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14 The future of cognitive mapping research

Rob Kitchin and Scott Freundschuh

Introduction

As detailed in the chapters in this book, cognitive mapping research has developed over the past forty years into a vibrant and multidisciplinary field of study, with several discernible sub-fields. Whilst the studies that compose the body of cognitive mapping research provide both breadth and depth, it is clear that there are still many facets of spatial knowledge that remain unexamined or are need of further investigation. Indeed, the volume of research within each sub-field is highly uneven, with some focuses receiving a disproportionate amount of attention. Moreover, most sub-fields are characterized by a set of divergent and competing findings and theories, each seeking to adequately explain how we learn, store, process and use spatial knowledge. Each of the contributors to this volume detailed a specific future agenda to address questions so far left unexplored or inadequately answered. In this final chapter we collate, cross-reference and add to their suggestions for future research to provide a comprehensive agenda that will help guide cognitive mapping research as we enter the new millennium. We have divided our discussion into three main sections: theoretical, methodological, application.

Theoretical

Basic research

Whilst there has been significant progress concerning the investigation of basic research questions, it clear that more research is needed before we have a comprehensive understanding of all aspects of cognitive mapping. As argued by Tversky (Chapter 3), basic questions concerning levels and types of spatial knowledge, and how knowledge is structured (alignment, reference points, frames of reference, hierarchical organization, canonical axes), need more attention, as do questions relating to how knowledge is acquired from different sources (e.g., direct experience, maps, virtual reality) and whether such knowledge is treated in the same or different manner.

Research to date provides a number of competing theoretical models, each with fairly limited empirical support, and current comprehension needs to be supplemented by further examination. In particular, basic research is needed in regard to specific media of spatial learning, processes of integration, socio-temporal effects, spatial language, and the links between spatial thought and spatial behaviour.

Media of spatial learning

As detailed in Chapters 5 to 7 there have been significant advances in our understanding of how spatial information is learnt from a variety of media. This understanding, however, is far from complete. In relation to spatial learning through direct experience a number of key questions still remain in relation to the exact mode of learning. For example, how is perceptual data processed and turned into long-term memory, and how is such memory used to guide spatial behaviour? Further, what has to be known about a route to take a shortcut or a detour? Cornell and Heth (Chapter 5) also suggest that some more cross-cultural research is needed, along with historical investigation into past navigation techniques.

Lloyd (see Chapter 6) suggests a number of issues in cartography that are in need of examination. Although there has been a number of studies which have sought to determine how spatial knowledge learnt from map presentations is stored in long-term memory, as yet, we have no clear models. Moreover, we do not know how map information displayed using animation techniques and alternative forms of map presentation such as cartograms are processed and remembered. Lloyd suggests that one strategy that might help guide future studies is to forge a link with visual information processing research. Whilst this will no doubt be an important link for comprehending sighted people's understanding of maps, it might have limited utility in comprehending how people with visual impairments learn, remember, and utilize spatial information derived from tactile maps.

Virtual environments are a relatively recent phenomenon, but are likely to become common place over the coming years. Because they are navigated through in ways visually similar to, but differing in other ways from, real world environments (e.g., lack kinaesthetic feedback), they offer an interesting medium in which to study spatial knowledge acquisition. As documented by Péruch *et al.* (Chapter 7), although studies of virtual environments have started in earnest, the number of studies remains relatively small. Key questions that need to be addressed relate to the extent to which spatial knowledge is the same or differs from that acquired in the real world, and how virtual environments can be designed to facilitate wayfinding. The latter point is particularly important given that, at present, navigation through these environments often causes disorientation (Ruddle *et al.*, 1997; Richardson *et al.*, in press).

Processes of integration

As most contributors to this volume have noted, in order to build a comprehensive theory of the process of cognitive mapping, it is necessary to examine processes of integration of spatial information. Studies are needed that explore how new spatial information is integrated with existing spatial knowledge, how spatial knowledge previously learned becomes distorted or forgotten, and how spatial information gained from travelling various routes through an environment is linked together. In particular, several authors noted the need to examine how spatial information from different media, such as direct experience, map representations, virtual reality, film/animation, text, and verbal dialogue is integrated both in storage and use (Montello and Freundschuh, 1995; Freundschuh and Taylor, 1999). At present, few studies have examined processes of integration, and our understanding, therefore, is mainly conceptual. It is clear, however, that these processes are central to the process of spatial learning and spatial thought. For a more complete understanding, detailed empirical evidence is needed to support what, at present, largely remain hypothetical explanations.

Spatio-temporal effects

SCALE

A number of studies provide empirical evidence that enables the distinction of 'manipulable space', 'environmental space' and 'map space' as 'cognitively different' (see Chapter 8). Further research is needed to explore these spaces, and to explore other kinds of spaces such as panoramic and geographic spaces, and other kinds of spaces that have yet to be identified (e.g., virtual reality). In addition to this work, systematic studies of the cognitive factors and abilities that are used to understand changes in scale and scale transformations is needed. We understand very little about how small-scale representations of a space are related to the larger-size space, or how and if multiple representations are used to cognitively link these spaces. In relation to understanding scale changes, longitudinal studies are needed that detail the development of scale understanding, from childhood to late life. These studies of 'life-long' learning will provide critical insights about benchmarks for learning, and possibly the un-learning of scale and spatial knowledge. An understanding of scale and size of space, we believe has important implications to the development of spatial tools, such as maps and GIS, and to the development of educational curriculums.

ENVIRONMENTAL DESIGN

Several studies have shown that environmental features can influence the rate, success and accuracy of spatial learning. For example, Canter (1977), Cohen *et al.* (1978), and Herman *et al.* (1983) have all found barrier effects on distance judgements, where those locations separated by a barrier (e.g., a river) were judged to be further apart. Similarly, city layout, structure, and size have all been found to affect the cognitive knowledge of urban areas. For example, Antes *et al.* (1988) found that cities with a regular layout made the city more 'legible', and Sadalla and Staplin (1980) and Kahl *et al.* (1984) reported that the greater the number of turns or intersections along a route the greater the chance that cognitive distance estimates are overestimated. As Cornell and Heth (Chapter 5) detail, however, a more sustained analysis of role of intermediary design factors is needed, along with an analysis of the effects of specific interventions designed to make an environment easier to navigate through (e.g., colour coding, the role of signage). Determining these effects are important because, as discussed below, people interact with these environments, not with controlled laboratories where such factors are often missing.

TIME

One factor that has received little attention to date has been time. We live and move through a time–space continuum. Temporality, then, may have an important role to play in the spatial cognition on an environment in two respects (Kitchin and Blades, forthcoming). First, time relates to *when*; the specific time in which a place is experienced. Places experienced at different times might lead to different spatial understanding. For example, at night, when visual stimuli are darkened, the effectiveness of spatial cues may be lessened; during a rush hour cognitive attention may be stretched and engaged in other tasks such as obstacle avoidance rather than spatial layout. Second, the time of travel – the speed of *mobility* – may lead to differing spatial understandings. For example, driving quickly through an area may provide little time to remember spatial information; walking slowly may allow time to gaze and note the relative locations of objects in the environment. It is our contention that the interrelationship between space, time, and cognition needs to be fully examined. Related to time, of course, is the age at which spatial information is acquired and which spatial concepts are understood (see Chapters 8, 9 and 10). Acquisition of information at different ages will impact what spatial information is learned and what spatial concepts will be understood, as well as what spatial knowledge will be acquired and what knowledge will be forgotten. Also related to time is the understanding of change in spatial phenomena. Research in the use of animation to illustrate temporal changes in spatial phenomena are needed, as well as the development and integration of animation technologies in GIS.

Spatial language

We have only recently started to address questions concerning the role of language in spatial cognition. As a consequence, as shown in the chapters by Tversky (Chapter 3) and Taylor (Chapter 11), language-orientated research is much needed. Both suggest that research should centre on analysing spatial descriptions, such as route and survey descriptions, using these to investigate basic questions concerning knowledge form and structure. It seems to us that there are a number of key concerns that need to be addressed. First, attention needs to be directed at understanding how verbal and written spatial descriptions are learnt and processed, how such processing is similar to or differs from knowledge gained from different media (direct experience, maps), and how this spatial information is integrated into existing knowledge (Freundschuh and Mercer, 1995). Second, attention needs to focus on how spatial language is used as medium for communicating spatial relations, both verbally and written. Third, research needs to address how spatial language develops across the life-span, and to investigate whether there are cultural, gender-related or individual differences in language style and form, and the nature and bases of any differences.

Linking spatial thought and spatial behaviour

A number of contributors to this volume (e.g., Tversky, Gärling and Golledge, Cornell and Heth) argue that much more work is needed to try and understand the relationship between spatial knowledge and spatial behaviour (action); of the processes that are employed in guiding spatial choice and decision-making. Gärling and Golledge correctly assert that to date we have been lax in investigating this process, and yet it is a key reason for studying cognitive map knowledge. They argue that a sustained, experimental approach using small- and large-scale, real world environments is needed in order to ascertain the mechanisms by which spatial knowledge (however complete) is used in making spatial decisions. Central to this study is a focus on the *process* of decision-making and an appreciation of theoretical models of decision-making *per se*.

Development across the lifespan

As the chapters by Uttal and Tan (Chapter 9) and Kirasic (Chapter 10) illustrate, research concerning the development of spatial knowledge across the life-span has been unevenly distributed. At present, research has tended to focus on the development of spatial knowledge and abilities in childhood, and in particular infancy. Research relating to older adults is lacking despite the evidence to suggest that an understanding may have many potential applications given an ageing society with potentially deteriorating spatial skills. It is therefore no surprise that we contend that a significant area for future research must be an examination of spatial abilities in later life. In particular, research needs to establish the extent to which there is deterioration of spatial abilities in older age, identify the processes that underlie this deterioration, and determine ways to implement findings into environmental design.

The urgent need for basic research concerning spatial knowledge and abilities of older adults, does not however, negate the fact that fundamental questions concerning childhood development still need to be addressed further. As Uttal and Tan detail (see Chapter 9), future research in the development of cognitive mapping will include studies exploring scale effects (see also Chapter 8), new technologies such as virtual reality (see also Chapters 7 and 8) and tracking technologies (GPS), and the causes of development. GPS (global positioning systems) will enable the tracking of children's movements, making it possible to track changes in range of exploration that are related to age and experience. Research exploring the 'mechanisms of change' in the development in cognitive mapping will help researchers understand the specific factors and/or benchmark events that result in significant changes in cognitive mapping and spatial abilities.

Individual differences

In general, research to date has concentrated on identifying coherent trends in data. As such, analysis has generally taken place at the aggregate/group level. As several contributors to this volume argue however, there is now a need to explore the differences between individual performances. These differences as Kirasic (Chapter 10) notes are predicated upon factors such as individual information processing abilities, personality variables, physical capabilities, and neurological states. The relative importance of each of these factors needs to be established, especially as within group differences are often larger than between group differences, and as noted by Kitchin (see Chapter 2), that group-based aggregations often lead to weak internal validity due to ecological fallacy (also see Kitchin and Fotheringham 1997). Until recently, calculating individual differences was relatively unviable due to the computation effort of data preparation and analysis. The development of powerful computers that perform complex spatial analysis enable the analysis of individual data in a matter of seconds rather than hours or days. This means it is now possible to perform disaggregate analysis, on individual data sets, establishing possible reasons for within-group differences.

Comparators

Although it is clear that substantially more research is needed in regard to examining and understanding individual differences it is also the case that further comparator work is also necessary. In particular, research is needed

to compare performances across cultures, across species, between sexes, and between sighted and non-sighted populations.

As yet, there have been few attempts to conduct cross-cultural, cognitive mapping research. As such, the influence of cultural environments (e.g., urban form, street layout), linguistic styles, and other cultural factors upon spatial knowledge and tasks are unknown. As noted by Cornell and Heth (see Chapter 5), those studies which have been undertaken highlight differences in methods of navigation based upon surrounding environments.

Similarly, there has been little research that has compared spatial knowledge and spatial behaviour across species. It is clear that many animals possess complex spatial abilities that allow them to travel great distances accurately. The mechanics of these abilities and how they compare to human abilities is largely unknown. Comparison studies will not only throw light on animal behaviour, but may reveal clues as to how we as a species comprehend and use spatial knowledge. As noted below, the methodologies used to produce comparable data needs to be thoroughly investigated but it seems like that neuro-psychological work might be a fruitful venture.

As Chapter 12 highlighted there has been considerable research attention applied to the issue of gender differences in spatial abilities. These studies have produced findings that indicate conflicting conclusions. Some studies have found significant differences between males and females on a number of tests. Other studies have found no such differences. Hypotheses to explain the differences between the sexes centre on a number of themes such as physiology and hormone levels, socio-cultural factors (e.g., early childhood training and expectations, parental and institutional expectations, stereotyping and experience), and abilities to cope with the task presented rather than abilities *per se* (Kitchin, 1996a). The viability and integrity of these hypotheses still needs to be established. As Self and Golledge (1994) have acknowledged elsewhere, determining and understanding differences is important for activities such as teaching to ensure equivalence of knowledge.

The final set of comparator work that needs to be addressed is that of sighted versus non-/partially-sighted. To date research comparing sighted and blind populations has been limited in number and scope. As Ungar (see Chapter 13) notes, several contrary findings have been reported, each attributing different levels of spatial ability to non-sighted populations. In the main, research has largely been confined to laboratory testing, but in recent years some studies have investigated spatial knowledge and behaviour in large-scale, real environments. This research tends to suggest that the spatial abilities of visually impaired people have been underestimated. Ungar suggests that a concerted research programme is needed to address both abilities to learn and interact with large-scale environments, and abilities to learn and use knowledge derived from spatial communication devices such as maps and personal guidance systems. In addition, Ungar suggests that research should focus on a number of key themes, namely early experiences, particularly the role of care-givers and intervention strategies, an examination of varying degrees of visual impairment, the effect of new spatial technologies on spatial abilities, the influence of environmental design, and what insights can be gained from neuro-psychological work.

Knitting specific theories

> . . . we operate on two levels, both as model builders concerned with a particular aspect of our subject and as students of our entire subject. For some, there is but one level: their intellectual curiosity has shrunk to the size of a specialty.
>
> Papageorgiou (1982: 346)

So far in this section we have discussed agendas relating to specific aspects of spatial knowledge. Equally important, however, is the theoretical knitting of these ideas into a conceptual whole. To date there has been little attempt to knit together specific theoretical explanations beyond generalized conceptual models of spatial thought and spatial behaviour (see Kitchin 1996b, for review). These generalized models tend to be highly abstract and lacking in specific details, and are generally used to provide a conceptual frame in which to guide empirical research. Indeed, one of the main criticisms of cognitive mapping research to date has been that while there has been no shortage of empirical studies, these have been motivated by hypotheses that are too limited to be of general applicability, or too general to have been meaningful hypotheses in the first place (Allen, 1985). As such, present theories are often too specific to relate to cognitive mapping in general (e.g., structure, form, learning strategy), or too vague to give rise to testable hypotheses (e.g., environment-behaviour interaction schemata). Moreover, Golledge *et al.* (1985) contend that in many cases cognitive mapping theories represent general positions rather than formal models, and that empirical studies are often not explicitly tied to formal models. As a consequence, a major hole in our understanding of the process of cognitive mapping is a comprehension of this process in entirety. A major theoretical project for the future then is to fully explore both conceptually and empirically the process of cognitive mapping as a system, integrating specific theories into a conceptual whole.

Methodological

As detailed in Chapter 2, whilst methodology has become more sophisticated there is still a need to improve methodological validity and integrity. This can be achieved in four main ways. First, there needs to be more research conducted on the actual process of research itself. It is now quite clear that the process of data generation has significant implications to the findings of a study. For example, a technique can introduce methodological

bias through spatial and location cueing (providing information to the respondent such as a spatial framework, e.g., part of a map, or a list of places to locate). Similarly, aggregation introduces effects through the removal of variance. The extent to which these biases influence the findings needs to be carefully established so that there effects can be compensated for. Until this is done, the integrity and validity of studies remains less robust.

Related to establishing the integrity of traditional research methodologies, is determining the applicability of using particular techniques to measure spatial knowledge acquired from different media. Whilst it seems intuitive that techniques which work well in a particular context such as the real world environment will work equally well in virtual environments, this needs to be established (see Chapter 8). Virtual environments, at present, do differ substantially in form from real world environments. Moreover, whilst there is clearly more need for more cross-cultural and cross-species research, the methodological integrity of such studies needs to be established. The danger, in relation to research on cross-cultural comparisons, is that results may differ not because of differences in knowledge or cognitive processes but because of cultural familiarity with the media of data collection. In relation to cross-species work there is always a danger of placing an anthropomorphic interpretation of findings.

Second, empirical studies need to adopt research strategies that allow some level of construct and convergent validity to be established. Construct validity refers to the extent to which a methodology is measuring what it is supposed to, and convergent validity the extent to which two methodologies designed to measure the same phenomenon produce similar findings. Establishing construct and convergent validity is important because it provides a 'natural' way to determine the integrity of the findings through a process of cross-checking. One method to achieve this is to use multiple strategies of data collection and analysis, comparing the results from different strategies to determine equivalence of findings. In this manner the internal and external validity of a study can be verified.

Third, new methods of enquiry and specific techniques of data generation and analysis need to be utilized and evaluated. Several of this volume's contributors have argued that methodological developments in neuropsychology, such as PET, could add significantly to our understanding of spatial knowledge. While there is a vast neuropsychological literature concerning the brain bases used during cognition, at present, theoretical and methodological developments within neuro-psychology have been slow to work their way into conventional cognitive mapping research. This in part is because neuro-psychologists have mainly focused their attention on the neurological bases of animal wayfinding, and in particular rats, but also because most psychologists and geographers are interested in what the neurons do rather than how they physically do it. Clearly the two, however, are related and there may be important insights to be learnt from marrying these two separate areas of research. This will be a difficult and lengthy task, but the development of connectionist models of neural networks may offer one path forward (see Chapter 6).

In addition, it has been speculated that qualitative methodologies, both those used within a scientific frame and those that are more interpretative in nature, may have significant utility as techniques for understanding spatial thought and spatial behaviour. Within a scientific frame, qualitative methodologies, such as talk-aloud protocols, will allow insights into the role of spatial language and, as a media of producing spatial products, other facets of spatial knowledge. Interpretative techniques, on the other hand, will allow an investigation of the role of value systems, situational context and socio-cultural factors relating to interrelationship between individual and society which is not easily captured using closed quantitative techniques such as questionnaires.

Fourth, we would suggest that more research needs to be conducted within natural settings rather than artificial laboratory space (see Chapter 8). Spatial behaviour takes place in complex, natural settings, often full of other people, not in highly controlled spaces that are devoid of life. Studies which take place in the orderedness of a laboratory may well suffer from problems of ecological validity. In the process of trying to create a controlled space to measure specific processes of cognitive mapping, the environment becomes something different to that normally experienced. What we are therefore measuring may differ substantially from what actually occurs when learning or interacting within a real world environment. Furthermore, there is a need to recognize and examine the situational context of spatial learning and spatial behaviour. These processes do not take place in a vacuum, but within a context that impinges upon their functioning. For example, there is evidence to show that rates of spatial learning are affected by the condition under which a location is experienced: passive explorers, for instance, show lower levels of spatial learning than active explorers (Feldman and Acredolo, 1979; Herman, 1980). A focus for study then is a detailed examination of the spatial (laboratory or natural setting) and situational context (condition) of learning and interacting in different environments.

Application

As noted in Chapter 1 particularly, as well as in subsequent chapters, cognitive mapping research tends to be conceptual in nature, despite repeated rhetoric concerning its potential applied worth. So far little attempt has been made to convert research findings into formal guidelines for application to specific issues. This to our reckoning is one of the biggest failings of cognitive mapping research to date, and one that needs significant attention.

Planning

One of the most consistent arguments for cognitive mapping research by geographers and planners is the potential for findings to be used to create environments that are easier to wayfind in and more pleasant to interact with. As Gärling and Golledge (1989: 203) and Lynch (1976: xi) stated:

> knowledge gained about perceptual-cognitive processes may improve the quality of human environments through policy, planning, and design, to the extent that it tells us how to plan and design environments that do not interfere with the proper functioning of these processes.

> . . . [we] can better plan, design and manage the environment for and with people if we know how they image the world.

There is little evidence to suggest that the findings of cognitive mapping researchers are being used to improve urban planning. Part of the reason for this is that researchers have been poor at communicating their findings and their potential implications beyond academic journals. These journals are not widely read by city planners or those in a position to make concrete changes on the ground. As a consequence, there is a need to produce a set of formal guidelines that explicitly detail how findings to date can translate into planning good practice. These guidelines need to be inclusive in nature so that they take account of different groups within society such as children, older people, and people with disabilities.

Wayfinding, spatial searches and teaching

A large proportion of cognitive mapping research has focused on examining how people learn routes through a city. To date, however, little research has considered how best to teach people more effective and efficient strategies of route finding; how best to cope with feelings of disorientation or of being lost; or the most effective and efficient ways of guiding people through an environment (e.g. sign type/location). One exception to this claim is the work by Streeter *et al.* (1985). In their study, Streeter *et al.* demonstrated that subjects using tape recorded instructions for navigating between two unknown locations had shorter travel times and made fewer navigation errors than subjects who relied on unmodified road maps, modified road maps, and modified road maps and recorded instructions. All in all, we know of no formal guidelines that advise on these issues beyond highly specialized courses given to individuals taking part in particular sports such as orienteering or mountain walking, or orientation and mobility training for people with visual impairments. In these cases, the methods taught have been long established and fail to draw from the insights of cognitive mapping research. Traditional means of aiding wayfinding such wayfinding such as signage are poorly understood and work more from commonsense practice than proven efficient utility.

In addition, it has been hypothesized that cognitive mapping research can be of potential benefit to those involved in professional spatial searches (e.g., police, mountain rescue), by providing an indication of likely patterns of spatial behaviour of those being searched for. In relation to the police it is believed that cognitive mapping research can highlight the likely spatial behaviours of criminals, allowing police to predict approximate locations of the offender's residence and future targets. In relation to search-and-rescue it is hypothesized that research will identify likely movements upon becoming lost or going missing, allowing searchers to narrow the field and time of their search. In some cases, cognitive mapping researchers are now working with professional searchers and are increasing the effectiveness of searchers (e.g., Canter and Larkin, 1993, Cornell *et al.*, 1996), but these links needs to be further established.

Despite rhetoric of how cognitive mapping research could improve the teaching of geographic concepts, there have been no specific guidelines of how to instigate such improvements, instil more effective strategies of spatial learning amongst pupils, or how to design geographic media so that they are more easily understood. As such, such guidelines need to be formulated and their worth effectively marketed to the teaching profession.

Geographic media

Many recent projects have investigated how people learn and use geographic information derived through secondary sources. In part, the research is motivated by a desire to improve the efficiency and effectiveness of communication through geographic media. As yet, however, there have been few guidelines as to how to translate theory into practice. As a consequence, most geographic media are designed and implemented with little reference to cognitive theory. This is now slowly beginning to change, particularly in reference to cartography and GIS, where a number of researchers based mainly in North America have published widely on cognitive cartography. Consequently, cognitive theory is now starting to form the underlying framework for standard texts on map design (e.g., MacEachren, 1995). In relation to GIS, substantial work has investigated the notion of naive GISs for use by non-experts (Mark *et al.*, 1997). However, this work has yet to have a significant impact on the systems produced by major GIS software companies such as Environmental Systems Research Institute (ESRI). It is a similar story for other geographic media such as orientation and navigation aids, in-car navigation systems and virtual reality systems where developments are, at present, technology and ideas driven with little consideration of cognitive theory. Again, there is a need for those engaged in empirical studies of cognitive mapping to try and translate their findings into formal guidelines for use by practioners.

Conclusion

Cognitive mapping research seems set to flourish as a multi- and hopefully interdisciplinary endeavour. The agenda outlined in this final chapter, if followed, will provide substantial additional insights into how people learn, store, process, and apply spatial knowledge relating to the environment that surrounds them. Whilst some of these insights will be achieved if the empirical studies are undertaken and theoretically contextualized within a disciplinary isolation, it is our contention that much more progress will be gained from interdisciplinary collaboration. Such collaboration will force many of us to re-evaluate our ideas, to explore alternative propositions, and push back the boundaries of study by challenging us to move beyond disciplinary-rooted, preconceived notions of theory and practice. This means that central to any future agenda of cognitive mapping research must be the development of appropriate integrative frameworks for study (Gärling *et al.* 1991). Indeed, Evans and Gärling (1991) contend that the integration of disciplinary paradigms (e.g., environmental psychology and behavioural geography) may be a fruitful venture because it will force an analysis that reveals points of convergence and divergence among topics of scholarly inquiry. They argue that integration might help to illuminate correct and incorrect models and hypotheses, and to shed constraining or incorrect paradigmatic restrictions. As Hanson (1983: 35) argues:

> only through the process of communication among divergent points of view, will any semblance of convergence ever be achieved or maintained; through discourse the bits and pieces can be fitted into larger structures, and some degree of order emerges from the mess. . . . At the heart of this process of change is communication.

As the multidisciplinary make-up of the contributing authors, and the bibliography of each chapter illustrates, researchers within specific disciplines have much to learn from colleagues in other disciplines. This need for interdisciplinary research has become readily apparent to those researchers fortunate enough to attend the Cognitive Mapping Symposium in Fort Worth in 1997 and the symposiums sponsored by the National Center for Geographic Information and Analysis. Indeed many of these attendees are now engaged in cross-disciplinary projects (including ourselves). We would urge all those engaged in cognitive mapping research to similarly explore research beyond their disciplinary boundaries. Such exploration will maintain and expand the vibrancy of the field, and advance methodological validity and theoretical integrity.

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