7

Spatial Cognition, Cognitive Mapping, and Cognitive Maps

7.1 Background

Cognitive mapping is defined as "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 & Stea, 1973: 7).

Cognitive mapping is usually considered to be a subset of *spatial cognition* which can be defined as "the knowledge and internal or cognitive representation of the structure, entities and relations of space; in other words, the internalized reflection and reconstruction of space and thought" (Hart & Moore, 1973: 248). In turn, spatial cognition is sometimes seen as a subset of *environmental cognition,* which refers to "the awareness, impressions, information, images, and beliefs that people have about environments. . . . It implies not only that individuals and groups have information and images about the existence of these environments and of their constituent elements, but also that they have impressions about their character, function, dynamics, and structural interrelatedness, and that they imbue them with meanings, significance, and mythical–symbolic properties" (Moore & Golledge, 1976: xii). Thus, environmental cognition adds a set of *affective* components to the *cognitive* components emphasized in spatial cognition. These affective components include feeling, attitude, belief, value, and other emotional characteristics (Hart & Conn, 1991). Other definitions that include an emphasis on the term *place* instead of *space* are given in Kitchin (1994), but in this chapter we emphasize space, in all its multidimensionality, as the key concept.

The end product of a *cognitive mapping process* is called a *cognitive map.* Usually accepted to be a device that helps to simplify and order the complexities of human–environment interactions (Walmsley, Saarinen, & MacCabe, 1990), the cognitive map is essentially our individual model of the world in which we live.

The term cognitive map is now widely accepted in a number of disciplines. It had its origins in the work by Tolman (1948), who described why a rat running a maze in search for food might transgress the boundaries of the maze and go directly

(as the crow flies) to the food source. This shortcutting procedure attributed to Tolman's rat has become a standard indication that animals—and by analogy humans—can proceed directly from an origin to a destination without being forced to retrace a previously learned path. It was suggested later by Shemyakin (1962) that Tolman's rat chose a solution to the food search problem that would be quite logical if one viewed the task environment from a birdseye or *survey* view. This overview would provide simultaneous information about the starting location, the target destination, and the sets of potential paths linking origin with target destination.

By the mid 1960s, geographers had become exposed to this inherently appealing concept of the representation of spatial and other environmental information in the mind in some maplike form. Behavioral geographers adopted the idea, with Gould (1963) suggesting that people formed *mental maps* of their environment. He illustrated this concept by producing sets of place-preference surfaces that were constructed from rankings of the residential desirability of places and regions in different countries (Figure 7.1). By the end of the 1960s, other behavioral geographers, such as Downs (1970a, 1970b) and Golledge, Briggs, and Demko (1969), had extended the idea of the mental map/preference surface into the broader domain of spatial cognition. Downs (1970b) identified cognitive dimensions of shopping centers, while Golledge and colleagues examined point, line, and areal components of cognitive maps. For example, Zannaras (1968) discussed the idea of perceived neighborhoods; Golledge et al. (1969) and Briggs (1972) examined the nature of cognitive distance and the role that cognitive distance played in wayfinding; Briggs (1969) used preferences and cognitive attributes to define place utilities for shopping centers; and Golledge and Rushton (1972) introduced the idea of using metric and nonmetric multidimensional scaling (MDS) to recover the latent spatial structure underlying people's preference and evaluations of proximity or similarity, constructing from these the first examples of cognitive configurations—that is the maplike externalization of implied or latent spatial knowledge derived from MDS output. Other behavioral geographers, working together or with psychologists (Blaut & Stea, 1969; Beck & Wood, 1976a, 1976b; Hart & Moore, 1973; Downs & Stea 1973; Cox & Golledge, 1969), introduced and investigated the use of the concept of cognitive mapping in such disparate research as: determining whether young children could cognize and understand maps and aerial photographs; examining children's behavior in play environments; analyzing spatial concepts such as proximity, direction, and orientation; and examining the rationality of observed spatial behavior when it was compared to behavior mapped into configurational representations of different environments.

To the geographer the concept of a cognitive map was a logical one. Those interested in spatial decision-making behavior had already argued that spatial behavior was most frequently *boundedly rational* (Wolpert, 1964) or *satisficing,* rather than being utility maximizing and optimal. The argument was advanced that what was perceived to exist and what was already experienced or known was often more important in the decision-making process than the objective reality of a problem situation. Since behavior in space was seen to be the outcome of decision-making processes that rely on combining stored information with ongoing experience, the significance of the cognitive map as the mechanism for storing, recalling, and using such information was an appealing one and began to spread widely.

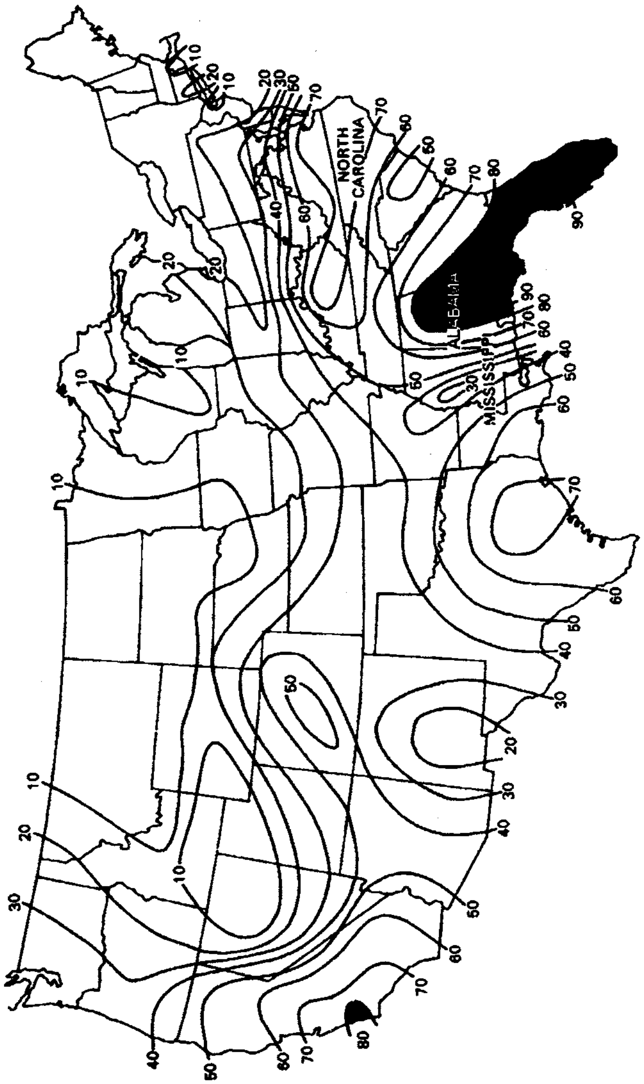


Figure 7.1. "Mental maps" of preference for places—the Alabama view. *Source:* Gould & White, 1974:101.

7.2 Characteristics of Spatial Cognition

7.2.1 A Developmental Base

Much of the initial research in environmental cognition and later spatial cognition (particularly among geographers and environmental design professionals) was heavily influenced by the development sequence theories expressed in Piaget and Inhelder (1967) (Figure 7.2). In particular, their work on the child's conception of space was extensively used. In this developmental context, they identified several stages of perceiving:

1. The first stage is one of *vague awareness,* when the perceiver is aware that something is impinging on the senses and that the sensory input appears to be coming from specific segments of the environment. At this stage, the geographer might develop expectations that the initial sensory input may relate to physical structure, location, or potential use of perceived objects.
2. At the second stage of this developmental process, *spatial characterzstics* are added to the *perceptual set.* Thus, the object is given an *existence or location* in space and time and is fitted into a *class or category* of objects that may have similar spatial characteristics. At this stage, the beginning of differentiation among objects on the basis of spatial characteristics commences.
3. A third stage involves *recognizing* the *relevantparts* of the *perceptual objects* and being able to *specify* these components. Such components, or attributes, become differentiating characteristics used to distinguish a given object from others in its class. Thus, identity, size, condition, color, function, and so on, are allocated to a stimulus object.
4. A fourth stage is one of *identification*, or more realistically, the *attachment of meaning* to the stimulus object. The meaning and significance of an object apparently influence its durability and usefulness to an observer. Once an object becomes an identifiable entity, it may thereafter occupy a regular niche in the cognitive structure of an individual. It, along with other members of the set, can be used as a reference point against which new stimuli are matched.

To elaborate on the process of spatial cognition, we now turn to a brief dis-

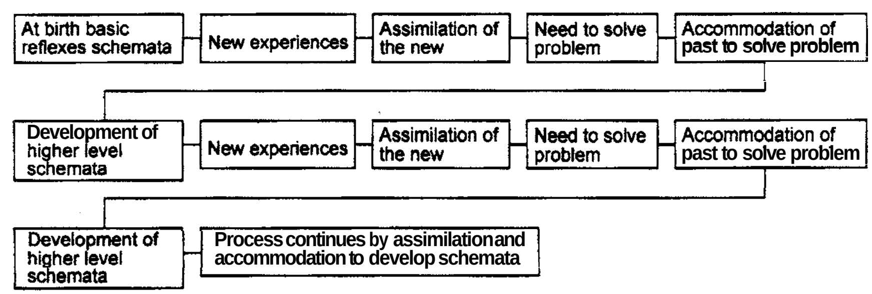


Figure 7.2. Sequence of spatial understanding. Source: Kaluger & Kaluger, 1974:75.

cussion of how information is coded, stored, reconstructed, and processed in memory. Lloyd (1982) reviewed a number of approaches associated with spatial cognition. These included radical image theory, conceptual propositional theory, and dual-coding theory. His findings are summarized in the following sections.

7.2.2 Radical Image Theory

Radical image theory postulates that the perceptual processes reduce information to a simpler and more organized form. The form suggested is called an *image*. Images are generated from underlying abstract representations. Images are seen to be pictorial in nature. This theory suggests that images, once formed, are wholes that may be compared to percepts in a template-like manner.

Evidence for the existence of radical image theory comes largely from studies of reaction times. Such studies suggest that images are scanned by the "mind's eye" in the same way one would use vision to scan an object. Response times for determining which of two named objects is larger were found to be inversely related to the actual size differences between the objects. For example, the response time to differentiate between a cat and a donkey was faster than that taken to differentiate between a goat and a horse. Similarly, response times for comparing which of two places is further north are found to be proportional to the difference in latitude between the places. In addition to response-time studies, however, other supporting evidence comes from rotation studies. Shepard and Metzler (1971), for example, undertook an experiment in which the results showed that response time to the question of whether or not two objects were the same was proportional to the rotational angle with which members of the pairs of objects were viewed.

7.2.3 The Conceptual Propositional Theory

This theory suggests that verbal and visual knowledge are stored as abstract conceptual propositions. Unlike imagery theory, which seems on the surface to be more tied to visualization, this theory has no specific tie to any particular sensory modality. It argues that part of the meaning of a concept can be represented in terms of its connections to other concepts. In other words, the concept is embedded in a *configurational meaning structure*. The closer together concepts are in a propositional network, the better cues they are for each other's recall.

Evidence for the existence of this theory came from experiments showing that, when subjects were given prior labels or meanings for squiggley designs ("droodles"), they could better reconstruct the pictures that the "droodles" were supposed to represent (e.g., Label: "Worm crawling over a razorblade"; Image: slices of worm piling up on one side of the blade and the balance of the whole worm on the other side).

7.2.4 Dual-Coding Theory

This suggests that there are two interconnected memory systems—verbal and imaginal. These interconnected systems operate in parallel (Paivio, 1969). For example, this theory suggests that pictures and concrete words that are easily imageable may be represented in both *verbal* and *visual* memory, but abstract material is represented in the verbal system. From this point of view, imageability makes things easier to remember.

A long debate has taken place in cognitive science between the image theorists and the conceptual–propositional theorists. This controversy impacted research on cognitive mapping in many disciplines. In geography, image theorists were prone to accept the idea that environmental knowledge was represented in maplike form and that it could be recalled and or externally represented by cartographic-like presentations (e.g., sketch maps or distorted Euclidean configurations). Conceptual–propositional theory had a significant impact on studies concerning the development of spatial knowledge. Anderson (1982) suggested that spatial knowledge consisted of a declarative base and a set of procedural rules that specified how components of the declarative base could be linked together. This was seen by some geographers to be in opposition to many of the spatial cognition theories that were developmentally based, and they argued that spatial knowledge evolved through developmental stages as well as through different metric structures. Today geographers interested in spatial cognition still evince no clear preference for one or the other of these theories.

In general, interest in spatial cognition has permeated a number of areas of human-geographic research. Specific problems that have generated significant geographic input include: the examination of cognitive distance and the asymmetric distances that appear to typify this concept; the warping of space because of asymmetric distance effects; the examination of hierarchical structures at different scales and at different levels of generalization; the concept of regionalizing at the macro level and chunking at the micro level; and the concept that the critical part of environmental structures includes the designation and definition of anchorpoints. In the sections that follow, as we discuss the nature of cognitive mapping and cognitive maps, we explore some of these concepts.

7.3 Cognitive Maps and Cognitive Mapping

7.3.1 Cognitive Mapping

We now turn to consider more structured approaches using a variety of experimental methods aimed at uncovering and representing the cognitive structure of both small-and large-scale environments.

The *process* of *cognitive mapping* is a means of structuring, interpreting, and coping with complex sets of information that exist in different environments. These environments include not only the observable physical environment, but also memories of environments experienced in the past, and the many and varied social, cultural, political, economic, and other environments that have impinged both on those past memories and on our current experiences. The nature, structure, and content of these many environments also influence our expectations whether these be in terms of immediate shortrun expectations that are essential to the more frequent episodes of our daily activity patterns (e.g., route selection in a daily trip to work or shopping), or those less-frequent episodes with greater temporal intervals between their occurrences (e.g., annual holidays).

This mapping process requires each individual to undertake a cognitive taxonomic process that is culturally constrained and that results in the filtering of the varied "to whom it may concern" messages emanating from the many environments in which we live.

Unlike much of the literature on perception, which emphasizes the acquisition of information through the senses in the presence of a stimulus, it is generally accepted that the process of cognitive mapping has no tie to a particular sensory modality but, instead, spans all of them.

7.3.2 The Mapping Process

The first assumption is that information extracted from large-scale external environments exists in an undetermined psychological *space*. This is the space in which characteristics, meanings, and configurational relationships about elements in the world are held as mental constructs. A second assumption is simply that individuals must have *internal knowledge* about external environments in order to exist in them. A third assumption is that internal representations will be part *idiosyncratic* and part *common* in structure (i.e., people in general will know the difference between a street and a stream, the significance of a traffic light, and the difference between privately and publicly owned transportation systems).

As indicated in Table 7.1, Golledge (1976c) has categorized methods for extracting and representing imagery into the following classes:

- Experimenter observation in naturalistic or controlled situations.
- Historical reconstructions.
- Analysis of external representation.
- Indirect judgmental tasks.

The above conceptualization includes a range of external representational formats such as verbal reports, sketch maps, tables, profiles, word lists, analog models, slides, novels, poems, paintings, diaries, interviews, protocols, toy play, proximity judgments, scalings, and creative stories or writings. Thus, at various times individuals have been asked and have provided an impressive array of written and oral descriptions, pictures, sketches, cartographic representations, and grouped or clustered, scaled, and otherwise modified or transformed, bits of environmental information. These have come from experiments using recall of interpoint distances and analysis by multidimensional scaling, from tasks requiring haptic (touch) exploration of layouts, from solving problems requiring auditory localization, and from simple wayfinding tasks.

One of the most widely referenced comprehensive works using a variety of the above methods was Lynch's (1960) pioneering work *The Image of the City*. *In* a later section we examine his concepts in detail and expand on them at different spatial scales.

TABLE 7.1.
Methods for Extracting Environmental Cognition Information

Method	Procedure	Subject Skill	External Representational Form	Example
Experimenter observation in naturalistic or controlled situations	Experimenter observes or tracks movement through actual environments (e.g., crawl patterns, search behavior overt spatial activity, wayfinding)	Cognitive Concrete Psychomotoric	Observations Reports Maps Tables	Lynch (1960) Marble (1967) Ladd (1970) Jones (1972) Devlin (1973) Zannaras (1973)
	Experimenter infers degrees of cognitive knowledge from behavior in unstructured "clinical" situations	Cognitive Concrete Motoric	Charts Profiles	Werner (1948) Piaget and Inhelder (1956) Hart (1974)
	Subjects reveal environmental knowledge in the process of sorting or grouping elements of actual or simulated environments	Cognitive Abstract Relational	Lists Tables Composite maps	Downs (1970a) Wish (1972) Zannaras (1973) Golledge et al. (1975)
	Subjects adopt roles or perform acts in simulated and/or real environments	Cognitive Abstract	Photographs Tables	Ittelson (1951) Milgram (1970) Acredolo (1976)
	Subjects arrange toys or objects representing environmental elements or model environments, and experimenter observes the sequence of acts in positioning elements and/or using the environment	Cognitive Concrete Motoric	Analog models	Piaget et al. (1960) Blaut and Stea (1969) Laurendeau and Pinard (970) Mark (1972) Hart (1974)

(continued)

TABLE 7.1 *(continued)*

Method	Procedure	Subject Skill	External Representational Form	Example
	Subjects draw sketches or sketch maps representing environments	Affective Graphic Relational	Pictoral sketches Sketch maps Quantitative and structural analyses	Lynch (1960) Shemyakin (1962) Stea (1969) Appleyard (1970) Ladd (1970) Moore (1973) Wood (1973)
	Subjects arrange toys or make models representing environments	Affective Cognitive Concrete Motoric	Models Arrangements of toys	Piaget and Inhelder (1967) Blaut and Stea (1969) Mark and Silverman (1971) Stea (1973) Hart (1974) Stea (1976)
	Subjects show existence, location, proximity, or other spatial relations of environmental elements; use of symbols to represent such elements	Cognitive Graphic Abstract Relational	Base maps with overlays Notation systems	Lynch (1960) Thiel (1961) Appleyard (1969) Wood and Beck (1990)
	Subjects are asked to identify photographs, models, etc.	Affective Motoric Abstract Relational	Verbal Protocols	Piaget and Inhelder (1956) Laurendeau and Pinard (197 Stea and Blaut (1973) Zannaras (1973)
Indirect judgmental tasks	Selection of constructs that reveal environmental information; adjective checklists, semantic differentials, repertory grid test, etc.	Cognitive Abstract Relational	Word lists Tables Graphs Grids	Kelly (1955) Downs (1970a) Honikman (1976) Harrison and Sarre (1976) Goiant and Burton (1969)
	Paired proximity judgments and other scaling devices that allow specification of latent structure in environmental information	Cognitive Abstract Relational	Maps Tables	Briggs (1973) Lowrey (1973) Golledge et al. (1975) Cadwallader (1973a) Golant and Burton (1969)
	Projective tests (e.g., T.A.T.)	Affective Abstract Relational	Verbal stories	Burton et al. (1969) Saarinen (1973b)

7.3.3 Cognitive Maps

A *cognitive* map may be defined as "long-term stored information about the relative location of objects and phenomena in the everyday physical environment" (Gärling, Böök, & Lindberg, 1979:200). Cognitive maps thus represent information about environments that are either known to exist or are imagined but not necessarily present. Any given map, therefore, may be a mixture of information received at quite disparate time periods, and at any particular point in time may be incomplete, more or less schematized, or distorted, and may contain fictional or hypothetical information, or relics of the past which no longer exist.

This model of reality is a complex one and should not be interpreted as a simple one-to-one internal mapping of discrete things that exist in an external environment. Thus, it is not assumed that a cognitive map is an equivalent of a cartographic map, nor is it assumed that there is a simple Euclidian one-to-one mapping between a piece of objective reality and a person's cognitive map of that reality. Cognitive maps are generally assumed to be incomplete, distorted, mixed-metric representations of real-world environments, but they can also be maps of the imaginary environments represented in literature, folk tales, legends, song, paintings, or film.

Even simple tasks, like going from home to work, to school, or to a store, or directing newcomers to places they have never been, require information to be stored, accessed, and used in a convenient and easy way. To perform such tasks it is necessary to use one's memory representations of spatial information—that is, one's cognitive map. Over the past three decades, scientists in a variety of fields have been examining questions relating to the nature of these cognitive maps, the process of acquiring and forming such mappings, and their role in everyday spatial activity. In what follows, we draw on concepts, theories, and empirical evidence from a variety of disciplines as a means of examining the process of developing cognitive maps and illustrating the product of such knowledge acquisition.

7.4 Cognitive Map Metaphors

7.4.1 Basic Metaphors

With more widespread acceptance, the concept of a cognitive map has become more clearly and more accurately defined. In the course of such clarification, the metaphor most often used in describing cognitive maps has changed.

Gould's (1963) early use of the preference surface metaphor for mental maps was next replaced by the rubber sheeting metaphor favored by Golledge et al. (1969), Golledge, Rayner, and Rivizzigno (1975), and Tobler (1976) when using nonmetric multidimensional scaling or trilateration procedures to construct cognitive configurations (Figure 7.3). S. Kaplan's (1973, 1976) development of an information-processing metaphor led to further elaborations of the cognitive map as a computerized data base and processing system. Concurrently with these metaphors was the less favored, but appealing, notion of a cognitive map as an internal cartographic-like representation or indeed as an atlas (Lieblich & Arbib, 1982). Cognitive scientists then suggested that cognitive maps were list processors or images,

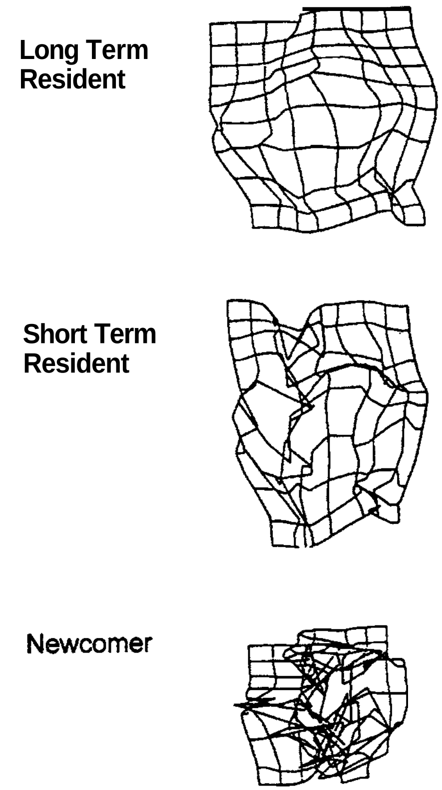


Figure 7.3. Distorted grids as examples of rubbersheeting.

metaphors that were closely examined for geographic relevance by Lloyd (1982). The rubber sheeting and cartographic representation metaphors were linked by Tobler's (1976) elaboration of the geometry of mental maps and by his development of bidimensional regression procedures for correlating objective and subjective configurations (Table 7.2).

Cognitive maps that include not just spatial information but also attributive values and meanings (Wood & Beck, 1990) provide yet another metaphor (i.e., the cognitive map as a belief system). The notion that cognitive maps involve the integration of images, information, attitudes, and values was also offered by Spencer and Blades (1986). In other words cognitive maps are not to be thought of as isolated entities but as being contextual, dynamic, and providing the interface mechanism between sensed information and behavior.

Golledge and Timmermans (1990) suggested that cognitive maps are a series of knowledge structures consisting of different levels of detail and integration. These knowledge structures develop with age and education and, in a sense, may be described more by the metaphor of a cognitive atlas than a cognitive map (see also Lieblich & Arbib, 1982: 640). From this atlas, individual cognitive maps can be resurrected and used for specific tasks (Golledge et al., 1985)

TABLE *7.2.*
Bidimensional Correlations between Objective and Subjective Configurations (Control Group of Long-Term Residents)

Control Group of Long-Term Residents	Bidimensionai Correlation between Objective and Subjective Maps
C1	0.891
C2	0.952
C3	0.855
C4	0.944
C5	0.938
C6	0.882
C7	0.889
C8	0.901
C9	0.709
C10	0.882

Source: Golledge, Rayner et al., 1982.

The evolution of understanding of the concept of cognitive maps is now at the stage where it is assumed that they represent the store of knowledge an individual has about an environment. Implicitly and explicitly, they contain spatial relational data along with environmental attributes and individualized and socioculturally conditioned beliefs, values, and attitudes. Context-specific and problem-specific cognitive maps can be constructed at will, each having a particular space–time context and containing some common information (e.g., common anchorpoints) and some idiosyncratic or personalized elements. The common elements facilitate communication with others about the characteristics of an environment; the idiosyncratic elements provide the basis of the personalized responses to such situations.

7.4.2 Cognitive Maps as Internal GIS

The idea that sets of environmental information might be represented as layers with differential attribute weights attached to hierarchically organized components within and between layers promotes yet another metaphor of the cognitive map. Recently Golledge and Bell (1995) suggested that the cognitive map should be viewed as an internalized geographic information system (GIS). In both systems, data are symbolized and coded. Decoding and recall are often focused on selective components of the total knowledge set. The recalled information can be represented in a variety of verbal, graphic, acoustic, or haptic forms. A range of manipulative processes can be accessed to help solve a task and produce a behavior (Figure 7.4).

It is difficult to think of a single functionality embedded in the GIS that does not have a parallel in human-information processing capability. The one difference, however, is that in the GIS, once activated, a manipulative procedure should be carried out quickly and accurately, whereas in humans, although the ability to perform a manipulative activity may in principle be within their intelligence realm, there are many personal and societal barriers that may induce error and inhibit the use of such a skill. Thus while the GIS is a practical tool for processing, analyzing, and

Constructing Gradients and Surfaces
Layering
Regionalizing
Decomposing
Aggregating
Correlating
Evaluating Regularity or Randomness
Associating
Assessing Similarity
Forming Hierarchies
Assessing Proximity
Measuring Distance
Measuring Directions
Defining Shapes
Defining Patterns
Deterimining Cluster
Determining Dispersion

Figure 7.4. Samples of manipulative processes used in cognitive mapping and GIS.

displaying spatial information, the comparable human processes may be error prone and poorly developed. And given the extensive literature on development and life-span theories of intellectual growth, one would expect these abilities to be more or less present depending on age and education.

7.4.3 Debatable Alternatives

In geography, different views on the cartographic nature of cognitive maps are elaborated in a debate between Graham (1976, 1982) and Downs (1981a,1981b), with the latter clearly identifying the metaphoric significance of the use of the term "map." With respect to this and other related debates, Kitchin (1994) summarizes the four critical debatable questions as follows:

1. "Is it the case that the cognitive map is a cartographic map (explicit statement)?
2. Is it the case that the cognitive map is like a cartographic map (analogy)?
3. Is it the case that the cognitive map is used as *if it* were a cartographic map (metaphor)?
4. Is it the case that the cognitive map has no real connections with what we understand to be a map (i.e., a cartographic map) and is neither an explicit statement, analogy, or a metaphor but, rather, an unfortunate choice of phrase: 'a *convenient fiction'* (Siegel, 1981), or in effect, just an hypothetical construct." (Kitchin, 1994:3)

The argument for the cognitive map being a map (explicit case) derives from the work of O'Keefe and Nadel (1978), who argued that the hippocampus, a part of the brain associated with long-term memory, *is* a cognitive map. With today's emphasis on neural mapping, there is renewed support for this idea. The cognitive map interpreted as analogous to a cartographic map generally relies on the argument that both have Euclidean spatial properties. Although there has been substantial empirical evidence that cognitive configurations constructed in two-dimensional Euclidean spaces correlate highly with Euclidean representations of objective reality (Golledge, 1975; Golledge et al., 1975; Golledge & Spector, 1978; Gärling, Book, & Lindberg, 1985), there is also much evidence that, for the most part, cognitive maps can violate some if not all of the basic Euclidean axioms (Gale, Doherty, Pellegrino, & Golledge, 1985). The elaboration of the fact that cognitive maps exist in multimetric spaces (Baird, Wagner, & Noma, 1982), along with some evidence that curvilinear spaces are perhaps more suited to represent the spatial relationships contained in cognitive maps (Golledge & Hubert, 1982), have caused this debate to lose force.

The use of a cognitive map as a *hypothetical construct* or *convenient fiction* implies that the use of the term map provides no literal meaning. Moore and Golledge (1976: 8) suggest that "as a hypothetical construct the term cognitive map and its approximate synonyms refer to covert, nonobserved processes and organizations of elements of knowledge." As principles of symmetry and transitivity, for example, are violated (Tversky, 1981; Baird et al., 1982), then the term "map" becomes a convenient fiction that provides a hook on which to hang interpretive structures but that is tied to no particular representational form.

But, for better or for worse, from medical science to engineering sciences, from the humanities to the social sciences, the term cognitive map is now widespread.

7.5 The Use of Cognitive Maps

7.5.1 Cognitive Maps and Spatial Behavior

If we accept the broadest definition of a cognitive map (i.e., as our internal model of the world in which we live), then cognitive maps play a role in all behaviors, both spatial and nonspatial.

Traditionally, geographers have focused on the role that cognitive maps play in deciding what overt spatial behaviors are to be performed in any problem-solving situation. This means that the cognitive map becomes a critical component of general spatial problem-solving activity. It is embedded in the process of spatial choice and decision making. This role was made explicit by Briggs (1973) after being implicitly recognized by geographic researchers in the 1960s. The cognitive map plays a role in deciding what choice to make and whether one has to travel or not to achieve a goal; it helps decide where to go, which route to take, and what travel mode to take to get there. These questions have been addressed in a variety of contexts such as consumer behavior (Coshall, 1985a, 1985b; Timmermans, 1979; Pacione, 1978, 1982). Many other examples can be found in a review by Timmermans and Golledge (1990).

Cognitive maps have also played a role in research on movement patterns both in a migration and a mobility context (Johnston, 1972; Briggs, 1973), as well as for movement associated with recreational and leisure choice (Pigram, 1993; Golledge & Timmermans, 1990). The latter have exhaustively reviewed the use of cognitive maps in many different environmental situations from establishing preferences for shops, shopping centers, apartments, and modes of transportation, to the planning of specific residential environments, and the use of cognitive maps as devices to aid wayfinding and navigation. They are in common use when one is examining the learning of unfamiliar layouts, at scales varying from the neighborhood to the international arena, and they are essential for the development of any examination of the nature and degree of fundamental spatial concepts, such as location, distribution, pattern, shape, direction, orientation, region, hierarchy, network, and surface. In the sections that follow we explore specific examples of some of these uses.

7.5.2 Cognitive Maps as Planning Aids

Often it has been suggested that cognitive maps are an essential part of the making of policy and the development of plans. This belief is held alike by geographers and planners. The underlying hypothesis here is that the quality of human decision making (whether individually or in congress) will be improved as the quality of knowledge about the task environment is improved. And if we are aware of people's preferences for, perceptions of, and attitudes toward different environments, then better matches between planning and policy making and the felt needs of the populations, for whom plans are being made, can be achieved (Gärling & Golledge, 1989).

This sentiment had been expressed much earlier by Lynch (1976) whose written work often stressed that better planning, design, and management of environments could be undertaken *for* people if they were done *with* people (i.e., participatory planning). Improved modeling, Lynch argued, would also occur if we understood the images of the world in which people perceive they live and the world in which they would like to live. Aitken, Cutter, Foote, and Sell (1989) more recently reiterated this sentiment, suggesting that the most adequate planning in the context of the built environment will reflect the behavioral propensity of residents and other users. Knowing something about people's perceptions, preferences, and images provides information that complements the designers' and planners' intuition, guidelines, and legal restrictions.

7.5.3 Cognitive Maps and Disability

One area where this advice is being taken into consideration is the design of environments to meet the needs of populations with disabilities (Passini, 1984). Investigation of the policy guidelines needed to encourage the development and improve the quality of life for the deinstitutionalized mentally retarded constitutes yet another area of successful integration of policy design and cognitive mapping (Golledge et al., 1979a and 1979b; Golledge, Richardson, Rayner, & Parnicky, 1983), as is the policy area represented by the work of Carpmen, Grant, and Simmons (1985) who explored the effects of hospital design upon the wayfinding activities of the hospital staff, patients, and visitors. In a similar environmental context, Ulrich (1984) discovered that rearranging hospital beds in a room could increase the ambiance of the room and reduce convalescent time for hospital patients.

In addition to the mentally retarded and the hospitalized other special populations that have benefited from research focused on cognitive maps include children's environments (Hart, 1981, 1984) and elderly environments (Ohta, 1983; Kirasic 1991; Kirasic, Allen, & Haggerty, 1992; Golant, 1982). Some of this research is developed at length in Chapters 14 and 15 of this book.

7.5.4 Cognitive Maps and Crime

Cognitive mapping also has become a useful device in combating criminal activity. Rengert (1980) and Rengert and Waselchick (1985) have examined the cognitive maps of residential burglars. More recently, Rengert (1994) has developed representations of what people think they know about the location of illegal drug sales and different forms of violence in urban areas. Canter and Larkin (1993) have used cognitive maps to track down criminals for the police. They showed the limited range of cognitive maps and commented on their circularity. Extrapolating to a real-world setting, they successfully predicted the probable location of a serial rapist, thereby allowing the police to trap the perpetrator. It has been suggested also that cognitive maps produced by friends and acquaintances may be useful in the process of tracking down missing persons.

Even though we have presented a variety of alternative conceptualizations of the process of cognitive mapping and the nature and use of cognitive maps, it should be apparent that no definitive answer exists at this stage to the question of how best to describe cognitive maps. It appears that the selection, coding, storage, decoding, reconstruction, and use of cognitive information potentially are fertile topics for further geographic investigation.

7.6 Methods for Externally Representing Cognitive Maps

7.6.1 Externalizing Information: Cognitive Configurations or Spatial Products

The use of many different metaphors for the term cognitive map has produced continuing confusion in the various disciplines that use the concept. Perhaps the most enduring of these is the notion that a cognitive map must have the same properties as a cartographic map.

The early 1970s saw much cross-disciplinary discussion about whether or not such a configural matching existed, with the overwhelming evidence pointing to the fact that cognitive maps were *not* simply internalized cartographic maps. In an early effort to differentiate between the internalized cognitive map and the external representation, Golledge (1975) differentiated between the cognitive map as the internal representation and a "cognitive configuration" as an externalization of information gleaned from a cognitive map. The cognitive configuration could be task specific and could have more or less properties of conventional cartographic maps. Thus, sketch maps were considered primarily nonmetric cognitive configurations, whereas multidimensional scaling outputs were considered to be more metric cognitive configurations. Although this differentiation continues to be used in some geography literature, in other disciplines it is more common to differentiate between the internal representation (cognitive map) and an externalization called a "spatial product"—a term used by Liben (1981) to describe an externalized representation.

Methods developed to recover cognitive configurations are as varied as the purposes behind such research. One of the earliest methods suggested by Lynch (1960) was the use of sketch map techniques (Figure 7.5). Other procedures

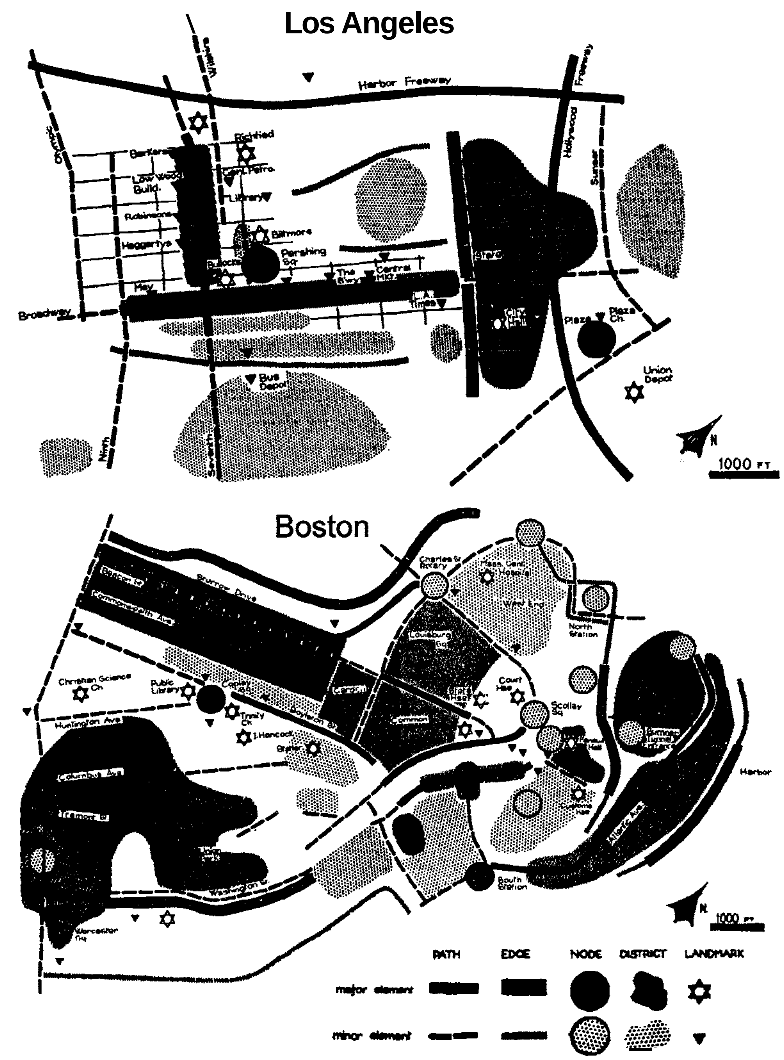


Figure 7.5. Sketch maps of Los Angeles and Boston. Source: Lynch, 1960.

include: requesting subjects to image scenes from different perspectives; to list the best recognized or most frequently visited places; to reconstruct images of unseen objects; to estimate lengths of streets and angles of intersections; to use various unidimensional scaling procedures to obtain interpoint distance judgments; and, by using proximity judgments in a paired comparison context, to develop cognitive distance estimates from multidimensional scaling configurations. More recently, table top modeling, interactive computer experiments, and even the use of aerial photos, all appear to be capable of producing reasonable configurational representations.

7.6.2 Sketch Maps

Sketch mapping has long appeared to be a useful instrument for recovering information about environments, if the maps are properly interpreted. This technique suffers from the assumptions that the subject understands the abstract notion of the model and its relationship to the real world has the sufficient motor skills to portray accurately in sketch format what she or he is attempting to complete, and that a uniform metric is applied across the sketched information. Where violations of these assumptions occur, the best information that can be obtained would be topological in nature.

Although rarely undertaken as a solo exercise anymore, sketch mapping is used often in conjunction with other methods for extracting cognitive information about environments. Although sketch maps usually cannot provide reliable metric information, they can provide information, such as the number of features included on the map, the mix of point, line, and area features used in the sketch, an indication of dominant functions in a locale as perceived by the sketcher, and ordinal information such as the sequence of cues along routes or the sequence of segments and turns along routes. Additional information can be obtained from the system constructed as the basis for the sketch, particularly the regularity or irregularity of frameworks such as street systems and environmental features. Frames of reference used in local environments can also be inferred from sketches.

It has been reported often that the amount of material on sketch maps and its accuracy increase over consecutive trials. An example of this can be seen in Figure 7.6, which shows sketches of a route in an unfamiliar environment that was learned in a forward and reverse direction on five consecutive days by a 12-year-old boy. It is clear that the sketch went from a minimal representation to a quite accurate and comprehensive representation by the end of the 10 trials (5 forward, 5 reversals). Although in the early stages there were characteristics such as segment reversals and directional errors, by the fifth trial these were generally eliminated, and the sketches converged on accurate rendition of the task environment.

Blades (1990) has provided evidence to show that the sketch-mapping procedure is quite consistent over time. This does not imply that metricity accrues to the sketch, but it does imply that when used in a multiple trial–task situation, confidence can be placed in the sketch-mapping procedure. Sketches can, therefore, indicate the quantity of information that comes readily to mind when one is given a task

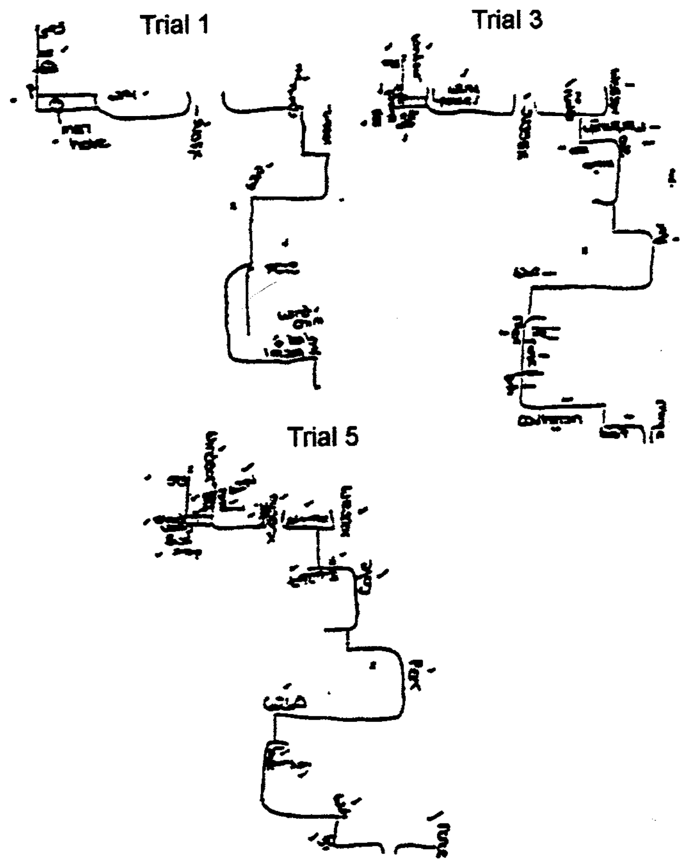


Figure 7.6. Sketch maps after multiple learning tasks.

of representing local knowledge within specified time constraints, and if the environment is known, the sketches produced are reliable—that is, they are consistent over time.

As with cognitive maps generally, sketches are incomplete, distorted, mixed-metric, or nonmetric modes of representation; they are schematized and are often full of blank spaces and nonconnected networks. In examination of selections of sketch maps for a given environment, frequency counts of the appearance of different features allow the development of composite maps on which are located those places known best by the largest number of people. The classic example still remains the map constructed by Milgram and Jodolet (1976) representing multiple levels of a common hierarchical knowledge structure of Paris, France. A listing of the most commonly cited landmark cues in selected urban areas is given in Figure 7.7.

Pa ris [a] (1 970)		Columbus [b] (1974)	Santa Bırbara [b] (1978)	San Francisco [c] (1989)
1.	Etoile	Graceland Shopping Ce ter	La Cunbre Plaza	Fisherman's Wharf
2.	Notre Da me	Eastland Shopping Cen r	Santa Barbara Aiirport	Chinatown
3.	Tour Eiffel	Westland Shopping Cer	County Court Hou al	Golden Gate Bridge
4.	Seine	Lazarus, downtown	Missior S: anta Ba ara	Union Square
5.	Bois de Boulogne	Port Columbus	UCIEN Bui lding at CSB	Cable Car Ride
6.	Champs Elysees	I-71 N and I-270 intersection	Golera Be ach	Golden Gate Park
7.	Concord e	Veterans Memorial Auditorium	FEDMART Goleta	Museums/Galleries
8.	Louvre	Ohio State Fairgrounds Coliseum	Santa Ba rbra Har or	Alcatraz
9.	Chaillot	Western Electric, East Industrial Plant	Botanica Grdens	Union Street
10.	Cite	I-71 S. and I-270 intersection	Robinson's Department Store	Broadway/North Beach
11.	Luxembourg	Northland Shpping Center	Dos Pueblo: Hligh School, Goleta	Japantown
12.	Montmartre	N. High Street and I-161 intersection	Arlington Thatre	Mission District
13.	Montparnass e	Columbus State Hospital	Santa Barbra Museum of Art	Haight-Ashbury
14.	St. Germain	Anheiser Busch Brewery	Magic Lanten Theatre, Isla Vista	Live Theatre
15.	St. Louis	Morse Road and N. High Street intersection	Picadilly Sqiare	Castro District
16.	St. Michel	Lane Avenue and N. High Street intersection	Bank of Amrica, Is Vista	The Zoo
17.	Tuileries	Capital University	YMCA	Sports Eve
18.	Bastille	Ohio Historical Society	Rob Gym at UCSB	Symphony/ ncert
19.	Buttes C nt	Riverside Hospital	Greyhoun Bs De	Opera

[a] Rake by importan Data from Milgram and Jodelet (1976).
[b] Not ranked by impo nce. Unpublished data from surveys conducted by Golledge.
[c] R ake by visitation Data from Economics Research Associates' 1989 Survey of Sa n Fa c iso Vi sitors.

Figure 7.7. Lists of major landmarks in iti es.

7.6.3 Multidimensional Methods

sophistication in specifying the design of experiments for recovering cognitive information, and the use of powerful *multidimensional methods,* have given researchers a great deal of confidence in their ability to recover useful spatial information from what appear to be nonspatial knowledge structures. Many people have proven to be amazingly accurate in remembering the essential details of the spatial layouts of large-scale environments with which they are familiar (Golledge & Spector, 1978; Golledge, Rayner, & Rivizzigno, 1982). To test this contention, emphasis placed on the development of methods for comparing recovered configurations with some representation of objective'reality (e.g., cartographic or other such representations).

As an example of the use of multidimensional methods for recovering and interpreting cognitive spatial information, we now examine a set of experiments designed to recover cognitive spatial information and examine it for accuracy of its spatial properties. This set of experiments was undertaken in the city of Columbus, Ohio (Golledge, Rivizzigno, & Spector, 1974). Over a period of 9 months, sets of subjects (subdivided into newcomers, intermediate residents, and long-term residents) participated in an experiment involving the grouping or clustering of pairs of locational cues and the allocation of scale scores based on their subjective estimates of the relative proximity of each pair. The scale scores obtained from each subject were analyzed using a nonmetric multidimensional scaling algorithm KYST (Kruskal, Young, & Seery, 1976) in which interpoint distance estimates proportional to the scale scores were developed. These were then used in an iterative procedure based on a gradient method for achieving convergence, and a two-dimensional point configuration of the locations of the target cues was developed. The interpoint distance information contained in this configuration was monotonically related to the original scale scores, and the fit between the data and the developed configuration was assessed through a monotonic regression procedure, which minimized the error variances between recovered points and the original scale scores. To produce interpretable configurations, an initial configuration representing the actual locational arrangement of the cues in the city was used as the starting (initial) configuration. Thus, the final configuration outputted from the scaling program represented a distortion of the actual pattern based on the proximity scales developed by each individual. Samples of such configurations showing different types of axial biases are shown in Figure 7.8. The stress (badness-of-fit) statistic in this way becomes an interpretable goodness-of-fit statistic proportional to the error obtained in the outputted configuration. Thus, by using a measure of spatial correlation, it illustrates the extent to which (after rotation, translation, and uniform stretching or shrinking of axes) the cognitive and objective configuration coincided.

Each two-dimensional output configuration obtained for each subject was matched with a two dimensional Euclidean configuration of the cues in their urban space via a process of standardizing, centralizing, and rotating the two configurations until the closest possible match had been achieved. The degree of coincidence associated with this procedure was recorded in the form of a bidimensional correlation coefficient (Tobler, 1978). Thus, individual configura-

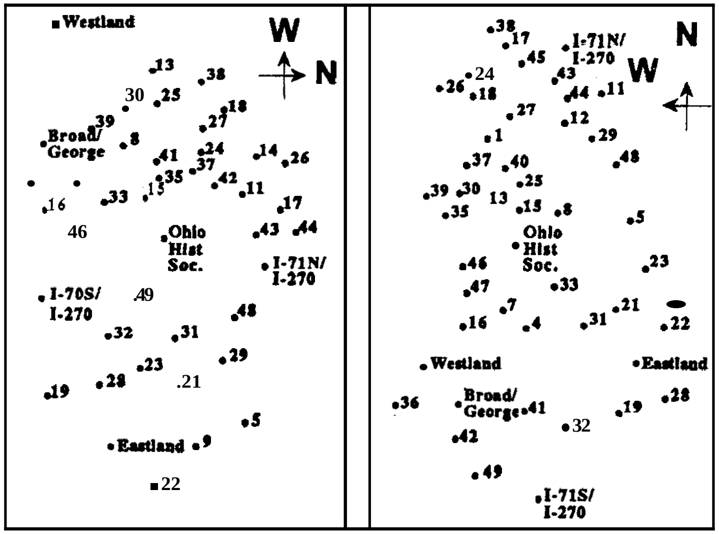


Figure 7.8. Typical axial biases. Source: After Golledge et al., 1969.

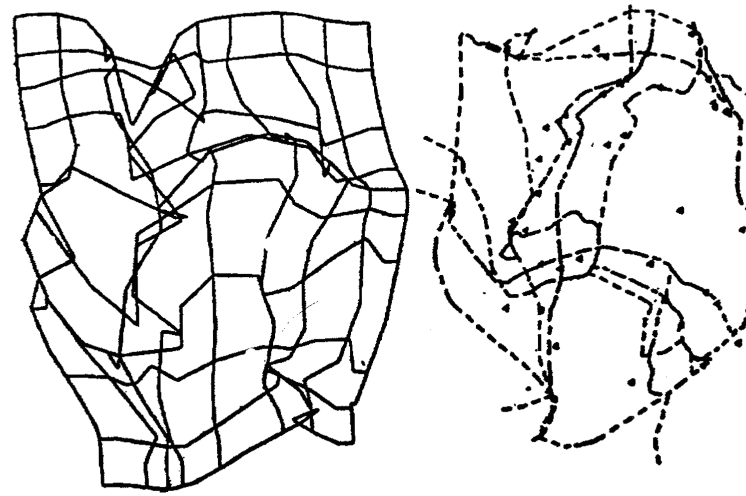
tions that closely match the two-dimensional Euclidean map would have high bidimensional coefficients.

A simpler visual interpretation of the degree of correspondence between subjective and objective configurations can be obtained by warping a standard grid to fit the subjective configuration (Figure 7.9). The grids are obtained in a manner similar to the way one would compile a contour map—that is, by interpolating grid lines between points in each configuration. Obviously, some of the finer displacements and distortions cannot be shown using this grid distortion technique, but the use of this simple generalization helps interpretation. Although each simplified grid has its own distinctive pattern of distortion, there are similarities repeated among many of the subjects, permitting some subjects to be grouped on the basis of similarity of distortions. Many grids, for example, indicated a pronounced exaggeration of the shorter distances. Overall, there was a pronounced localization effect with distortion being least in the daily activity space of sets of individuals. The use of grid representations of the configurations provide further evidence that people's knowledge structures of urban information is incomplete, schematized, and filled with holes or folds or warps. Obviously there are pronounced local effects, with the general knowledge surface declining exponentially away from places that could be designated as primary nodes or anchorpoints.

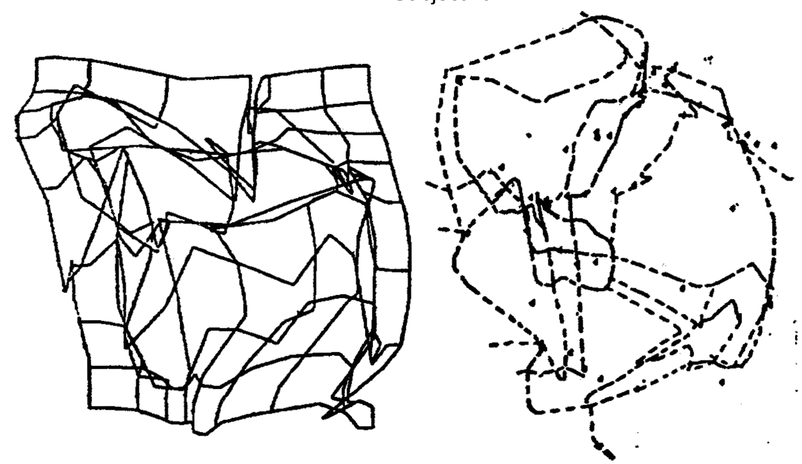
7.6.4 Anchors and Errors in Cognitive Maps

In discussing the concept of correspondence, we have used the notion of bidimensional regression and grid pattern matching as indicators of structural agreement. In

Columbus, Ohio



Subject *207*



Subject 156

Figure 7.9. Distorted grid and street maps.

a more precise context, it is possible to estimate the degree of distortion (or displacement of subjective cues-from their objective locations) and fuzziness (or the degree of variability of subjective estimates of cue locations).

One way of examining information on cognitive maps and/or assessing degrees of coincidence has been developed by Tobler (1977). For example, for the population as a whole one may locate all subjective estimates of each location and summarize the resulting locational set in terms of error ellipses (Figure 7.10).

Such a construction indicates the degree to which the location of individual cues in the total set is more or less known by the subject population. Obviously, the

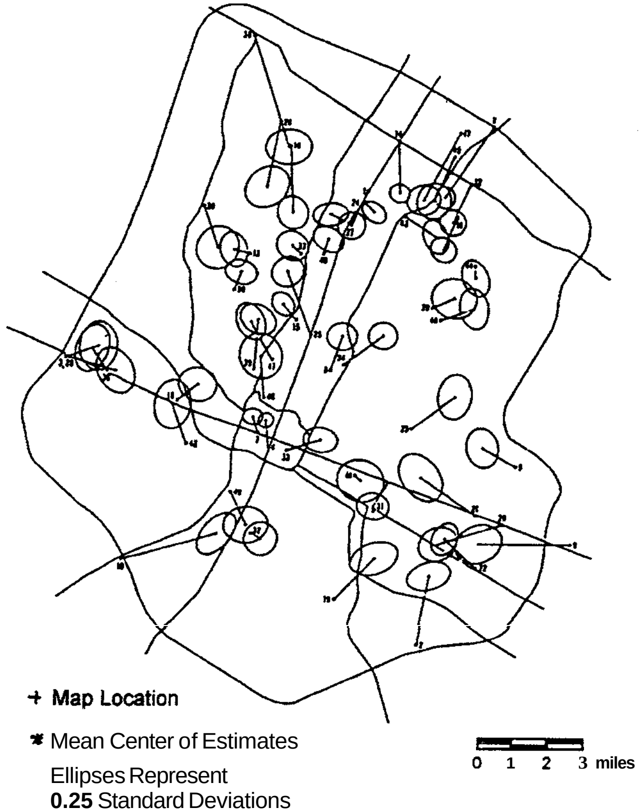


Figure 7.10. Error ellipses.

larger the ellipse and the more circular the ellipse, the less accurate is the general knowledge structure of the cue's location. Similarly, by examining the magnitude of the distance displacement between a cue in a matched subjective and objective configuration pair, and estimating its directional distortion, the fuzziness component previously calculated can be complemented with an individual's distortional component (Figure 7.11). From examining distortions of the cues used in the Columbus experiment, it appears that distortion is least in the cue set contained in an individual's activity space or associated with primary nodes and greatest associated with places visited less frequently. Generally, a strong relationship exists between the amount of fuzziness associated with each location cue and the amount of distortion. Using such procedures, one can identify the least distorted and fuzzy cues as ***anchorpoints*** in the environment. Increasing error properties then indicate less concise knowledge about other cases and imply the cues are lower in a knowledge hierarchy. Also, by examining the directional bias in the ellipses and relating these to characteristics of the anchorpoints, we can develop some idea of hierarchical order or dominance. This provides some ordering principles for understanding the knowledge structure revealed in the configuration.

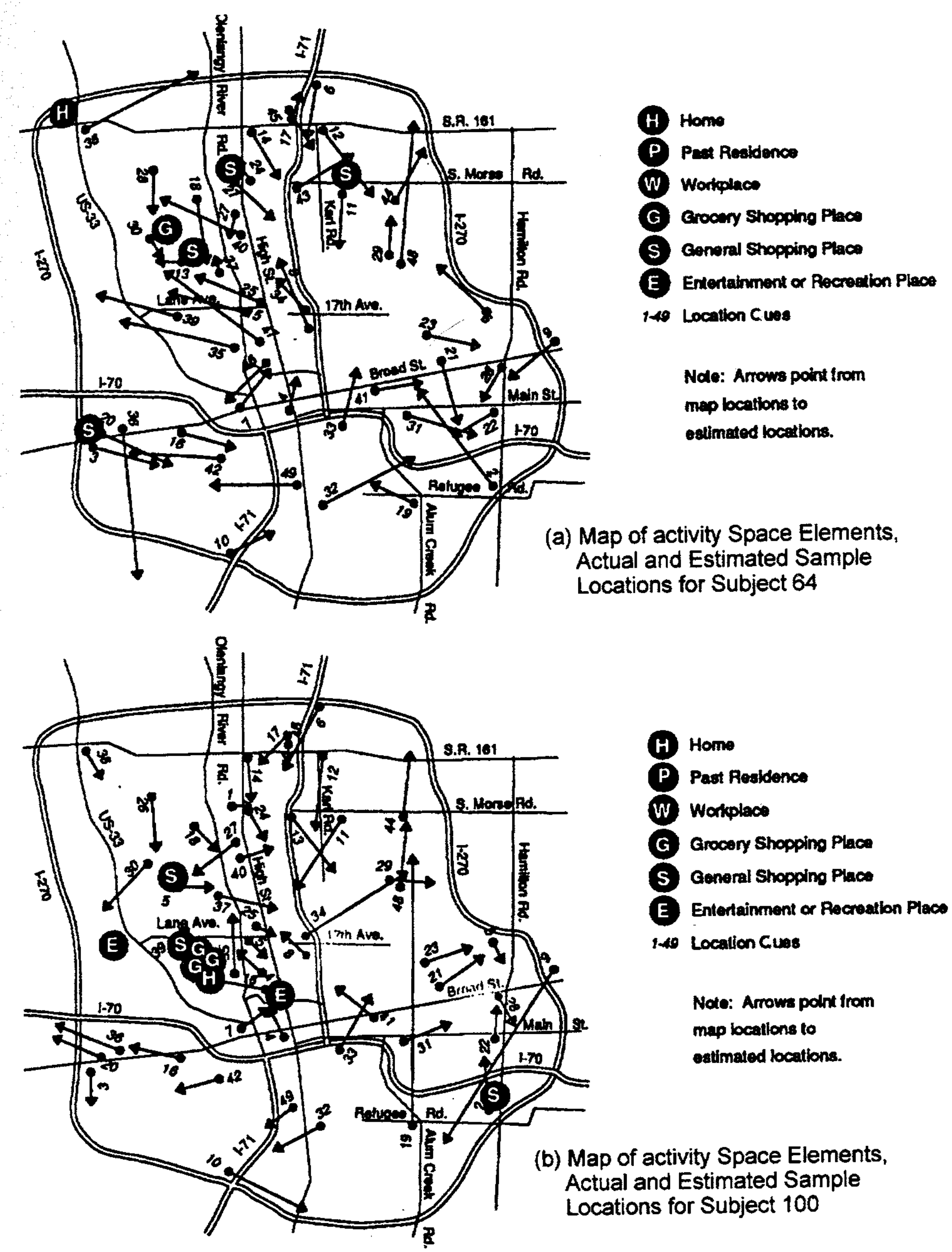


Figure 7.11. Activity space elements and locational errors. (a) Map of activity space elements and actual and estimated sample locations for subject 64. (b) Map of activity space elements and actual and estimated sample locations for subject 100.

7.7 Images of Cities

A major advance in work investigating *city image* was made by Kevin Lynch (1960). His book, *The Image of the City*. This book not only served to focus attention on perceptual and cognitive qualities of urban environments, but it also provided a conceptual framework for the discussion of the structural components of city images that still occupies a primary place in the literature on city structure.

Lynch proposed a five-element classification system consisting of paths, boundaries, districts, nodes, and landmarks:

1. *Paths* were the basic channels along which persons would occasionally or customarily move around a given environment.
2. *Boundaries* were conceived as barriers tending to mark off differentiated segments of space, with the barriers being more or less permeable, depending on whether they consisted of natural environmental features, (e.g., rivers, parks, freeways), or social, political, cultural features (e.g., boundaries of a gang turf, administrative boundaries, ghetto boundaries, and so on).
3. *Districts* were the main areal component of the urban image and were defined as recognizable areas contained within sets of well-defined edges. Districts were generally larger than neighborhoods and often were allocated an official or unofficial descriptive title such that they were readily recognizable by the local population and by many others living outside their boundaries.
4. *Nodes* were defined as strategic spots that acted as foci for human behavioral activity. They may be things such as bus stops, outdoor luncheon or recreational areas, critical street comers, or specific buildings that had well-known functions associated with them.
5. *Landmarks* were visibly dominant and easily identifiable elements of the landscape and could be drawn from the natural, built, or cultural environments (e.g., an overlook, a major distinctive building, a place of historical significance, a place of religious significance, and so on).

These five elements were illustrated earlier for Los Angeles and Boston in Figure 7.5.

While the initial research on city images incorporated fundamental concepts from the psychology of perception—such as figure-background composition, clarity, singularity of form, visual dominance, perceptual closure, and so on—many of Lynch's imitators moved beyond these fundamental perceptual qualities to add the values, meaning, and significance of city elements in both a societal and a cultural sense. For example, Appleyard's (1969) research on why buildings are known included a discussion of basic characteristics such as singularity, level of visibility, community significance, and intensity; but he also emphasized societal and cultural context, historicity, and local significance as critical features of recognition. Other research focused on a search for reasons behind the departure from objective "accuracy" in city images and included things such as residential history of the respondents, levels of familiarity with places, basic elements of form, ethnic or cultural heritage, or mode of travel (e.g., Maurer & Baxter, 1972; Orleans & Schmidt, 1972; Ladd, 1970; Ley, 1972). It must be remembered, however, that although the emphasis on affect and form dominated a considerable part of the research in this area, other research focused on attempts to refine modes of representing cognitive information other than via sketch maps and verbal descriptions (e.g., Golledge & Zannaras, 1973; Golledge, Rivizzigno, & Spector, 1976).

Although Lynch's model is a valuable conceptual tool, it falls foul of the set of problems involved in aggregating and disaggregating data. Even though any city can be decomposed into its component parts, detailed analysis of the parts raises questions of how they can possibly be reassembled. Gale et al. (1985) show that cognized distances violate Euclidean axioms, that nodes and landmarks are often poorly located in memory, that paths often cannot be integrated, and that perceived districts overlap. The separate decomposed elements cannot be reassembled into a whole using conventional geometric or cartographic methods.

7.8 The City as a Trip

A transactionally based hypothesis concerning our knowledge of urban environments would be that one obtains knowledge about the city according to the type of interactions that one has with it. Thus, urban knowledge accumulates as a result of the various trips undertaken as part of the everyday process of living. Whereas other conceptualizations focus more on the node and landmark structure or areal pattern of urban knowledge, this conceptualization is path based.

As an example of a *path-based* view of city images, we present a discussion of the city as a trip by Carr and Schissler (1969). They interviewed a number of commuters, both car drivers and passengers, in the city of Boston in an attempt to identify the types of environmental cues noticed and used by individuals when they are undertaking trips within an urban environment. To obtain information on the recognized and used cue structure, subjects were examined prior to the day of the field trip and asked to state their preconceptions of the trips they were to make, including regular trips undertaken by the individuals and specific tasks set them by the experimenters. In addition, subjects were laboratory tested to determine such things as the accuracy of recall and depth of memory and the angle of eye movements. The next day, subjects were taken on a trip with a camera mounted on their head to record where they were looking, and optical devices focused on the corneas of the subjects' eyes enabled the researchers to identify the directions in which the subjects were looking. This helped to identify possible landmarks seen at various places along the route. Thus, by establishing points of fixation and also requesting a verbal summary of what was noticed and used as navigational aids along the trip, the researchers attempted to define those elements of the city that were observed, recognized, and used in a trip-making context. The subjects were exposed to a variety of verbal, graphic, and descriptive materials associated with the trips and films of the trip in order to provide a data bank. Data banks were then searched using content analysis to find those places, cues, or areas that provided anchors for an individual's cognitive representation of the environment. The features recovered using these processes were then ranked according to the frequency with which they appeared in the subject's responses (Table 7.3).

ping), or those less-frequent episodes with greater temporal intervals between their occurrences (e.g., annual holidays).

This mapping process requires each individual to undertake a cognitive taxonomic process that is culturally constrained and that results in the filtering of the varied "to whom it may concern" messages emanating from the many environments in which we live.

Unlike much of the literature on perception, which emphasizes the acquisition of information through the senses in the presence of a stimulus, it is generally accepted that the process of cognitive mapping has no tie to a particular sensory modality but, instead, spans all of them.

7.3.2 The Mapping Process

The first assumption is that information extracted from large-scale external environments exists in an undetermined psychological *space*. This is the space in which characteristics, meanings, and configurational relationships about elements in the world are held as mental constructs. A second assumption is simply that individuals must have *internal knowledge* about external environments in order to exist in them. A third assumption is that internal representations will be part *idiosyncratic* and part *common* in structure (i.e., people in general will know the difference between a street and a stream, the significance of a traffic light, and the difference between privately and publicly owned transportation systems).

As indicated in Table 7.1, Golledge (1976c) has categorized methods for extracting and representing imagery into the following classes:

- Experimenter observation in naturalistic or controlled situations.
- Historical reconstructions.
- Analysis of external representation.
- Indirect judgmental tasks.

The above conceptualization includes a range of external representational formats such as verbal reports, sketch maps, tables, profiles, word lists, analog models, slides, novels, poems, paintings, diaries, interviews, protocols, toy play, proximity judgments, scalings, and creative stories or writings. Thus, at various times individuals have been asked and have provided an impressive array of written and oral descriptions, pictures, sketches, cartographic representations, and grouped or clustered, scaled, and otherwise modified or transformed, bits of environmental information. These have come from experiments using recall of interpoint distances and analysis by multidimensional scaling, from tasks requiring haptic (touch) exploration of layouts, from solving problems requiring auditory localization, and from simple wayfinding tasks.

One of the most widely referenced comprehensive works using a variety of the above methods was Lynch's (1960) pioneering work *The Image of the City*. *In* a later section we examine his concepts in detail and expand on them at different spatial scales.

TABLE 7.1.
Methods for Extracting Environmental Cognition Information

Method	Procedure	Subject Skill	External Representational Form	Example
Experimenter observation in naturalistic or controlled situations	Experimenter observes or tracks movement through actual environments (e.g., crawl patterns, search behavior overt spatial activity, wayfinding)	Cognitive Concrete Psychomotoric	Observations Reports Maps Tables	Lynch (1960) Marble (1967) Ladd (1970) Jones (1972) Devlin (1973) Zannaras (1973)
	Experimenter infers degrees of cognitive knowledge from behavior in unstructured "clinical" situations	Cognitive Concrete Motoric	Charts Profiles	Werner (1948) Piaget and Inhelder (1956) Hart (1974)
	Subjects reveal environmental knowledge in the process of sorting or grouping elements of actual or simulated environments	Cognitive Abstract Relational	Lists Tables Composite maps	Downs (1970a) Wish (1972) Zannaras (1973) Golledge et al. (1975)
	Subjects adopt roles or perform acts in simulated and/or real environments	Cognitive Abstract	Photographs Tables	Ittelson (1951) Milgram (1970) Acredolo (1976)
	Subjects arrange toys or objects representing environmental elements or model environments, and experimenter observes the sequence of acts in positioning elements and/or using the environment	Cognitive Concrete Motoric	Analog models	Piaget et al. (1960) Blaut and Stea (1969) Laurendeau and Pinard (970) Mark (1972) Hart (1974)

(continued)

TABLE 7.1 *(continued)*

Method	Procedure	Subject Skill	External Representational Form	Example
	Subjects draw sketches or sketch maps representing environments	Affective Graphic Relational	Pictoral sketches Sketch maps Quantitative and structural analyses	Lynch (1960) Shemyakin (1962) Stea (1969) Appleyard (1970) Ladd (1970) Moore (1973) Wood (1973)
	Subjects arrange toys or make models representing environments	Affective Cognitive Concrete Motoric	Models Arrangements of toys	Piaget and Inhelder (1967) Blaut and Stea (1969) Mark and Silverman (1971) Stea (1973) Hart (1974) Stea (1976)
	Subjects show existence, location, proximity, or other spatial relations of environmental elements; use of symbols to represent such elements	Cognitive Graphic Abstract Relational	Base maps with overlays Notation systems	Lynch (1960) Thiel (1961) Appleyard (1969) Wood and Beck (1990)
	Subjects are asked to identify photographs, models, etc.	Affective Motoric Abstract Relational	Verbal Protocols	Piaget and Inhelder (1956) Laurendeau and Pinard (197 Stea and Blaut (1973) Zannaras (1973)
Indirect judgmental tasks	Selection of constructs that reveal environmental information; adjective checklists, semantic differentials, repertory grid test, etc.	Cognitive Abstract Relational	Word lists Tables Graphs Grids	Kelly (1955) Downs (1970a) Honikman (1976) Harrison and Sarre (1976) Goiant and Burton (1969)
	Paired proximity judgments and other scaling devices that allow specification of latent structure in environmental information	Cognitive Abstract Relational	Maps Tables	Briggs (1973) Lowrey (1973) Golledge et al. (1975) Cadwallader (1973a) Golant and Burton (1969)
	Projective tests (e.g., T.A.T.)	Affective Abstract Relational	Verbal stories	Burton et al. (1969) Saarinen (1973b)

7.3.3 Cognitive Maps

A *cognitive map* may be defined as "long-term stored information about the relative location of objects and phenomena in the everyday physical environment" (Gärling, Böök, & Lindberg, 1979:200). Cognitive maps thus represent information about environments that are either known to exist or are imagined but not necessarily present. Any given map, therefore, may be a mixture of information received at quite disparate time periods, and at any particular point in time may be incomplete, more or less schematized, or distorted, and may contain fictional or hypothetical information, or relics of the past which no longer exist.

This model of reality is a complex one and should not be interpreted as a simple one-to-one internal mapping of discrete things that exist in an external environment. Thus, it is not assumed that a cognitive map is an equivalent of a cartographic map, nor is it assumed that there is a simple Euclidian one-to-one mapping between a piece of objective reality and a person's cognitive map of that reality. Cognitive maps are generally assumed to be incomplete, distorted, mixed-metric representations of real-world environments, but they can also be maps of the imaginary environments represented in literature, folk tales, legends, song, paintings, or film.

Even simple tasks, like going from home to work, to school, or to a store, or directing newcomers to places they have never been, require information to be stored, accessed, and used in a convenient and easy way. To perform such tasks it is necessary to use one's memory representations of spatial information—that is, one's cognitive map. Over the past three decades, scientists in a variety of fields have been examining questions relating to the nature of these cognitive maps, the process of acquiring and forming such mappings, and their role in everyday spatial activity. In what follows, we draw on concepts, theories, and empirical evidence from a variety of disciplines as a means of examining the process of developing cognitive maps and illustrating the product of such knowledge acquisition.

7.4 Cognitive Map Metaphors

7.4.1 Basic Metaphors

With more widespread acceptance, the concept of a cognitive map has become more clearly and more accurately defined. In the course of such clarification, the metaphor most often used in describing cognitive maps has changed.

Gould's (1963) early use of the preference surface metaphor for mental maps was next replaced by the rubber sheeting metaphor favored by Golledge et al. (1969), Golledge, Rayner, and Rivizzigno (1975), and Tobler (1976) when using nonmetric multidimensional scaling or trilateration procedures to construct cognitive configurations (Figure 7.3). S. Kaplan's (1973, 1976) development of an information-processing metaphor led to further elaborations of the cognitive map as a computerized data base and processing system. Concurrently with these metaphors was the less favored, but appealing, notion of a cognitive map as an internal cartographic-like representation or indeed as an atlas (Lieblich & Arbib, 1982). Cognitive scientists then suggested that cognitive maps were list processors or images,

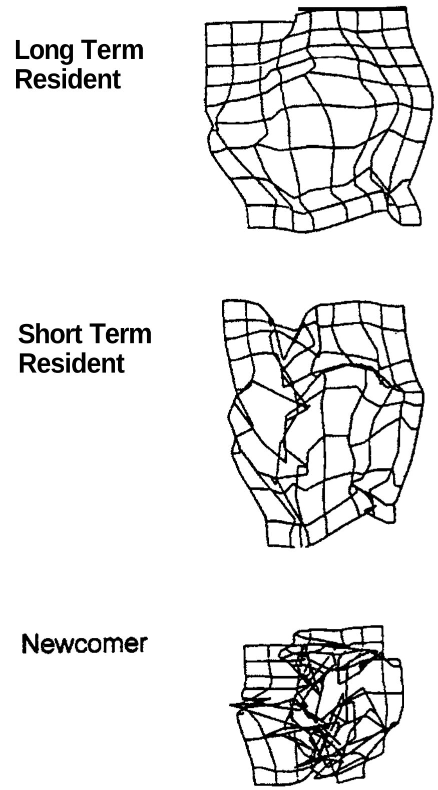


Figure 7.3. Distorted grids as examples of rubbersheeting.

metaphors that were closely examined for geographic relevance by Lloyd (1982). The rubber sheeting and cartographic representation metaphors were linked by Tobler's (1976) elaboration of the geometry of mental maps and by his development of bidimensional regression procedures for correlating objective and subjective configurations (Table 7.2).

Cognitive maps that include not just spatial information but also attributive values and meanings (Wood & Beck, 1990) provide yet another metaphor (i.e., the cognitive map as a belief system). The notion that cognitive maps involve the integration of images, information, attitudes, and values was also offered by Spencer and Blades (1986). In other words cognitive maps are not to be thought of as isolated entities but as being contextual, dynamic, and providing the interface mechanism between sensed information and behavior.

Golledge and Timmermans (1990) suggested that cognitive maps are a series of knowledge structures consisting of different levels of detail and integration. These knowledge structures develop with age and education and, in a sense, may be described more by the metaphor of a cognitive atlas than a cognitive map (see also Lieblich & Arbib, 1982: 640). From this atlas, individual cognitive maps can be resurrected and used for specific tasks (Golledge et al., 1985)

TABLE *7.2.*
Bidimensional Correlations between Objective and Subjective Configurations (Control Group of Long-Term Residents)

Control Group of Long-Term Residents	Bidimensionai Correlation between Objective and Subjective Maps
C1	0.891
C2	0.952
C3	0.855
C4	0.944
C5	0.938
C6	0.882
C7	0.889
C8	0.901
C9	0.709
C10	0.882

Source: Golledge, Rayner et al., 1982.

The evolution of understanding of the concept of cognitive maps is now at the stage where it is assumed that they represent the store of knowledge an individual has about an environment. Implicitly and explicitly, they contain spatial relational data along with environmental attributes and individualized and socioculturally conditioned beliefs, values, and attitudes. Context-specific and problem-specific cognitive maps can be constructed at will, each having a particular space–time context and containing some common information (e.g., common anchorpoints) and some idiosyncratic or personalized elements. The common elements facilitate communication with others about the characteristics of an environment; the idiosyncratic elements provide the basis of the personalized responses to such situations.

7.4.2 Cognitive Maps as Internal GIS

The idea that sets of environmental information might be represented as layers with differential attribute weights attached to hierarchically organized components within and between layers promotes yet another metaphor of the cognitive map. Recently Golledge and Bell (1995) suggested that the cognitive map should be viewed as an internalized geographic information system (GIS). In both systems, data are symbolized and coded. Decoding and recall are often focused on selective components of the total knowledge set. The recalled information can be represented in a variety of verbal, graphic, acoustic, or haptic forms. A range of manipulative processes can be accessed to help solve a task and produce a behavior (Figure 7.4).

It is difficult to think of a single functionality embedded in the GIS that does not have a parallel in human-information processing capability. The one difference, however, is that in the GIS, once activated, a manipulative procedure should be carried out quickly and accurately, whereas in humans, although the ability to perform a manipulative activity may in principle be within their intelligence realm, there are many personal and societal barriers that may induce error and inhibit the use of such a skill. Thus while the GIS is a practical tool for processing, analyzing, and displaying spatial information, the comparable human processes may be error prone and poorly developed. And given the extensive literature on development and lifespan theories of intellectual growth, one would expect these abilities to be more or less present depending on age and education.

Constructing Gradients and Surfaces
Layering
Regionalizing
Decomposing
Aggregating
Correlating
Evaluating Regularity or Randomness
Associating
Assessing Similarity
Forming Hierarchies
Assessing Proximity
Measuring Distance
Measuring Directions
Defining Shapes
Defining Patterns
Deterimining Cluster
Determining Dispersion

Figure 7.4. Samples of manipulative processes used in cognitive mapping and GIS.

7.4.3 Debatable Alternatives

In geography, different views on the cartographic nature of cognitive maps are elaborated in a debate between Graham (1976, 1982) and Downs (1981a,1981b), with the latter clearly identifying the metaphoric significance of the use of the term "map." With respect to this and other related debates, Kitchin (1994) summarizes the four critical debatable questions as follows:

1. "Is it the case that the cognitive map is a cartographic map (explicit statement)?
2. Is it the case that the cognitive map is like a cartographic map (analogy)?
3. Is it the case that the cognitive map is used as *if it* were a cartographic map (metaphor)?
4. Is it the case that the cognitive map has no real connections with what we understand to be a map (i.e., a cartographic map) and is neither an explicit statement, analogy, or a metaphor but, rather, an unfortunate choice of phrase: 'a *convenient fiction'* (Siegel, 1981), or in effect, just an hypothetical construct." (Kitchin, 1994:3)

The argument for the cognitive map being a map (explicit case) derives from the work of O'Keefe and Nadel (1978), who argued that the hippocampus, a part of the brain associated with long-term memory, *is* a cognitive map. With today's emphasis on neural mapping, there is renewed support for this idea. The cognitive map interpreted as analogous to a cartographic map generally relies on the argument that both have Euclidean spatial properties. Although there has been substantial empirical evidence that cognitive configurations constructed in two-dimensional Euclidean spaces correlate highly with Euclidean representations of objective reality (Golledge, 1975; Golledge et al., 1975; Golledge & Spector, 1978; Gärling, Book, & Lindberg, 1985), there is also much evidence that, for the most part, cognitive maps can violate some if not all of the basic Euclidean axioms (Gale, Doherty, Pellegrino, & Golledge, 1985). The elaboration of the fact that cognitive maps exist in multimetric spaces (Baird, Wagner, & Noma, 1982), along with some evidence that curvilinear spaces are perhaps more suited to represent the spatial relationships contained in cognitive maps (Golledge & Hubert, 1982), have caused this debate to lose force.

The use of a cognitive map as a *hypothetical construct* or *convenient fiction* implies that the use of the term map provides no literal meaning. Moore and Golledge (1976: 8) suggest that "as a hypothetical construct the term cognitive map and its approximate synonyms refer to covert, nonobserved processes and organizations of elements of knowledge." As principles of symmetry and transitivity, for example, are violated (Tversky, 1981; Baird et al., 1982), then the term "map" becomes a convenient fiction that provides a hook on which to hang interpretive structures but that is tied to no particular representational form.

But, for better or for worse, from medical science to engineering sciences, from the humanities to the social sciences, the term cognitive map is now widespread.

7.5 The Use of Cognitive Maps

7.5.1 Cognitive Maps and Spatial Behavior

If we accept the broadest definition of a cognitive map (i.e., as our internal model of the world in which we live), then cognitive maps play a role in all behaviors, both spatial and nonspatial.

Traditionally, geographers have focused on the role that cognitive maps play in deciding what overt spatial behaviors are to be performed in any problem-solving situation. This means that the cognitive map becomes a critical component of general spatial problem-solving activity. It is embedded in the process of spatial choice and decision making. This role was made explicit by Briggs (1973) after being implicitly recognized by geographic researchers in the 1960s. The cognitive map plays a role in deciding what choice to make and whether one has to travel or not to achieve a goal; it helps decide where to go, which route to take, and what travel mode to take to get there. These questions have been addressed in a variety of contexts such as consumer behavior (Coshall, 1985a, 1985b; Timmermans, 1979; Pacione, 1978, 1982). Many other examples can be found in a review by Timmermans and Golledge (1990).

Cognitive maps have also played a role in research on movement patterns both in a migration and a mobility context (Johnston, 1972; Briggs, 1973), as well as for movement associated with recreational and leisure choice (Pigram, 1993; Golledge & Timmermans, 1990). The latter have exhaustively reviewed the use of cognitive maps in many different environmental situations from establishing preferences for shops, shopping centers, apartments, and modes of transportation, to the planning of specific residential environments, and the use of cognitive maps as devices to aid wayfinding and navigation. They are in common use when one is examining the learning of unfamiliar layouts, at scales varying from the neighborhood to the international arena, and they are essential for the development of any examination of the nature and degree of fundamental spatial concepts, such as location, distribution, pattern, shape, direction, orientation, region, hierarchy, network, and surface. In the sections that follow we explore specific examples of some of these uses.

7.5.2 Cognitive Maps as Planning Aids

Often it has been suggested that cognitive maps are an essential part of the making of policy and the development of plans. This belief is held alike by geographers and planners. The underlying hypothesis here is that the quality of human decision making (whether individually or in congress) will be improved as the quality of knowledge about the task environment is improved. And if we are aware of people's preferences for, perceptions of, and attitudes toward different environments, then better matches between planning and policy making and the felt needs of the populations, for whom plans are being made, can be achieved (Gärling & Golledge, 1989).

This sentiment had been expressed much earlier by Lynch (1976) whose written work often stressed that better planning, design, and management of environments could be undertaken *for* people if they were done *with* people (i.e., participatory planning). Improved modeling, Lynch argued, would also occur if we understood the images of the world in which people perceive they live and the world in which they would like to live. Aitken, Cutter, Foote, and Sell (1989) more recently reiterated this sentiment, suggesting that the most adequate planning in the context of the built environment will reflect the behavioral propensity of residents and other users. Knowing something about people's perceptions, preferences, and images provides information that complements the designers' and planners' intuition, guidelines, and legal restrictions.

7.5.3 Cognitive Maps and Disability

One area where this advice is being taken into consideration is the design of environments to meet the needs of populations with disabilities (Passini, 1984). Investigation of the policy guidelines needed to encourage the development and improve the quality of life for the deinstitutionalized mentally retarded constitutes yet another area of successful integration of policy design and cognitive mapping (Golledge et al., 1979a and 1979b; Golledge, Richardson, Rayner, & Parnicky, 1983), as is the policy area represented by the work of Carpmen, Grant, and Simmons (1985) who explored the effects of hospital design upon the wayfinding activities of the hospital staff, patients, and visitors. In a similar environmental context, Ulrich (1984) discovered that rearranging hospital beds in a room could increase the ambiance of the room and reduce convalescent time for hospital patients.

In addition to the mentally retarded and the hospitalized other special populations that have benefited from research focused on cognitive maps include children's environments (Hart, 1981, 1984) and elderly environments (Ohta, 1983; Kirasic 1991; Kirasic, Allen, & Haggerty, 1992; Golant, 1982). Some of this research is developed at length in Chapters 14 and 15 of this book.

7.5.4 Cognitive Maps and Crime

Cognitive mapping also has become a useful device in combating criminal activity. Rengert (1980) and Rengert and Waselchick (1985) have examined the cognitive maps of residential burglars. More recently, Rengert (1994) has developed representations of what people think they know about the location of illegal drug sales and different forms of violence in urban areas. Canter and Larkin (1993) have used cognitive maps to track down criminals for the police. They showed the limited range of cognitive maps and commented on their circularity. Extrapolating to a real-world setting, they successfully predicted the probable location of a serial rapist, thereby allowing the police to trap the perpetrator. It has been suggested also that cognitive maps produced by friends and acquaintances may be useful in the process of tracking down missing persons.

Even though we have presented a variety of alternative conceptualizations of the process of cognitive mapping and the nature and use of cognitive maps, it should be apparent that no definitive answer exists at this stage to the question of how best to describe cognitive maps. It appears that the selection, coding, storage, decoding, reconstruction, and use of cognitive information potentially are fertile topics for further geographic investigation.

7.6 Methods for Externally Representing Cognitive Maps

7.6.1 Externalizing Information: Cognitive Configurations or Spatial Products

The use of many different metaphors for the term cognitive map has produced continuing confusion in the various disciplines that use the concept. Perhaps the most enduring of these is the notion that a cognitive map must have the same properties as a cartographic map.

The early 1970s saw much cross-disciplinary discussion about whether or not such a configural matching existed, with the overwhelming evidence pointing to the fact that cognitive maps were *not* simply internalized cartographic maps. In an early effort to differentiate between the internalized cognitive map and the external representation, Golledge (1975) differentiated between the cognitive map as the internal representation and a "cognitive configuration" as an externalization of information gleaned from a cognitive map. The cognitive configuration could be task specific and could have more or less properties of conventional cartographic maps. Thus, sketch maps were considered primarily nonmetric cognitive configurations, whereas multidimensional scaling outputs were considered to be more metric cognitive configurations. Although this differentiation continues to be used in some geography literature, in other disciplines it is more common to differentiate between the internal representation (cognitive map) and an externalization called a "spatial product"—a term used by Liben (1981) to describe an externalized representation.

Methods developed to recover cognitive configurations are as varied as the purposes behind such research. One of the earliest methods suggested by Lynch (1960) was the use of sketch map techniques (Figure 7.5). Other procedures

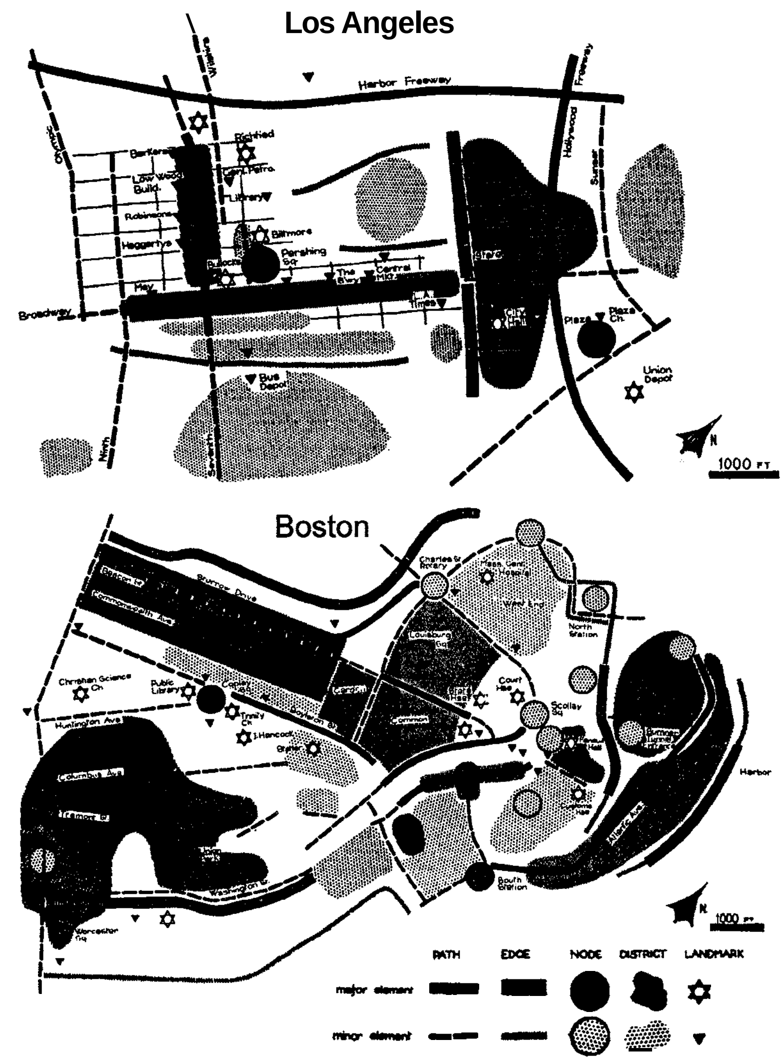


Figure 7.5. Sketch maps of Los Angeles and Boston. Source: Lynch, 1960.

include: requesting subjects to image scenes from different perspectives; to list the best recognized or most frequently visited places; to reconstruct images of unseen objects; to estimate lengths of streets and angles of intersections; to use various unidimensional scaling procedures to obtain interpoint distance judgments; and, by using proximity judgments in a paired comparison context, to develop cognitive distance estimates from multidimensional scaling configurations. More recently, table top modeling, interactive computer experiments, and even the use of aerial photos, all appear to be capable of producing reasonable configurational representations.

7.6.2 **Sketch** Maps

Sketch mapping has long appeared to be a useful instrument for recovering information about environments, if the maps are properly interpreted. This technique suffers from the assumptions that the subject understands the abstract notion of the model and its relationship to the real world has the sufficient motor skills to portray accurately in sketch format what she or he is attempting to complete, and that a uniform metric is applied across the sketched information. Where violations of these assumptions occur, the best information that can be obtained would be topological in nature.

Although rarely undertaken as a solo exercise anymore, sketch mapping is used often in conjunction with other methods for extracting cognitive information about environments. Although sketch maps usually cannot provide reliable metric information, they can provide information, such as the number of features included on the map, the mix of point, line, and area features used in the sketch, an indication of dominant functions in a locale as perceived by the sketcher, and ordinal information such as the sequence of cues along routes or the sequence of segments and turns along routes. Additional information can be obtained from the system constructed as the basis for the sketch, particularly the regularity or irregularity of frameworks such as street systems and environmental features. Frames of reference used in local environments can also be inferred from sketches.

It has been reported often that the amount of material on sketch maps and its accuracy increase over consecutive trials. An example of this can be seen in Figure 7.6, which shows sketches of a route in an unfamiliar environment that was learned in a forward and reverse direction on five consecutive days by a 12-year-old boy. It is clear that the sketch went from a minimal representation to a quite accurate and comprehensive representation by the end of the 10 trials (5 forward, 5 reversals). Although in the early stages there were characteristics such as segment reversals and directional errors, by the fifth trial these were generally eliminated, and the sketches converged on accurate rendition of the task environment.

Blades (1990) has provided evidence to show that the sketch-mapping procedure is quite consistent over time. This does not imply that metricity accrues to the sketch, but it does imply that when used in a multiple trial–task situation, confidence can be placed in the sketch-mapping procedure. Sketches can, therefore, indicate the quantity of information that comes readily to mind when one is given a task

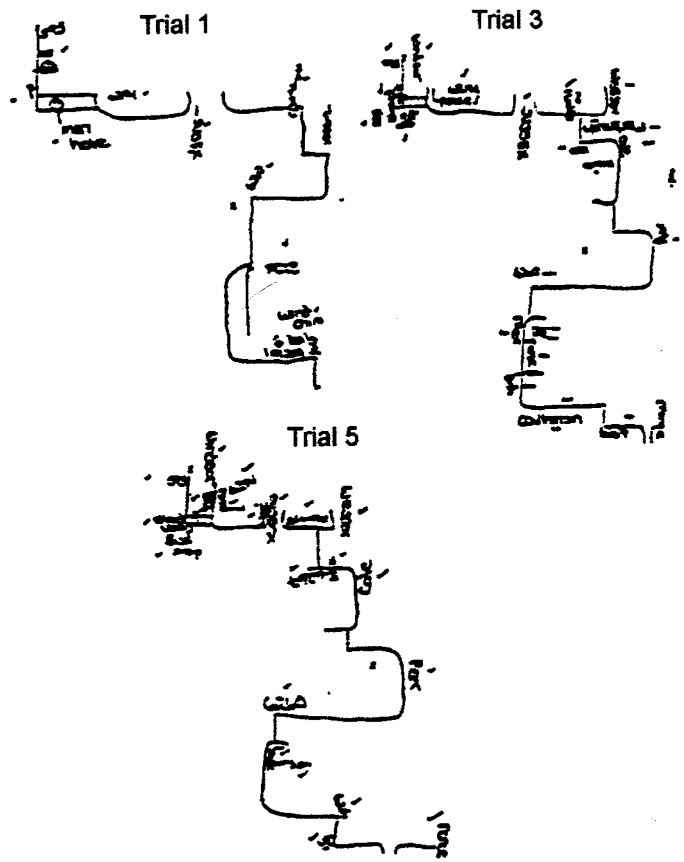


Figure 7.6. Sketch maps after multiple learning tasks.

of representing local knowledge within specified time constraints, and if the environment is known, the sketches produced are reliable—that is, they are consistent over time.

As with cognitive maps generally, sketches are incomplete, distorted, mixed-metric, or nonmetric modes of representation; they are schematized and are often full of blank spaces and nonconnected networks. In examination of selections of sketch maps for a given environment, frequency counts of the appearance of different features allow the development of composite maps on which are located those places known best by the largest number of people. The classic example still remains the map constructed by Milgram and Jodolet (1976) representing multiple levels of a common hierarchical knowledge structure of Paris, France. A listing of the most commonly cited landmark cues in selected urban areas is given in Figure 7.7.

	Paris[a] (1970)	Columbus[b] (1974)	Santa Barbara[b] (1978)	San Francisco[c] (1989)
1.	Etoile	Graceland Shopping Center	La Cumbre Plaza	Fisherman's Wharf
2.	Notre Dame	Eastland Shopping Center	Santa Barbara Airport	Chinatown
3.	Tour Eiffel	Westland Shopping Center	County Court House	Golden Gate Bridge
4.	Seine	Lazarus, downtown	Mission Santa Barbara	Union Square
5.	Bois de Boulogne	Port Columbus	UCEN Building at UCSB	Cable Car Ride
6.	Champs Elysees	I-71 N and I-270 intersection	Goleta Beach	Golden Gate Park
7.	Concorde	Veterans Memorial Auditorium	FEDMART, Goleta	Museums/Galleries
8.	Louvre	Ohio State Fairgrounds Coliseum	Santa Barbara Harbor	Alcatraz
9.	Chaillot	Western Electric, East Industrial Plant	Botanical Gardens	Union Street
10.	Cite	I-71 S. and I-270 intersection	Robinson's Department Store	Broadway/North Beach
11.	Luxembourg	Northland Shpping Center	Dos Pueblos High School, Goleta	Japantown
12.	Montmartre	N. High Street and I-161 intersection	Arlington Theatre	Mission District
13.	Montparnasse	Columbus State Hospital	Santa Barbara Museum of Art	Haight-Ashbury
14.	St. Germain	Anheiser Busch Brewery	Magic Lantern Theatre, Isla Vista	Live Theatre
15.	St. Louis	Morse Road and N. High Street intersection	Picadilly Square	Castro District
16.	St. Michel	Lane Avenue and N. High Street intersection	Bank of America, Isla Vista	The Zoo
17.	Tuileries	Capital University	YMCA	Sports Eve
18.	Bastille	Ohio Historical Society	Rob Gym at UCSB	Symphony/Concert
19.	Buttes Chaumont	Riverside Hospital	Greyhound Bus Depot	Opera

[a] Ranked by importance. Data from Milgram and Jodelet (1976).
[b] Not ranked by importance. Unpublished data from surveys conducted by Golledge.
[c] Ranked by visitation. Data from Economics Research Associates' 1989 Survey of San Francisco Visitors.

Figure 7.7. Lists of major landmarks in cities.

7.6.3 Multidimensional Methods

sophistication in specifying the design of experiments for recovering cognitive information, and the use of powerful *multidimensional methods*, have given researchers a great deal of confidence in their ability to recover useful spatial information from what appear to be nonspatial knowledge structures. Many people have proven to be amazingly accurate in remembering the essential details of the spatial layouts of large-scale environments with which they are familiar (Golledge & Spector, 1978; Golledge, Rayner, & Rivizzigno, 1982). To test this contention, emphasis placed on the development of methods for comparing recovered configurations with some representation of objective'reality (e.g., cartographic or other such representations).

As an example of the use of multidimensional methods for recovering and interpreting cognitive spatial information, we now examine a set of experiments designed to recover cognitive spatial information and examine it for accuracy of its spatial properties. This set of experiments was undertaken in the city of Columbus, Ohio (Golledge, Rivizzigno, & Spector, 1974). Over a period of 9 months, sets of subjects (subdivided into newcomers, intermediate residents, and long-term residents) participated in an experiment involving the grouping or clustering of pairs of locational cues and the allocation of scale scores based on their subjective estimates of the relative proximity of each pair. The scale scores obtained from each subject were analyzed using a nonmetric multidimensional scaling algorithm KYST (Kruskal, Young, & Seery, 1976) in which interpoint distance estimates proportional to the scale scores were developed. These were then used in an iterative procedure based on a gradient method for achieving convergence, and a two-dimensional point configuration of the locations of the target cues was developed. The interpoint distance information contained in this configuration was monotonically related to the original scale scores, and the fit between the data and the developed configuration was assessed through a monotonic regression procedure, which minimized the error variances between recovered points and the original scale scores. To produce interpretable configurations, an initial configuration representing the actual locational arrangement of the cues in the city was used as the starting (initial) configuration. Thus, the final configuration outputted from the scaling program represented a distortion of the actual pattern based on the proximity scales developed by each individual. Samples of such configurations showing different types of axial biases are shown in Figure 7.8. The stress (badness-of-fit) statistic in this way becomes an interpretable goodness-of-fit statistic proportional to the error obtained in the outputted configuration. Thus, by using a measure of spatial correlation, it illustrates the extent to which (after rotation, translation, and uniform stretching or shrinking of axes) the cognitive and objective configuration coincided.

Each two-dimensional output configuration obtained for each subject was matched with a two dimensional Euclidean configuration of the cues in their urban space via a process of standardizing, centralizing, and rotating the two configurations until the closest possible match had been achieved. The degree of coincidence associated with this procedure was recorded in the form of a bidimensional correlation coefficient (Tobler, 1978). Thus, individual configura-

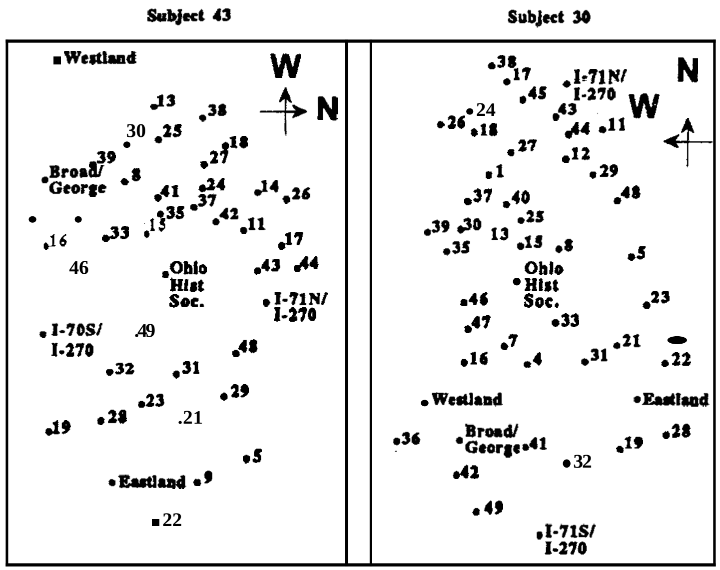


Figure 7.8. Typical axial biases. Source: After Golledge et al., 1969.

tions that closely match the two-dimensional Euclidean map would have high bidimensional coefficients.

A simpler visual interpretation of the degree of correspondence between subjective and objective configurations can be obtained by warping a standard grid to fit the subjective configuration (Figure 7.9). The grids are obtained in a manner similar to the way one would compile a contour map—that is, by interpolating grid lines between points in each configuration. Obviously, some of the finer displacements and distortions cannot be shown using this grid distortion technique, but the use of this simple generalization helps interpretation. Although each simplified grid has its own distinctive pattern of distortion, there are similarities repeated among many of the subjects, permitting some subjects to be grouped on the basis of similarity of distortions. Many grids, for example, indicated a pronounced exaggeration of the shorter distances. Overall, there was a pronounced localization effect with distortion being least in the daily activity space of sets of individuals. The use of grid representations of the configurations provide further evidence that people's knowledge structures of urban information is incomplete, schematized, and filled with holes or folds or warps. Obviously there are pronounced local effects, with the general knowledge surface declining exponentially away from places that could be designated as primary nodes or anchorpoints.

7.6.4 Anchors and Errors in Cognitive Maps

In discussing the concept of correspondence, we have used the notion of bidimensional regression and grid pattern matching as indicators of structural agreement. In

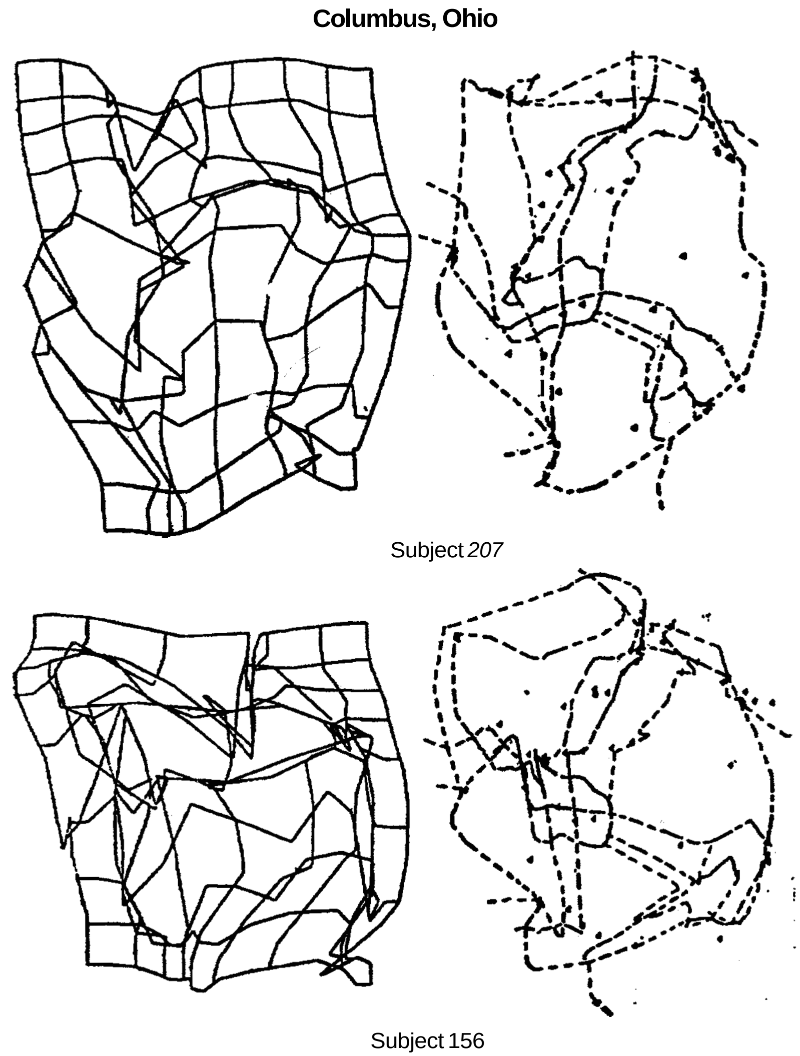


Figure 7.9. Distorted grid and street maps.

a more precise context, it is possible to estimate the degree of distortion (or displacement of subjective cues-from their objective locations) and fuzziness (or the degree of variability of subjective estimates of cue locations).

One way of examining information on cognitive maps and/or assessing degrees of coincidence has been developed by Tobler (1977). For example, for the population as a whole one may locate all subjective estimates of each location and summarize the resulting locational set in terms of error ellipses (Figure 7.10).

Such a construction indicates the degree to which the location of individual cues in the total set is more or less known by the subject population. Obviously, the

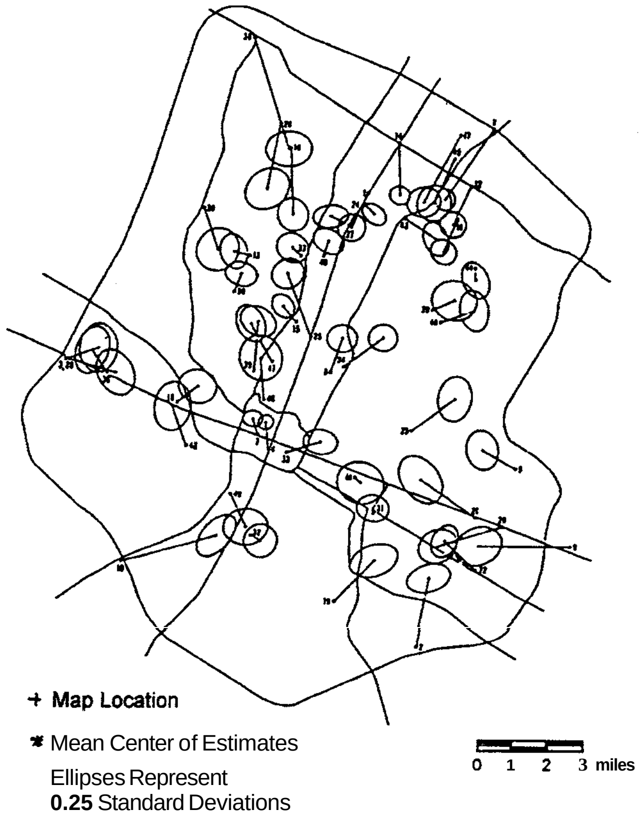


Figure 7.10. Error ellipses.

larger the ellipse and the more circular the ellipse, the less accurate is the general knowledge structure of the cue's location. Similarly, by examining the magnitude of the distance displacement between a cue in a matched subjective and objective configuration pair, and estimating its directional distortion, the fuzziness component previously calculated can be complemented with an individual's distortional component (Figure 7.11). From examining distortions of the cues used in the Columbus experiment, it appears that distortion is least in the cue set contained in an individual's activity space or associated with primary nodes and greatest associated with places visited less frequently. Generally, a strong relationship exists between the amount of fuzziness associated with each location cue and the amount of distortion. Using such procedures, one can identify the least distorted and fuzzy cues as *anchorpoints* in the environment. Increasing error properties then indicate less concise knowledge about other cases and imply the cues are lower in a knowledge hierarchy. Also, by examining the directional bias in the ellipses and relating these to characteristics of the anchorpoints, we can develop some idea of hierarchical order or dominance. This provides some ordering principles for understanding the knowledge structure revealed in the configuration.

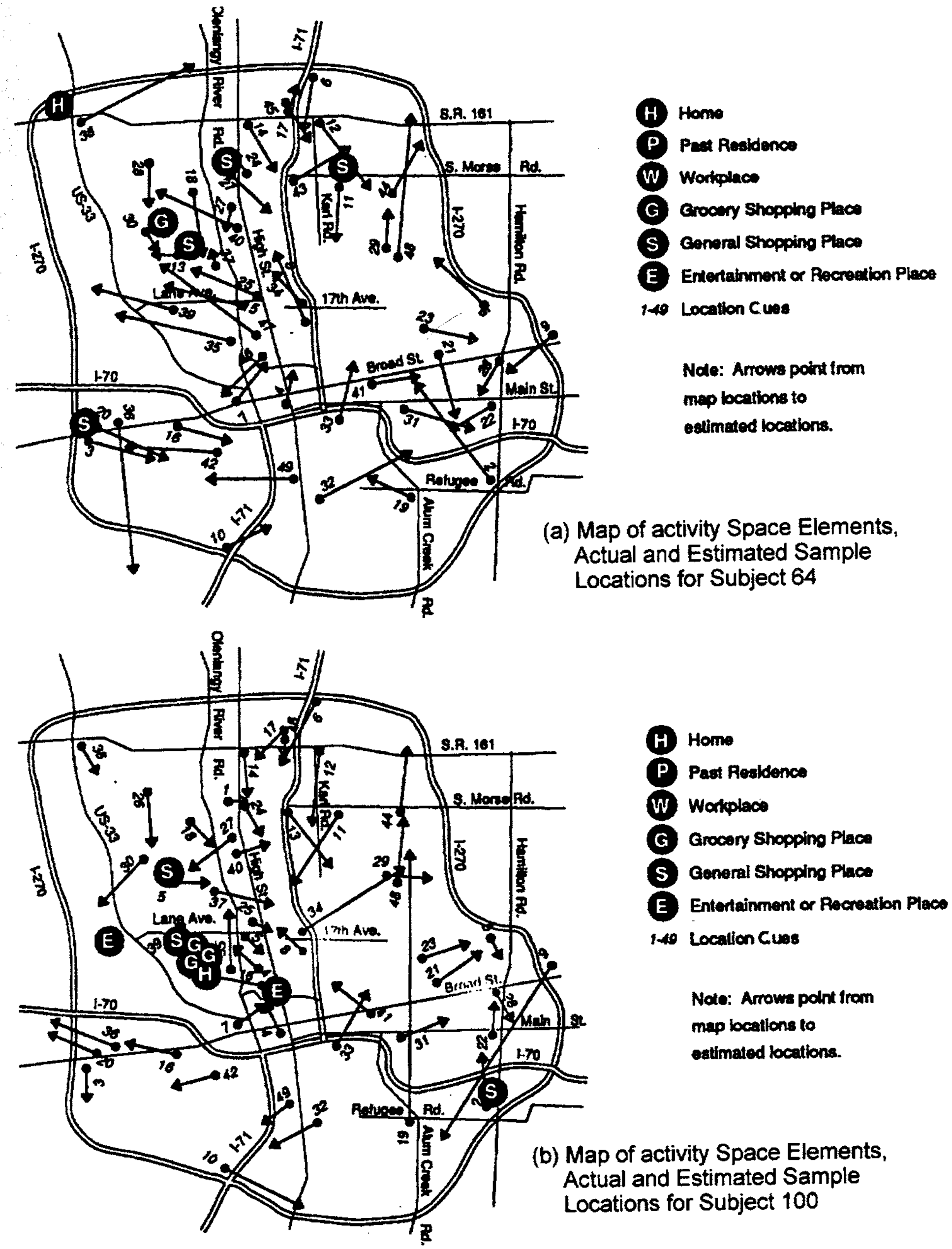


Figure 7.11. Activity space elements and locational errors. (a) Map of activity space elements and actual and estimated sample locations for subject 64. (b) Map of activity space elements and actual and estimated sample locations for subject 100.

7.7 Images of Cities

A major advance in work investigating *city image* was made by Kevin Lynch (1960). His book, *The Image of the City*. This book not only served to focus attention on perceptual and cognitive qualities of urban environments, but it also provided a conceptual framework for the discussion of the structural components of city images that still occupies a primary place in the literature on city structure.

Lynch proposed a five-element classification system consisting of paths, boundaries, districts, nodes, and landmarks:

1. *Paths* were the basic channels along which persons would occasionally or customarily move around a given environment.
2. *Boundaries* were conceived as barriers tending to mark off differentiated segments of space, with the barriers being more or less permeable, depending on whether they consisted of natural environmental features, (e.g., rivers, parks, freeways), or social, political, cultural features (e.g., boundaries of a gang turf, administrative boundaries, ghetto boundaries, and so on).
3. *Districts* were the main areal component of the urban image and were defined as recognizable areas contained within sets of well-defined edges. Districts were generally larger than neighborhoods and often were allocated an official or unofficial descriptive title such that they were readily recognizable by the local population and by many others living outside their boundaries.
4. *Nodes* were defined as strategic spots that acted as foci for human behavioral activity. They may be things such as bus stops, outdoor luncheon or recreational areas, critical street comers, or specific buildings that had well-known functions associated with them.
5. *Landmarks* were visibly dominant and easily identifiable elements of the landscape and could be drawn from the natural, built, or cultural environments (e.g., an overlook, a major distinctive building, a place of historical significance, a place of religious significance, and so on).

These five elements were illustrated earlier for Los Angeles and Boston in Figure 7.5.

While the initial research on city images incorporated fundamental concepts from the psychology of perception—such as figure-background composition, clarity, singularity of form, visual dominance, perceptual closure, and so on—many of Lynch's imitators moved beyond these fundamental perceptual qualities to add the values, meaning, and significance of city elements in both a societal and a cultural sense. For example, Appleyard's (1969) research on why buildings are known included a discussion of basic characteristics such as singularity, level of visibility, community significance, and intensity; but he also emphasized societal and cultural context, historicity, and local significance as critical features of recognition. Other research focused on a search for reasons behind the departure from objective "accuracy" in city images and included things such as residential history of the respondents, levels of familiarity with places, basic elements of form, ethnic or cultural heritage, or mode of travel (e.g., Maurer & Baxter, 1972; Orleans & Schmidt, 1972; Ladd, 1970; Ley, 1972). It must be remembered, however, that although the emphasis on affect and form dominated a considerable part of the research in this area, other research focused on attempts to refine modes of representing cognitive information other than via sketch maps and verbal descriptions (e.g., Golledge & Zannaras, 1973; Golledge, Rivizzigno, & Spector, 1976).

Although Lynch's model is a valuable conceptual tool, it falls foul of the set of problems involved in aggregating and disaggregating data. Even though any city can be decomposed into its component parts, detailed analysis of the parts raises questions of how they can possibly be reassembled. Gale et al. (1985) show that cognized distances violate Euclidean axioms, that nodes and landmarks are often poorly located in memory, that paths often cannot be integrated, and that perceived districts overlap. The separate decomposed elements cannot be reassembled into a whole using conventional geometric or cartographic methods.

7.8 The City as a Trip

A transactionally based hypothesis concerning our knowledge of urban environments would be that one obtains knowledge about the city according to the type of interactions that one has with it. Thus, urban knowledge accumulates as a result of the various trips undertaken as part of the everyday process of living. Whereas other conceptualizations focus more on the node and landmark structure or areal pattern of urban knowledge, this conceptualization is path based.

As an example of a *path-based* view of city images, we present a discussion of the city as a trip by Carr and Schissler (1969). They interviewed a number of commuters, both car drivers and passengers, in the city of Boston in an attempt to identify the types of environmental cues noticed and used by individuals when they are undertaking trips within an urban environment. To obtain information on the recognized and used cue structure, subjects were examined prior to the day of the field trip and asked to state their preconceptions of the trips they were to make, including regular trips undertaken by the individuals and specific tasks set them by the experimenters. In addition, subjects were laboratory tested to determine such things as the accuracy of recall and depth of memory and the angle of eye movements. The next day, subjects were taken on a trip with a camera mounted on their head to record where they were looking, and optical devices focused on the corneas of the subjects' eyes enabled the researchers to identify the directions in which the subjects were looking. This helped to identify possible landmarks seen at various places along the route. Thus, by establishing points of fixation and also requesting a verbal summary of what was noticed and used as navigational aids along the trip, the researchers attempted to define those elements of the city that were observed, recognized, and used in a trip-making context. The subjects were exposed to a variety of verbal, graphic, and descriptive materials associated with the trips and films of the trip in order to provide a data bank. Data banks were then searched using content analysis to find those places, cues, or areas that provided anchors for an individual's cognitive representation of the environment. The features recovered using these processes were then ranked according to the frequency with which they appeared in the subject's responses (Table 7.3).

TABLE 7.3.
Individual Items Memory List for Drivers, Passengers, and Commuters in Order of Best-Remembered Item

Rank	Drivers	Passengers	Commuters
1	Mystic River Bridge	Mystic River Bridge	Mystic River Bridge
2	Toll Booth	Toll Booth	Overpass (early)
3	Overpass (late)	Prudential Building	Prudential Building
4	Sign for Haymarket	Three-Deckers: Chelsea	Bunker Hill Monument
5	Overpass (early)	Overpass (early)	State Street Bank
6	Second Bridge	Bunker Hill Monument	Three-Deckers: Chelsea
7	Three Deckers: Chelsea	Overpass (late)	Government Center
8	Billboard: John Hancock	Government Center	Custom House Tower
9	Sign for Downtown Boston	John Hancock Building	Soldier's Home
10	Sign for Charlestown	Charlestown residences	Toll Booth
11		Custom House Tower	U.S.S. Constitution
12		Charles River Park Apts.	Naval Hospital
13		State Street Bank	Signs for Storrow Drive
14		Sign: Chelsea	William's School
15		North End residences	American Optical Co.
16		U.S.S. Constitution	John Hancock
17		Colored oil drums	Charles River Park Apts.
18		Billboard: John Hancock	Colored oil drums
19		Twin Tower Church	Sign: Fitzgerald Expressway
20		Billboard: Seagrams	Bradlee's Shopping Center
21		Residences on Soldier's Home Hill	North Station
22			Sign for High Street
23			Sign for Dock Square
24			Sign for Chelsea
25			Grain Elevators
26			Wallpaper Factor
27			Barrel Factory
28			Cemetery

Source: Carr and Schissler, 1969:21.

Some of the results from this study focused on the difference between the number of items recorded by regular commuters, as opposed to newcomers in the area, and the number of features recorded by passengers, as opposed to drivers. For example, the average driver remembered only 10 objects over a test section of 4 miles of road, but passengers remembered an average of 21 objects. Commuters who regularly traveled the route remembered an average of 28 objects. It was also found that individuals performing different functions tended to remember similar things in the same order of importance. Thus, the features remembered by drivers were included in the set of features remembered by the passengers, which in turn were contained within the set of features recalled by regular commuters. It appeared that familiarity with the route did change the range of things that were recorded in terms of adding more detail (and less significant features) rather than adding other major anchorpoints. This is indeed a critical feature because it suggests that even newcomers to an area will focus on a fundamental set of primary

cues or anchorpoints. These will then commonly be used to anchor cognitive maps and to provide detail in the vicinity of paths, such that expectations with respect to major decision points along the path can be defined with a great deal of reliability.

The above findings, in turn, suggest that some structural properties of a city impress themselves more on memory than do others. This appears to be the case either for casual or regular observers, and it appears likely that these points of fixation become *orientation nodes* (focal points) in the structuring of a path-dominated image of an area. Given that regular commuters observed and recalled the greatest range and variety of elements in the city, it appears that individuals learn about the environment over time and that they constantly modify their knowledge set as they travel throughout the local environment and accumulate further information. The connection of major nodes or landmarks by paths adds a critical spatial dimension, for it gives an individual an idea of spatial separation and connectivity that helps define the concept of relative location or layout among all points in the environment.

As represented in memory, and as evidenced by behavior, the city as a trip appears to be a highly meaningful concept to all individuals. Whether it is the young child first exploring a neighborhood, or the bored long-time commuter, the structure, sequencing, and dominance of features of the environment related to trip-making are critical in terms of specifying the spatial extent of knowledge at any given point in time. The acquisition of information as one selects and travels a subset of all possible paths in the city helps define the concept of a node path structure that provides a basic framework for cognitive maps. In short, for people to be able to relate to any given environment, they must be able to "read" it, or comprehend what is there. Apparently this is what all individuals must do in their day-by-day interactions with the external environment. This helps them build coherent knowledge structures that, in turn, allow them to quickly store and access the information needed to operate on a day-by-day basis with a minimum amount of confusion and a minimum amount of effort. The path or network structure used in episodic activities thus becomes a critical feature of an image of a spatial environment.

7.9 The City as a Hierarchical Structure

Lynch (1960) identified landmarks and nodes as two of the major components of city images. Much of the early work on urban cognitive structures also focused on landmarks and other features that could be represented as points.

7.9.1 Anchorpoints

Typical of this research was Golledge's (1978a) *anchorpoint theory* of urban cognition. In this theory the acquisition of simple declarative knowledge (understanding individual nodes and landmarks in relation to self) is followed by procedural knowledge in which primary nodes are linked by primary paths in a hierarchical linking of places. As information about place accumulates, spread effects in the vicinity of primary nodes and paths allow the development of simple areal concepts such as neighborhoods. Geometrically, the primary node–path network (or *skeletal* structure) of the emerging cognitive map is filled out by the addition of intermittent areas surrounding the primary nodes and paths. Distortions in the relative location of primary nodes and their associated areas produce foldings or warpings in the fabric of understanding of space. A lack of knowledge of segments of the environment may cause folding in which known places are drawn closer together in the cognitive map structure or may result in the emergence of holes or blank areas that can contribute to locational and relational errors in the spatial information acquired. The final set of spatial information encoded, therefore, may include simple Euclidean properties among places that are well known, and hierarchically conditioned topological relations for those places less well known in a general spatial context. Given this conceptualization, it is easy to see how a definition of a cognitive map as being incomplete, schematized, distorted, and without continuous regular metric or geometric structure may emerge and be found acceptable.

7.9.2 Regionalized Hierarchies

Empirical evidence for the hierarchical organization of spatial knowledge generally, and the arrangement of knowledge about cities in particular, has been offered also by Stevens and Coupe (1978) and Hirtle and Jonides (1985).

The former used a classic geographic problem to illustrate how spatial knowledge was embedded in a dominant–subordinate structure. This was tested by questions asking for clarification about location within and between states. A basic question was: "Which is further east—Reno, Nevada or San Diego, California?' Stevens and Coupe (1978) found that more people chose Reno as the answer to this question. They explained it by suggesting that Reno was embedded in the state concept of Nevada, whereas San Diego was embedded in the state concept of California. Since for the most part Nevada is perceived to be east of California, inference would lead one to suspect that cities in Nevada are further east than cities in California. Thus, a landmark embedded in a region, or dominated directly by another landmark, may take on the characteristics of the dominant place. The result of course is distortion of spatial information.

Hirtle and Jonides (1985) examined how people organized information about specific places in Ann Arbor, Michigan. Lists of places were given to subjects with the task of reproducing them from memory. Using a variation of clustering techniques called ordered tree analysis, Hirtle and Jonides showed that recall proceeded by a focusing on critical anchorpoints or landmarks and then a listing of places subordinate to them (Figure 7.12). Thus a set of key anchorpoints were defined throughout the city, each directly controlling sets of secondary places, which in turn dominated subsets of lower-order places. The city was seen as a multinodal, hierarchically organized system. Such results provide some empirical support for the anchorpoint hypothesis and provide insights into how individuals structure information about the cities in which they live.

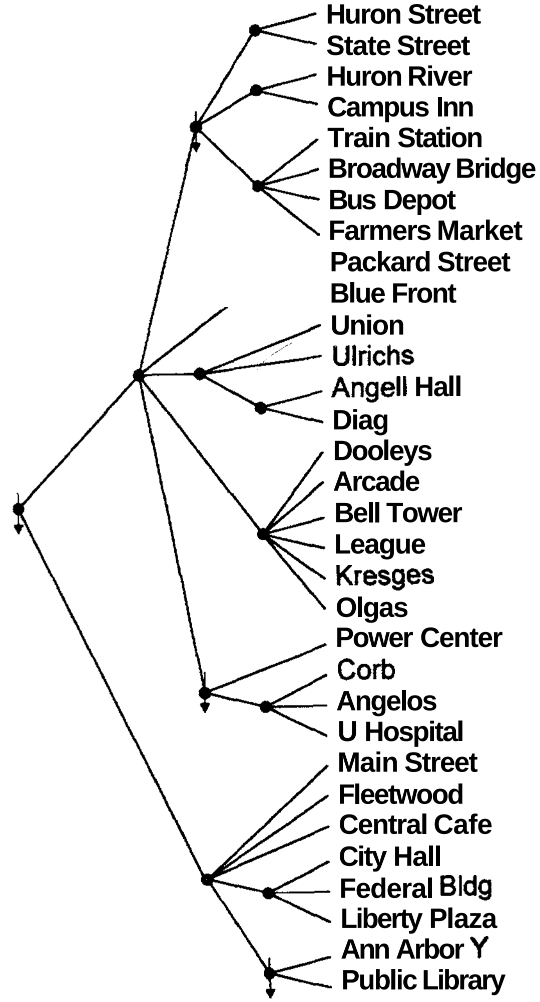


Figure 7.12. Hierarchy of cues in Ann Arbor. Source: Hirtle & Jonides, 1985:213.

7.9.3 Hierarchies of Paths

In a manner similar to that used in landmark organization, Ptruch, Giraudo, and Gärling (1989) suggested that the road and highway network of most cities was also organized hierarchically. They identified at least three levels that were commonly used when one is driving between origins and destinations. The three levels consisted of major highway and freeway segments, which dominated regionalized segments of arterial and main roads, and which in turn dominated local community and neighborhood street systems. Pétruch et al. (1989) found that from any origin the usual process would be to proceed as quickly as possible through the lower orders of the hierarchy to get to the nearest primary level. This would then be used as the path to an exit as close as possible to the potential destination. A final step would involve going down through the hierarchy again until the specific target had been reached. This cognitive structure parallels the traditional Department of Transportation classification of routes into categories such as interstate, state highway, limited access, multilane arterials, arterials with unimpeded bidirectional flow, and local streets.

Much of the literature on urban, economic, and social structure also identifies hierarchical organization. Within the business domain, a hierarchy of business centers can be identified ranging from the CBD to major and minor regional shopping centers, suburban shopping areas or business districts, community centers, neighborhood centers, and isolated store clusters. Socially, cities are often divided into regions, districts, communities, and neighborhoods. Both of the latter hierarchical structures involve the embedding of lower orders within the sphere of influence of higher orders.

Thus, it can be shown objectively that hierarchical systems exist within urban areas and that people either recognize them or create their own hierarchies to help make sense of the complex information system that typifies cities. It is interesting to note that hierarchical organizations appear to be a fundamental process in the cognitive domain also. Here objective and subjective categorization procedures complement each other. The end product is a simplified and more easily comprehended cognitive map of a highly complex and multidimensional environment.

7.9.4 Priming

Holdings (1994) offers further evidence of the existence of hierarchical ordering of spatial information by referring to studies using ***priming.*** Priming occurs when the presentation of one cue leads to quicker recall or recognition of another cue. For priming to happen, the two cues must be linked somehow in memory. It is suggested that if there is a hierarchical organization embedded in the memory structure, then the distances between pairs of cues in the same cluster will be less than the distances between pairs of cues in different clusters. Thus, ***spreading activation*** will result in quicker recall of the paired intracluster cues than for the intercluster cues.

In her analysis, Holdings created two maps with similar structure but with one map being a rotated version of the first. Labels on the map were also switched. On her maps, specific cue names were placed with a constant distance between selected pairs of cues located at different places across the map but with unequal distances between members of different pair groups. Given a hierarchical representation of the map, the pairs should fall progressively further apart within the hierarchy. Holdings concluded that the physical structure of the maps produced the anticipated clustering of cues such that buildings that lay together on the same street were stored closer together in memory than were buildings located on separate streets. Similarly, cues within a given township were stored closer together than were cues from separate townships. She concluded that the maps were mentally represented in a hierarchical form and that these hierarchies mirrored the latent spatial hierarchical structure embedded in the map. Also it was found that it was possible to

make predictions as to the level at which features such as townships, streets, and houses enter in a person's hierarchical ordering.

The assumption underlying this latter conclusion was that cues that were removed from one another by more than two links in the hierarchical network are unlikely to follow one another on any simple recall list. For example, if one recalled a house, it might call to mind the street on which it lies or the township in which it is located, or it could call to mind one of the other houses on the same street. Thus, a house might call to mind a wide variety of items. The street also could call to mind the houses on the street, the other streets in the township, or the township itself. Likewise, a township could call to mind any of the houses or streets within it or any of the other townships. Thus, the level of entry of any cue into the hierarchy was expected to mirror the relationship among the numbers of cues that it was likely to activate.

As an example of the basic intercluster distances, Holdings suggested that houses on the same street would be joined by two links (house–street–house). Houses on separate streets in the same township would be joined by four links (house–street–township–street–house). Houses in separate townships would be joined by seven links (house–street–townshipmap–township–street–hose). Thus, the more links that separate any two cues in the hierarchy, the greater should be the subject's estimation of the distance between them. And as the number of links increases to include adjacent clusters, a distance overestimation tendency will tend to emerge. It is interesting also to note that Holdings found no significant effects of sex, thus indicating that both male and female individuals utilize a hierarchical form of representation of spatial data.

McNamara (1986) also had subjects learn locations within a subdivided layout, They were then asked to perform a direction judgment test, a distance estimation test, and a cue recognition test on the learned objects. The cue recognition test was used for priming purposes. It found that directional judgments were distorted in such a way that they corresponded with the superordinate spatial relationships represented in the hierarchy, and distance judgments were underestimated for within-cluster distances and overestimated for between-cluster distances (Figure 7.13). The priming experiment also indicated that cue names were recognized much faster when they were preceded by a cue in the same region (or same cluster) than if preceded by a cue in a different regional cluster.

In another clustering experiment, Merrill and Baird (1987) made the strong point that priming was far more effective when the environmental features used were both functionally and spatially related. In other words, locations generally found near each other in reality tend to fall close together in hierarchical representations.

7.10 Cognition and Behavior in Classical Models of City Structure

Zannaras (1973) undertook what is still a unique study in terms of examining the role that cognitive representations of the spatial structure of cities have on movements to the city center. Using the existing descriptive models of city structure discussed in Chapter 2 (i.e., concentric zonal, wedge and sector, and multiple nuclei),

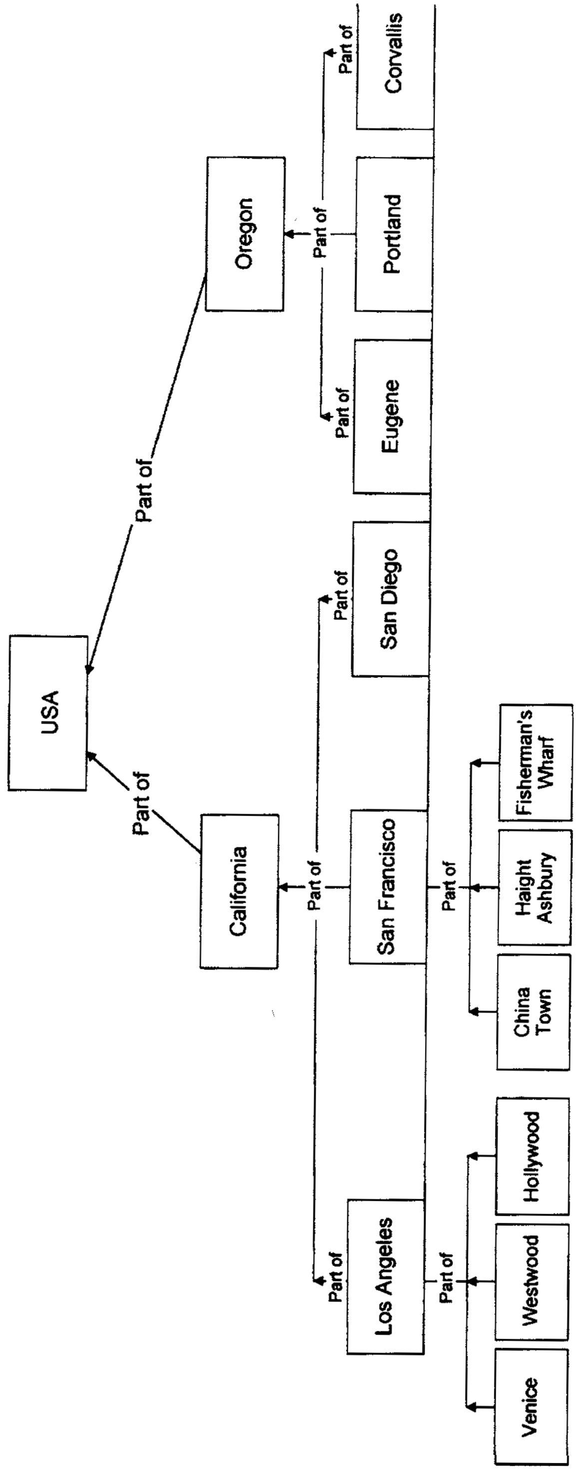


Figure 7.13. Hierarchical nonspatial arrangement of layout.

she found cities in Ohio that approximately fitted each model (Marion, Newark, and Columbus). Land use maps and scale land use models of each of their environments were constructed. Figure 7.14 illustrates how the base land use model was overlain with distance rings for calculating errors associated with wayfinding tasks. Her task was to see if changes in the physical structure of cities significantly influenced image building and consequent wayfinding behavior from the periphery to the city center. This study was unique because, whereas previous work on urban images had focused on deconstructing the city into its component imaged parts, there had been no previous (or later) attempts to relate organizational characteristics of elements in the urban image to the generalized models of the arrangement of city elements suggested in the geographic and planning literature.

Zannaras adopted a twofold approach that: (1) examined the difference in the importance attached by a sample of respondents to the same environmental cues as potential wayfinding aids in various urban structures (Figure 7.15); and (2) investigated differences in how the perception of distance might vary as the physical and built environment varied.

Two sets of hypotheses were proposed and were tested in the laboratory (us-

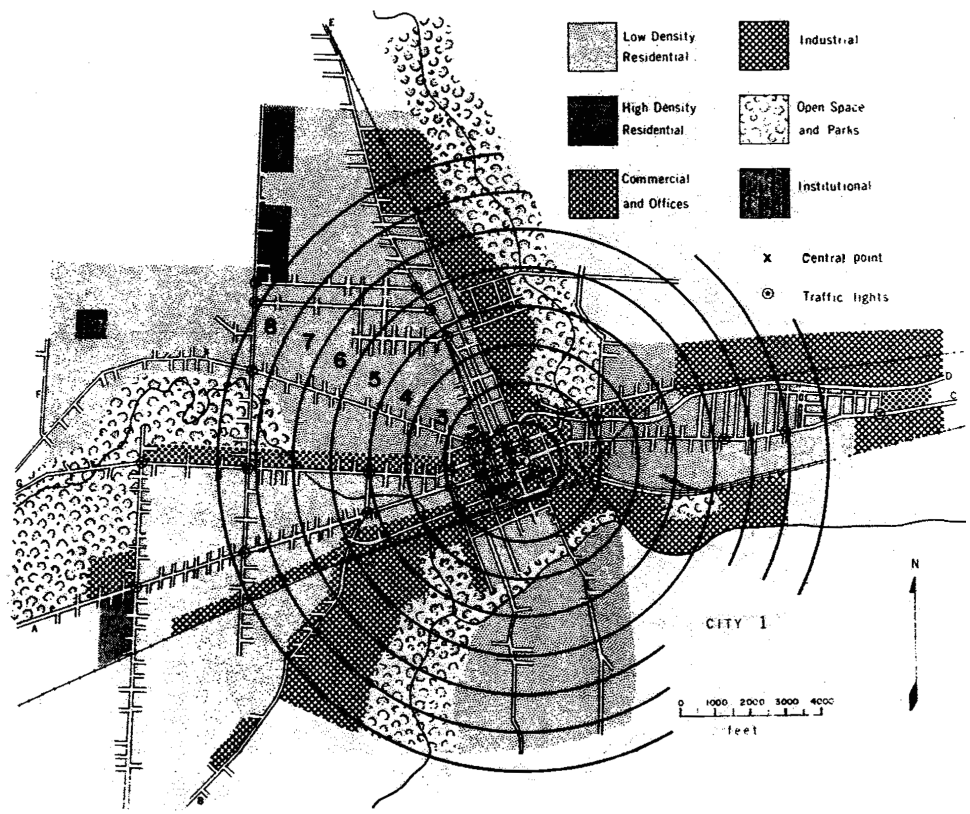


Figure 7.14. Sectoral city with land use and distance zones. Source: Zannaras, 1973.

How often do you notice the following features as you travel to the City Center? Please circle the appropriate number

1. Never 2. Rarely 3. Occasionally 4. Fairly often 5. Frequently

1 2 3 4 5	1. shopping centers
1 2 3 4 5	2. railroad tracks
1 2 3 4 5	3. direction signs
1 2 3 4 5	4. school buildings
1 2 3 4 5	5. banks
1 2 3 4 5	6. churches
1 2 3 4 5	7. movie theaters
1 2 3 4 5	8. restaurants
1 2 3 4 5	9. open space areas such as parks or green space
1 2 3 4 5	10. speed limit signs
1 2 3 4 5	11. the city skyline
1 2 3 4 5	12. traffic congestion
1 2 3 4 5	13. traffic lights
1 2 3 4 5	14. street width changes
1 2 3 4 5	15. billboards
1 2 3 4 5	16. bridges
1 2 3 4 5	17. neon lights in business areas
1 2 3 4 5	18. rivers
1 2 3 4 5	19. hills [b]
1 2 3 4 5	20. freeway systems
1 2 3 4 5	21. number and spacing of freeway exits
1 2 3 4 5	22. industrial buildings (factories)
1 2 3 4 5	23. public buildings
1 2 3 4 5	24. residential quality changes
1 2 3 4 5	25. residential density changes (spacing of houses)
1 2 3 4 5	26. smog
1 2 3 4 5	27. buildings become more numerous and closer together
1 2 3 4 5	28. major department stores
1 2 3 4 5	29. slums
1 2 3 4 5	30. construction work

[a] This figure includes the features which solicited the most responses.
[b] This feature had a mean of 2.83; all other features had means above 3.0.

Figure 7.15. Rating scales for environmental cues used in wayfinding. Source: Zannaras, 1973.

ing slides and scale models) and in the field. Additional hypotheses were proposed to examine the effect of personal characteristics on cue selection and accuracy of distance estimates.

The results showed that city structure significantly explained variations in the mean importance assigned to environmental cues used for wayfinding (Figure 7.15) (Zannaras, 1973). City structure also significantly explained variation in the mean

accuracy of responses associated with the slide and field trip experiments. Thus, it influenced subjects' ratings of wayfinding potential in each of the different settings, the type of urban features selected as cues to assist wayfinding, and the comprehension of the implicit interpoint distance relationship between selected features and the city center. She found that cities structured in terms of wedges and sectors better fostered an understanding of the spatial relationship between urban features and the city center. She also found that variations in city structure were more important than variations in personal characteristics in determining what features would be chosen, the accuracy of locating and sequencing such features, and the accuracy of using such features in wayfinding tasks from the periphery to the center.

Zannaras (1973) also found that navigational experience was a more important factor in successful task performance than length of residence in an urban environment. She hypothesized that residents who used the center on a regular basis (e.g., for work and shopping) would have more accurate distance perceptions and would be more confident wayfinders with respect to movement from the periphery to the city center; and these hypotheses were confirmed.

The critical finding of this study was that structure of the actual urban environment was of considerable importance in determining how the city was imaged and how behavior took place within it. She found also that real differences exist in the importance assigned to the same urban features as wayfinding aids as the structure of the environment changes (i.e., traffic lights and land use zones were more important in wedge- and sector-type structures than they were in concentric zonal or multinuclear-type structures).

Overall Zannaras (1973) found that the physical structure or layout of a city significantly explained variations in the accuracy of location tasks and on wayfinding tasks regardless of what mode (map, slide, model, or field trip) was used. She found also that the concentric structure model, apparently the simplest of all to understand does not produce the best accuracy values for the range of tasks involved. Rather, the sectoral city proved to be the simplest structure for remembering locations, for arranging them, and for using them in wayfinding tasks.

7.11 Cognitive Distance

7.11.1 Distinguishing between Subjective and Objective Distance

In the cognitive mapping process, information is accumulated about relative locations and degrees of connectivity of environmental cues. The term *cognitive distance* has evolved to describe the relative spatial separation of objects in a cognitive map.

One of the earlier examples of applying the concept of cognitive distance occurred in the consumer behavior area (Thompson, 1963). In this context, *subjective distance* estimates were incorporated into conventional gravity models to help explain store choice. Along with this applied interest there developed a basic research interest in the concept of cognitive distance (Golledge et al., 1969; Briggs, 1969, 1972; Lowrey, 1970; Burroughs & Sadalla, 1979; Sadalla & Staplin, 1980a). In most cases a curvilinear relationship was seen to occur between subjective and objective distance (see Figure 7.16). Other authors, such as Cadwallader (1975, 1981), MacKay and Olshavsky (1975), and Pacione (1976), continued an applied interest in cognitive distance in the context of consumer behavior. In both basic and applied research it soon became obvious that the type of procedure used to estimate subjective distance, or to convert objective to subjective distance, was of critical importance (see Table 7.4). Some studies (Briggs, 1972; Lowry, 1973; Thorndyke, 1981) supported Stevens' (1956) contention that a power function was the most appropriate transformation. Both Day (1976) and Cadwallader (1979) argued that the type of function likely to be found was significantly affected by the measurement procedure used in obtaining subjective estimates. Features such as whether estimates of distance were obtained in metric or nonmetric units and whether the research question was specifically oriented toward spatial distance or temporal, social or functional, proximities or similarities, also proved to be critical.

Early investigations of cognitive distance produced some apparently contradictory results. Lee (1962) found that distances outward from the center of the Scottish city of Dundee were overestimated more than inward distances. Golledge et al. (1969), among others, found the distances toward downtown in U.S. cities were overestimated, whereas those toward the periphery were underestimated. Some reasons for the apparent differences were related to the size and functional complexity of the cities in question and also possibly to their internal structure (e.g., whether or not they had many regional shopping centers). Thus, differences in the nature of the local environment and its regional or cultural setting also proved to be a critical factor in the estimate of cognitive distance.

In discussions on the notion of cognitive distance there have been suggestions that differences occur due to sex (Lee, 1970), the nature and frequency of intervening barriers (Lowrey, 1970), and the nature of the endpoints between which cognitive distances are estimated (Sadalla & Staplin, 1980a, 1980b). It is accepted generally that cognitive distances may be asymmetric and that, in some cases, the distances may be interpreted in a functional, proximity, or similarity context rather than in a geometrical one. There have been speculations concerning the use of non-Euclidean metrics to represent cognitive distance (Spector, 1978; Richardson, 1979;

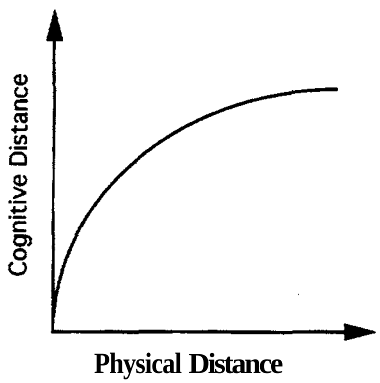


Figure **7.16.** Relationship between cognitive distance and physical distance.

TABLE 7.4.
Relationship between Magnitude and Category Scales

coefficients	Pearson Correlation Coefficients for Relationship between Magnitude Scale and Category Scale (Frequency)	Pearson Correlation Coefficients for Relationship between Logarithm of Magnitude and Category Scale (Frequency)
0.40 or less	0	0
0.41 to 0.60	7	7
0.61 to 0.80	32	35
0.81 to 1.00	26	23

Source: Cadwallader, 1979:568.

Golledge & Hubert, 1981; Tobler, 1976). Furthermore, Baird et al. (1982) have suggested that, given the asymmetric nature of cognitive distance, its representation may be impossible in any known geometric space.

7.11.2 Methods for Evaluating Cognitive Distance

Montello (1991) has defined cognitive distances as mental representations of distances encountered in large-scale environments that cannot be perceived from a single vantage point. Such distances often require movement through the environment before they can be properly apprehended. Alternatively, a scaled-down version may be developed from maps or diagrams. Montello argued that cognitive distance usually is defined using one of five methods: ratio scaling, interval or ordinal scaling, mapping, reproduction, or route following. Cognitive distance is thus different from perceptual distance, which can be defined as the estimate of distance between pairs of points or objects when both members of the pair are simultaneously viewed (Baird et al., 1982).

Of the five classes of methods used to estimate cognitive distance, Montello suggests that the first two represent traditional psychophysical scaling techniques. The last three methods are better suited for estimating distances rather than reproducing them. For example, mapping requires estimation or simultaneous representation of the relative locations of several places but at a scale that is reduced from the original environmental occurrences. Reproduction involves reproducing a traversed distance without a change in scale from the original environment in which the distance was traversed. For example, one may be asked to evaluate the distance between two buildings then, after ensuring that the buildings are occluded from sight, be asked to walk a distance equivalent to that which separated them. Alternatively, one can be walked over a specific length for a number of trials and then be requested to reproduce the length after some disorienting or distracting interval.

The psychophysical methods for estimating cognitive distance vary with respect to the degree of precision required. An ordinal estimation will require only suggesting which distances are shorter or longer than others; there is no need to say how much shorter or longer. Interval measurement, however, asks for quantitative measures of distances so that one can obtain an indication of how much longer or shorter one distance is than another. But, even in this case, one cannot describe the distance estimates so obtained as having the property of being proportional to another distance. This property belongs alone to *ratio scaling* where an absolute zero occurs on the distance scale, and meaningful distance ratios can be obtained.

Montello (1991) summarizes the four principal methods of ratio scaling as follows:

1. *Magnitude production:* Here an observer adjusts a test distance to a length that matches a number provided by an experimenter. The number is said to represent the length of a standard distance. The standard can be provided by the experimenter (e.g., 100 yards) or implicitly generated by the observer (e.g., equal to the length of three football fields).
2. *Magnitude estimation:* Here a test distance is provided with a number proportional to its perceived length in comparison to a standard distance assigned some other value. The standard distance and the number representing it (the modulus) again can be provided by either the experimenter or the observer.
3. *Ratio production:* Here a subject is given a standard distance and adjusts the length of a test distance until it appears to represent a prescribed ratio to the standard.
4. *Ratio estimation:* This is one of the most frequently used techniques and involves direct estimation of the ratio of the length of two distances. Alternatively, one may adjust one of a pair of lines so that the ratio between the two line lengths equals the ratio of a test distance to a standard distance. Examples in the geography literature include the use of magnitude estimation by Cadwallader (1979). Examples of ratio estimation include cognitive distance studies by Lowrey (1970, 1973), Briggs (1973, 1976), Byrne and Salter (1983), and MacEachren (1991).

Briggs (1973) used the ratio-scaling techniques to examine cognitive distances within a major urban area. In the geography literature, the standard line used to invoke the ratio-scaling procedure is often taken to represent a crow-fly distance between two well-known points (e.g., two landmarks). Depending on the scale at which the study is being undertaken, the standard distance may vary from a few hundred meters (for example, as might be the case when one is looking at estimates of distance across a campus or other institution) to a mile or more as would be the case if one were looking at interpoint distances at the level of an entire city. While these procedures are common in geography, Montello (1991) warns that there are difficulties with interpreting ratio-scaled data, particularly if different standards are used with different subjects and there is uncontrolled exposure to those standards.

Briggs (1973) found that the relationship between *subjective* and *objective* distance (i.e., cognized distance and physical distance) was best expressed by a power function. Often, interest is expressed in the value of the exponent in the power function. Where a value greater than 1 occurs, this indicates that subjective or cognitive distance changes more rapidly than does physical distance. Multiple repetitions of this finding have led to the generalization that shorter and well-known distances are often overestimated and longer and less-known distances are frequently underestimated. This process is sometimes referred to as "regressing toward the mean."

Even though magnitude and ratio scaling have been commonly used methods in geography and continue to be used in cognitive distance studies, Montello (1991) suggests that we should be aware of the following four difficulties associated with these practices:

1. *The ratio calculation problem.* Substantial differences may exist among individuals in their ability to determine the ratio between the length of a standard distance and the length of a test distance.
2. *The scale translation problem.* This might occur when the standard distance in an environment is represented by an arbitrarily scaled length of line to make the appropriate estimate; a subject must be able to perform the scale translation between the given standard and the real-world standard before a legitimate result can be achieved.
3. *The problem of bias.* Giving a standard distance with certain lengths provides no guarantee that all subjects will internally represent the standard as being of equivalent length.
4. *The orientation problem.* This may occur when the standard line is given in an orientation different to that normally experienced with respect to the usual frames of reference used in the environment (e.g., a north–south distance being represented by an east–west scale line). Vertical lines often appear longer than horizontal lines (i.e., vertical illusion). Aligning standards with real-world occurrences helps to reduce this type of problem.

Cognitive distances produced by interval- and ordinal-scaling methods are often collected using procedures such as paired comparisons, stimulus ranking, rating scales, proximity judgments, and similarity judgments.

Many of the difficulties associated with ratio-scaled data have been found to be relevant also for ordinal- and interval-scaled data (Montello, 1991). In addition, problems involving inconsistency of estimating procedures, asymmetries in paired comparison, and violations of transitivity when making judgments among all possible combinations of paired comparisons can produce problems and consequent difficulties of interpreting experimental results. For example, subjects might estimate differences differently depending on whether they are viewed as emanating from an anchorpoint or going to an anchorpoint. Similar problems may arise when one is estimating a distance between pairs in which one was an anchorpoint or landmark and the other was a lower-order feature or object. In this case, the cognized distance from the anchorpoint might be foreshortened, while the cognized distance to the anchorpoint may be enlarged.

Cognitive distances are often used to help an observer locate a place in an environment. To do this, classical surveying methods can be used. For example, *triangulation* involves drawing direction lines from two or more points to locate an object. When three or more locations are used, the intersection of these directional lines produces a triangle of error. Taking the smallest triangle produced by this method and then solving for its midpoint gives an estimate of the object's location. Another method is called *resection,* which uses the reverse procedure. Again a triangle of error is produced, and the centroid of the triangle is taken as an approximation of location. In the cognitive distance literature, triangulation is often done using a pointing procedure. For example, a subject may be asked to point to location "A," which is in some occluded place. Each time the subject points to the place from a different location, an angular measurement is made. The solution of the problem follows the same procedure in terms of finding the centroid of the triangle of error that results. This procedure is sometimes called projective convergence. Although such procedures work at local scales and in very familiar settings, as Golledge, Dougherty, and Bell (1995) show, people are not necessarily good at pointing toward distant places, particularly if they are not highly familiar with the place and the surrounding frame of reference is not well known.

Cadwallader (1973a, 1976) has compared ratio and magnitude estimation of cognitive distances in large-scale environments. This research, and later work by Montello (1991), isolates some of the problems associated with methods for measuring cognitive distances. These include:

1. Differences may be expected depending on whether subjects are instructed to estimate "over the route" distance or "crow-fly" distance.
2. Problems may arise when subjects confuse temporal separation between places with spatial separation.
3. Differences may occur depending on whether one is asked to estimate physical distance or perceived distance.
4. Serious questions arise concerning whether or not individual distances can be aggregated.

To summarize, although the *cognitive distance* concept has been shown to be a useful substitute for *physical distance* in models such as those predicting consumer behavior (Cadwallader, 1979), and cognitive distances are frequently used to provide estimates of the reliability of people's cognitive maps and sometimes their travel behaviors, undoubtedly there are problems associated with the collection and measurement of cognitive distance that must be addressed if the concept is to be widely accepted as a practical one that can be integrated into different predictive models. We have outlined some of the difficulties associated both with methods of collecting cognitive distance estimates and problems of using such measurements in explanatory contexts. As studies of cognitive mapping processes and cognitive maps generally become more widespread in geography and other disciplines, a solution to many of these problems becomes a more urgent research issue.

8

Activities in Time and Space

8.1 The Nature of Human Activities in Time and Space

All human activities occur coincidentally in *time* and *space*. Traditionally, human geographers have given considerable attention to the study of locational aspects of human activities. However, in the past three decades or so, the location of activities in time as well as in space has been given increasing significance in research. It is relatively easy to study the absolute spatial locations of activities and the locational outcomes of human decision making using GIS. But the absolute locations of activities can refer also to location in time that is derived from a clock or calendar. In this context clock time acts as a type of grid, and activities and decisions are put into it. We may consider the position of one activity in time in relation to the position of another activity in time or relative to some other location in clock time.

Parkes and Thrift (1980) emphasize the importance of analyzing human activities in a spatiotemporal framework:

> The separation of two items in space may be described by the distance between them and the separation of two items in time by the interval between. When spatial metrics such as meters or kilometers are used to measure distance, we have a measure of absolute distance. If temporal metrics such as hours or days are used to measure interval, we have a measure of absolute interval. However when an a spatial metric is used to indicate distance and an a temporal metric is used to indicate time, then distance and interval are being represented in relative terms, as relative distance and relative time. One of the most common relative space measures combines space with time, and distance with interval. Thus in everyday life we consider the time it takes to get somewhere. This notion of distance and interval in combination is now frequently referred to a as a time–space metric. The geographer's space time is not a new physical structure, as is the four-dimensional space time of Minkowski or Einstein; instead it is a technical convenience and a more realistic way of looking at the world. (p. 4)

We may think of human activities occurring within a context of locational space coordinates, with distance being separated within a space metric and all of