinary) in character. Although psychology, particularly cognitive and developmental psychology, has tended to dominate theoretical and empirical studies, other disciplines, notably geography, but also planning, architecture, anthropology, computer science, information science, cognitive science and neuro-psychology have made significant contributions.

A reflection of its multidisciplinary character is that just five years after the publication of Lynch's book, representatives from ten separate disciplines met at the 1965 Association of American Geographers' conference in Columbus, Ohio, to present research concerning the links between spatial thought and spatial behaviour. This meeting ultimately led to the establishment of the Environmental Design & Research Association (EDRA) and to the beginning of the cross-disciplinary journal, *Environment and Behavior* (1969) (Kitchin *et al.*, 1997). These links continued to develop in the early 1970s leading to the publication of a number of edited collections with a cross-disciplinary range of authors (e.g., Downs and Stea, 1973, 1977; Moore and Golledge, 1976). However, it is fair to state that at this time links were more usually forged through disciplines approaching psychology, and using psychological thought and techniques, than vice versa (Gärling and Golledge, 1993). During the late 1970s, links started to unravel – mainly due to crises in confidence in behavioural geography (under which most geographic, cognitive mapping research was conducted). Behavioural geography was criticized by humanists for being mechanistic and dehumanizing, and by structuralists for failing to acknowledge the broader social and cultural context in which decision-making operated (namely capital relations). While some links remained in place, notably through the work of Golledge, it was not until the early 1990s that multidisciplinary links were extensively re-forged, leading to range of interdisciplinary research, notably between geographers and psychologists. Instrumental in this process has been the National Science Foundation funded National Center for Geographic Information and Analysis (NCGIA). During the ten years of the NCGIA's existence, the Center has sponsored and funded cross-disciplinary research through its many research initiatives including Languages of Spatial Relations, Spatial-Temporal Reasoning, Multiple Representations, User-Interface Design, Common-Sense Geographic Reasoning, Scale and Cognition in Geographic Space, Dynamic Representations, and Multiple Modalities and Multiple Reference Frames for Spatial Knowledge. Many of the authors in this collection have taken part in these initiatives, and are now engaged in interdisciplinary research.

Theoretically and empirically, cognitive mapping research has come a long way in the last forty years, and a number of core sub-fields are discernible – some of these are reflected in the chapter titles in this book. Throughout this period a number of specific theories relating to processes of spatial thought have been developed, tested and refined. For example,

there has been a long running debate as to how people learn a new environment (see Chapter 5). Some researchers suggest that a landmark-based strategy is used in which distinctive features in the environment can be used to provide cognitive cues around which other information is anchored (e.g., Couclelis *et al.*, 1987). Others favour a path-based strategy of learning (e.g., Gärling *et al.*, 1981) or a process of recognizing vistas (Cornell and Hay, 1984; see Chapter 5). Similar debates relate to: levels and development of spatial knowledge (see Chapter 3); how people make spatial decisions (see Chapter 4); how people acquire spatial knowledge from secondary media such as maps (see Chapter 6) and virtual reality (see Chapter 7); and in small- and large-scale spaces (see Chapter 8); how knowledge develops across the life-span, particularly in early childhood (see Chapter 9) and old age (see Chapter 10); knowledge form (whether knowledge is held in imaginal or propositional form) and what language can reveal about spatial knowledge (see Chapter 11); knowledge structure (whether knowledge is structured hierarchically or in a network), brain location (where knowledge is stored within the brain structure – hippocampus, parietal cortex), and the influence of certain intervening factors such as gender (see Chapter 12) and visual impairment (see Chapter 13).

Although certain models and associated underlying theories have gained more empirical and academic support, it is fair to say that there is still a plurality of explanations as to how we come to know, process and use spatial relations relating to the environment that surrounds us.

Why undertake cognitive mapping research?

There are a number of both theoretical and practical reasons for conducting cognitive mapping research. At a theoretical level, cognitive mapping research seeks to explain fundamental questions concerning spatial knowledge acquisition, spatial processing, and how spatial understanding is realized, and spatial choices and decisions are made. At a basic level, it is commonly understood that spatial behaviour – daily navigation, such as routes chosen (wayfinding), and also decisions concerning everyday activities such as where to shop (see Chapter 4) – is predicated upon levels and use of spatial knowledge. Therefore an understanding of spatial knowledge necessarily leads to an understanding of people's spatial behaviour. Furthermore, cognitive mapping research provides basic insights into the workings of the mind, and how we learn, process and remember spatial and non-spatial information. As such, it provides evidence that feeds into fundamental debates concerning knowledge acquisition, knowledge form and structuring, and mental processes.

At a practical level, cognitive mapping research is thought to have a number of potential applications (see Kitchin, 1994, for a full review). These applications vary from those that are more conceptual in nature (the application of ideas) to those that are more concrete. At the conceptual end of

the scale it is believed that an understanding of the process of cognitive mapping will provide insights that may improve urban planning, education, and professional searches (police, rescue). Here, it is hypothesized that if we understand how people think about and interact in urban environments we can design environments that facilitate rapid learning and easy retention, thus lessening the likelihood of disorientation (Canter, 1977; Downing, 1992). Similarly, if we know how people understand geographic concepts we can produce geographic materials that are easier to comprehend, or we can determine methods to teach people to be more competent at understanding geographic material (Catling, 1978; Matthews, 1992). Moreover, if we know how people make spatial decisions about where to commit certain crimes (e.g., Canter and Larkin, 1993), or how people spatially think and behave when lost (see Chapter 5) we can determine more efficient methods of spatial search.

At the more concrete end of the scale, it is believed that cognitive mapping research can provide insights that will improve technical, geographically-based media such as cartography, geographic information systems, in-car navigation systems, orientation and navigation aids for people with visual impairments, and signage placement. For example, as noted by Lloyd (Chapter 6), it is believed that an understanding of how people comprehend and use maps may lead to the developments in cartographic presentation that will facilitate greater utility. Similarly, it is anticipated that an understanding of the most effective means of spatial communication will help facilitate the development of geographic information systems (see Egenhofer and Golledge, 1998), in-car navigation systems (e.g., Jackson, 1996) and orientation and navigation aids (e.g., Golledge *et al.*, 1998), which can be used efficiently and effectively by naive lay users (non-spatial experts).

At present, theoretically-driven research far exceeds in quantity that which is practically-operationalized (Kitchin, 1994; Jackson and Kitchin, 1998). That is to say that whilst much research is motivated by potential practical applications, this research has been slow to feed into practical developments. The situation is slowly changing, with research from cognitive cartography now starting to influence map design (see MacEachren, 1995), and research relating to visual impairment starting to feed into the design of orientation and navigation aids for blind people (see Golledge *et al.*, 1998; Jacobson and Kitchin, 1997).

This book

The origin of this book was a day-long symposium held at the 1997 Annual Meeting of the Association of American Geographers in Fort Worth, Texas. The focus of this symposium was cognitive mapping in its broadest interpretation, and its aim was two-fold. First to bring together an international gathering of researchers to exchange ideas and foster research collaborations.

Second to examine recent developments, empirical research and future directions in cognitive mapping research, attempting to gain a coherent summary of cognitive mapping research as currently theorized and practised. The symposium consisted of twenty-seven papers divided into five sessions, plus a plenary panel session. The papers that were presented detailed a wide range of empirical studies and addressed a number of substantive theoretical issues across a spectrum of topical areas:

- spatial abilities
- development
- image and narrative learning
- wayfinding
- virtual worlds
- disabilities
- representation
- route learning
- environmental learning

Papers given at this symposium focused on current research and theory in cognitive mapping, and highlighted the multidisciplinary nature of the field and the unique opportunities for cross-disciplinary research. The varied disciplinary backgrounds of the participants, including behavioural and cognitive geographers, developmental and cognitive psychologists, and computer, cognitive and information scientists, reflect this multidisciplinary (and increasing interdisciplinary) nature of cognitive mapping research.

Papers presented during the symposium serve, in part, as the foundation for the chapters in this book. Rather than simply publish the papers presented at this symposium (see Freundschuh and Kitchin, 1999), the chapters in this text go beyond the scope of the symposium providing an account of past, present and future research within a specific field of enquiry, cognitive mapping. In the 'past' section of each chapter, authors provide a brief history of the main developments leading to the present thinking and empirical approaches. In the 'present' section, authors discuss their own empirical research to provide concrete examples of work in progress. In the 'future' section, authors identify key concerns and questions that future research should address. Authors were chosen because of their expertise in relation to a particular topic, and to provide a balance of contributors from different disciplines and geographic location. The focus of each chapter was chosen so as to provide a comprehensive overview of the field of cognitive mapping, taking into account the range of discernible sub-fields. After forty years of research we felt it timely to take stock of how the field of cognitive mapping has developed, the breadth and depth of present research, and the future questions which need to be addressed.

The resulting book is, we think, a coherent, comprehensive, accessible account of cognitive mapping research that provides a description of the

current state of play and a 'map' of what future research should investigate. It is our hope that the book will provide a useful source book to researchers in a number of disciplines interested in cognitive mapping research and also provide impetus for future interdisciplinary collaboration.

References

Blaut, J.M. (1999) Maps and space. *The Professional Geographer*, 51, 510–15.

Canter, D. (1977) *The Psychology of Place*. London: Architectural.

—— and Larkin, P. (1993) The environmental range of serial rapists. *Journal of Environmental Psychology*, 13, 63–9.

Catling, S. (1978) Cognitive mapping exercises as a primary geographical experiences. *Teaching Geography*, 3, 120–3.

Cornell, E.H. and Hay, D.H. (1984) Children's acquisition of a route via different media. *Environment and Behavior*, 16, 627–41.

Couclelis, H., Golledge, R.G., Gale, N. and Tobler, W. (1987) Exploring the anchor-point hypothesis of spatial cognition. *Journal of Environmental Psychology*, 7, 99–122.

Downing, F. (1992) Image banks – dialogues between the past and the future. *Environment and Behavior*, 24, 441–70.

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

—— and Stea, D. (1973) Theory, in Downs, R.M. and Stea, D. (eds), *Image and Environment*, Chicago, IL: Aldine, pp. 1–7.

—— and —— (1977) *Maps in Minds: Reflections on Cognitive Mapping*. New York: Harper and Row.

Egenhofer, M. and Golledge, R. (eds), (1998) *Spatial and Temporal Reasoning in Geographic Information Systems*. Oxford: Oxford University Press.

Freundschuh, S.M. and Kitchin, R. (1999) Contemporary thought and practice in cognitive mapping research: an introduction, *The Professional Geographer* (in press).

Gärling, T., Book, A., Lindberg, E. and Nilsson, T. (1981) Memory for the spatial layout of the everyday physical environment: factors affecting rate of acquisition. *Journal of Environmental Psychology*, 1, 263–77.

—— and Golledge, R. (1993) Preface, in Gärling, T. and Golledge, R.G. (eds), *Behavior and Environment: Psychological and Geographical Approaches*. London: North Holland.

Golledge, R.G., Klatzky, R.L., Loomis, J.M., Speigle, J. and Tietz, J. (1998) A geographical information system for a GPS-based personal guidance system. *International Journal of Geographic Information Systems*, 12, 727–50.

Hardy, G. (1939) *La geographie psychologique*. Gallimard, Paris.

Jackson, P. (1996) How will route guidance information affect cognitive maps? *Journal of Navigation*, 49, 178–86.

Jackson, P. and Kitchin, R.M. (1998) Editorial: applying cognitive mapping research. *Journal of Environmental Psychology*, 18: 219–21.

Jacobson, R.D. (1999) *Learning, Reading and Communicating Space: Exploring Geographies of Blindness*. Unpublished PhD, Queen's University of Belfast.

—— and Kitchin, R.M. (1997) GIS and people with visual impairments or blindness: exploring the potential for education, orientation and navigation. *Transactions in Geographic Information Systems*, 2 (4) 315–32.

Johnson, M (1987) *The Body in the Mind*. Chicago, IL: University of Chicago Press.

Kitchin, R.M. (1994) Cognitive maps: what are they and why study them? *Journal of Environmental Psychology*, 14, 1–19.

—— Blades, M. and Golledge, R.G. (1997) Relations between psychology and geography. *Environment and Behavior*, 29, 554–73.

Kuipers, B. (1982) The 'map in the head' metaphor. *Environment and Behavior*, 14, 202–20.

Lakoff, G. (1987) *Women, Fire, and Dangerous Things: What Categories Reveal About the Mind*. Chicago, IL: University of Chicago Press.

Levine, M., Jankovic, I. and Palij, M. (1982) Principles of spatial problem solving. *Journal of Experimental Psychology: General*, 111, 157–71.

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

MacEachren, A. (1995) *How Maps Work: Representation, Visualization, and Design*. New York: Guilford.

Matthews, M.H. (1992) *Making Sense of Place*. Hemel Hempstead: Harvester Wheatsheaf.

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

—— and Golledge, R.G. (1976) Environmental knowing: concepts and theories, in Moore, G.T. and Golledge, R.G. (eds), *Environmental Knowing*. Stroudsberg, PA: Dowden, Hutchinson and Ross, pp. 3–24.

Newcombe, N. (1985) Methods for the study of spatial cognition, in Cohen, R. (ed.), *The Development of Spatial Cognition*. Hillsdale, NJ: Erlbaum Lawrence, pp. 1–12.

O'Keefe, J. and Nadel, J. (1978) *The Hippocampus as a Cognitive Map*. Oxford: Clarendon Press.

Siegel, A.W. and Cousins, J.H. (1985) The symbolizing and symbolized child in the enterprise of cognitive mapping, in Cohen, R. (ed.), *The Development of Spatial Cognition*. Hillsdale, NJ: Erlbaum Lawrence.

Swan, J.A. and Newell, S. (1994) Managers' beliefs about factors affecting the adoption of technological innovation: a study using cognitive maps. *Journal of Managerial Psychology*, 9, 3–26.

Tolman, E.C. (1948) Cognitive maps in rats and men. *Psychological Review*, 55, 189–208.

Trowbridge, C.C. (1913) On fundamental methods of orientation and imaginary maps. *Science*, 38, 888–97.