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Cognitive Maps and Spatial Behavior: Process and Products

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Introduction

A surprising fact is associated with studies of cognitive mapping: although the emergence of this vigorously developing research area has been recent, we are not discussing something newly discovered such as a subatomic particle or a cell protein structure. Instead we are concerned with phenomena so much part of our everyday lives and normal behavior that we naturally overlook them and take them for granted.

A series of examples indicate the pervasive influence of cognitive maps and mapping processes. *Newsweek* (June 15, 1970) quoted a London cab driver: "It's crazy, . . . How do they expect anyone to find their way around here?" This plea resulted from an ingenious planning experiment in which sidewalks were widened and streets narrowed and turned into a system of mazes, dead-ends, and one-way routes. The objective was to create a confusing obstacle to drivers, forcing them to abandon habitual short cuts in favor of main streets, or, better still, to give up driving and use public transportation. That the drivers have well-developed cognitive maps is implied in one planner's claim: "You can't make it just difficult. You have to make it nearly impossible or you won't win."

As a graphic example of the value of cognitive maps consider the 1970 Apollo 14 moon walk. Astronauts Shepard and Mitchell were within 75 feet of their objective, the rim of Cone Crater, but returned to "Antares" without completing their mission. The reason? They had become confused and disoriented by the lack of distinctive lunar landscape features and the endless sequence of gullies. It was only later that they realized just how close they had been to their objective.

We are all aware of the image evoked when the news media use a locational term such as "the South" in the U.S.A. or "the Midlands" in England. We share common reactions when told that "it" happened in the South:

images of the climate, the prevailing social system, the attitudes of the people, the food they eat, readily "spring to mind." We rely on these images for understanding and explaining the event (it) because "you would expect that sort of thing to happen there." Cognitive maps are convenient sets of shorthand symbols that we all subscribe to, recognize, and employ: these symbols vary from group to group, and individual to individual, resulting from our biases, prejudices, and personal experiences. In the same way, we respond to an advertisement's exhortation to "come to sunny Florida" or, on the other side of the Atlantic, to "come to sunny Brighton." We associate images of beaches, sun-bathing, amusement parks, golf courses with such simple locational terms; our cognitive mapping processes fill in the necessary details. Thus an advertisement offering ice cream store franchises in the *New York Times* made the following appeal:

> Tired of snow? Tired of crowded city life?
> BE A CONTENTED SOUTHWESTERNER!
> Enjoy life the way it should be: among neighborly congenial folks on the balmy Gulf Coast, or the dry Texas "Hill Country;" or the scenic "Piney Woods" of East Texas. (February 21, 1971, Section 5, p. 2)

So we find that planners try to alter cognitive maps, astronauts need them, the news media use them, and advertisers tempt us with them: they *are* part of our everyday lives. But for research designed to understand and explain them, definitions by example are necessary but *not* sufficient. Consequently, we offer a formal definition: *Cognitive mapping is a process composed of a series of psychological transformations by which an individual acquires, codes, stores, recalls, and decodes information about the relative locations and attributes of phenomena in his everyday spatial environment.*

In this paper, we will expand this definition and examine the conceptual frameworks which are subsumed within it.

An Analysis of Cognitive Mapping Processes

COGNITIVE MAPS AND ADAPTIVE BEHAVIOR

Underlying our definition is a view of behavior which, although variously expressed, can be reduced to the statement that *human spatial behavior is dependent on the individual's cognitive map of the spatial environment.* That this formulation is necessary is indicated by a comparison of the characteristics of the individual with those of the spatial environment.

The environment is a large-scale surface, complex in both the categories of information present and in the number of instances of each category. Things are neither uniformly distributed over this surface, nor ubiquitous: they have a "whereness" quality. In contrast, the individual is a relatively small organism with limited mobility, stimulus-sensing capabilities, information processing ability, storage capacity, and available time. The individual receives information from a complex, uncertain, changing, and unpredictable source via a series of imperfect sensory modalities operating over varying time spans and intervals between time spans. From such diversity the individual must aggregate information to form a comprehensive representation of the environment. This process of acquisition, amalgamation, and storage is *cognitive mapping*, and the product of this process at any point in time can be considered as a *cognitive map*.

Given a cognitive map, the individual can formulate the basis for a strategy of environmental behavior. We view cognitive mapping as a basic component in human adaptation, and the cognitive map as a requisite both for human survival and for everyday environmental behavior. It is a coping mechanism through which the individual answers two basic questions quickly and efficiently: (1) Where certain valued things are; (2) How to get to where they are from where he is.

COGNITIVE MAPS AND SPATIAL BEHAVIOR

Although the cognitive map represents a set of processes of unknown physiological and controversial psychological nature, its effect and function are clear. We believe that a cognitive map exists if an individual behaves as if a cognitive map exists (Stea and Downs, 1970). Above we cited anecdotal examples of the relationship between behavior and the cognitive mapping process. Normal everyday behavior such as a journey to work, a trip to a recreation area, or giving directions to a lost stranger would *all* be impossible without some form of cognitive map. These ubiquitous examples are overlooked and relegated to "second nature" status. Admittedly, much spatial behavior is repetitious and habitual—in travelling, you get the feeling that "you could do the trip blindfolded" or "do it with your eyes shut." But even this apparent "stimulus-response" sequence is not so simple: you must be *ready* for the cue that tells you to "turn here" or *prepare* for the traffic light that tells you to "stop now" or *evaluate* the rush hour traffic that tells you to "take the other way home tonight." Even in these situations you are *thinking ahead* (in both a literal and metaphorical sense) and using your cognitive map. In human spatial behavior, we consider even a series of stimulus-response connections as a "simple" (or "impoverished") form of cognitive map, in which the general aspects of spatial relationship implicit in cognitive mapping play a minimal role. In terms of the two basic questions raised earlier, the person *knows* that an object is valued and one way of getting to it, but knowledge of the "whereness" in relation to the *location* of other objects is absent. The goal is always a part of the cognitive map, however primitive the map might be, even when the degrees of closeness of approach to the goal cannot be articulated. Thus, someone "who knows only one route" knows more about that route than just the appropriate responses at certain choice points, and because he "thinks ahead," is also engaging in cognitive mapping. We are postulating the cognitive map as the basis for deciding upon and implementing *any* strategy of spatial behavior.

However, we must make it perfectly clear that a cognitive map is not necessarily a "map." This apparently paradoxical statement focuses on a misconception which has emerged in research in this area over the past ten years and which our definition might exacerbate. We are using the term *map* to designate a functional analogue. The focus of attention is on a cognitive representation which has the *functions* of the familiar *cartographic* map but not necessarily the physical properties of such a pictorial graphic model (Blaut, McCleary, and Blaut, 1970). Consequently, it is an analogy to be used, not believed. The problem of the map analogy is particularly acute for geographers, a group with a distinctive viewpoint or "spatial style" (Beck, 1967). In fact, if we are to believe Beck, geographers are strangely ambivalent as to whether they prefer features to be "up" versus "down" or "horizontal" versus "vertical". This ambivalence may result from their way of approaching the world, based on concepts of relative location, proximity, and distance, and especially geared to the use of cartographic maps. Boulding (1956) argued that "the map itself . . . has a profound effect on our spatial images (p. 65)." More particularly, drawing upon Lynch's (1960) attractive and appealing series of cognitive maps of U.S. cities portrayed as cartographic maps, we might paraphrase Boulding's statement to read: "The cartographic map has had a profound effect on our concept of a cognitive map."

Spatial information can be represented in a variety of ways. Consider, for example, a street directory in which streets are ordered alphabetically and people ordered spatially (by residences *and* apartments) and contrast it with a telephone directory listing exchange areas spatially and people alphabetically. Further representations include tape-recorded walking tours for museums or European cities, rail and bus route schedules, and electronic media such as radar and laser holograms. All of these media share the same function, not structure; and thus cognitive maps are derived from analogies of process, not product.

COGNITIVE MAPPING SIGNATURES AND COGNITIVE REPRESENTATIONS

As Blaut, McCleary, and Blaut (1970) indicate, the basic functional identity among the media exemplified above can be subsumed under a general "black box" model. All of the media rely upon the same sort of spatial information, and all are employed in the same sorts of spatial behavior: thus, the inputs and outputs are specified while the intervening storage system (the black box) is not. The way in which spatial information is *encoded* (map making) and *decoded* (map reading or interpreting) gives rise to a set of operations called the *signature* of a given mapping code. Thus, a cartographic map signature is dependent upon three operations: rotation of point of view to a vertical perspective, change in scale, and abstraction to a set of symbols (for example, red dots for towns, blue lines for rivers). These operations are more general than the specific signatures, however. Thus, many other signatures are feasible; we have no reason to anticipate that cognitive maps should necessarily have the same form of signature as cartographic maps. Above all, we should avoid getting "locked" into a form of thinking through which we, as investigators, force a subject to "produce" a *cartographic* cognitive map and which we then "verify" against an objective cartographic map. It is significant, therefore, that Lynch (1960) used several input signatures (verbal and graphic) in his original study and a single, graphic output signature to produce his now famous maps of Boston, Jersey City, and Los Angeles.

The issue of mapping signatures involves some fundamental theoretical and methodological issues in the study of cognitive mapping processes. Underlying the whole approach is the basic question: How is information, derived from the absolute space of the environment in which we live, transformed into the relative spaces that determine our behavior? The transformation can be viewed as a general mapping process involving any or all three fundamental operations: change in scale, rotation of perspective, and a two stage operation of abstraction and symbolization, all of which result in a representation in relative space.

We are interested in the class of cognitive representations which result from the transformation of information about spatial phenomena from one set of absolute space relationships into a set which is adaptive or useful in terms of human spatial behavior.

Thus, we should be interested in developing theoretical statements about the *cognitive signatures* that are employed in dealing with information from the spatial environment. We have given these signatures a seemingly bewildering series of labels (cognitive maps, mental maps, images, and schemata) without applying the necessary critical scrutiny. For example, the only differences between Lynch's "images" (1960) and the city maps of cartographers lie in the degree of abstraction employed and in the type of symbols chosen to depict information. The research procedure is the result of a series of transformations: each individual constructs his own relative space based upon approximately the same absolute space. Lynch aggregates and summarizes these relative spaces reconverting the information by using another signature—conventional cartography with associated scale change and rotation to a vertical perspective. Such representations may be heavily *content-loaded*—that is, they may stress *what* is being represented and not the *way* in which it is being represented. Instead, we should be concerned with the nature or signature of relative space as it is construed and constructed by the individual. Only if we do this can we ask how relative and absolute spaces compare and differ. Speculatively, it seems likely that cognitive representations may employ a variety of signatures simultaneously; some aspects of our composite cognitive maps may resemble a cartographic map; others will depend upon linguistic signatures (in which scale and rotation operations are irrelevant), and still others upon visual imagery signatures derived from eye-level viewpoints (in which the scale transformations

may be disjointed or convoluted). These remain speculations because we have not yet fully understood *what* we should be looking for—in our view we must regard cognitive maps as the result of these mapping signatures and try to understand the nature of such signatures.

We have defined cognitive mapping as the process of acquiring, amalgamating, and storing spatial information. We have tried to specify more clearly the meaning of a cognitive map. However, before considering the nature and functions of cognitive maps in more detail, we must discuss some basic definitions and attempt to clarify a few misconceptions which currently prevail.

The Concepts of Perception, Cognition, Attitude, and Preference

PERCEPTION AND COGNITION: DISTINCTIONS

Unfortunately, perception and cognition have been employed in a confusing variety of contexts by psychologists and other social scientists. Frequently, the context itself is ambiguous, since the word falls into the "process-product" category (Rudner, 1966, p. 7). When such a word is used it is difficult to determine whether the *process* of perceiving is being discussed or whether the concern is with the *product* of the perception process. Both aspects are of importance in our studies of cognitive mapping, but if we are to develop cumulative scientific knowledge, an explicit statement of the focus of interest must be included. Such a statement is notably lacking in geographic studies. In addition, perception has been used in a variety of ways: to experimental psychologists, it involves the awareness of stimuli through the physiological excitation of sensory receptors; to some social psychologists, it implies both the recognition of social objects present in one's immediate sensory field *and* the impressions formed of persons or groups experienced at an earlier time. To many geographers, perception is an all-encompassing term for the sum total of perceptions, memories, attitudes, preferences, and other psychological factors which contribute to the formation of what might better be called environmental *cognition*.

The complex interrelationship between perception and cognition is illustrated by the definition of a perceptual-conceptual repertory as:

> The stable, recognized patterns of perceptions into which sensory complexes are organized. Species differ radically in their capacity to organize sensory complexes into such patterns. The confirmed city dweller does not see the browning wheatfield as ready for harvest; the country dweller may find the directions in the subway confusing rather than patterned. (English and English, 1958, p. 379)

Given the varied uses of the terms, it is difficult to distinguish between perception and cognition, but we will make a "distinction of convenience," the necessity for which is indicated not so much by the responses of individuals to "stimuli," but by their responses to "labels." Environmental designers and geographers have identified some of the issues in human response to natural and designed environments as "perceptual problems," but, to their dismay, often found that studies of single-neuron preparations and autokinetic effects have little to say about human "perception" of the landscape.

Thus we reserve the term *perception* for the process that occurs because of the presence of an object, and that results in the immediate apprehension of that object by one or more of the senses. Temporally, it is closely connected with events in the immediate surroundings and is (in general) linked with immediate behavior. This accords with the view of perception delineated by experimental psychology. *Environmental cognition* is thus the subject matter of interest to geographers, physical planners, and environmental designers working on behavior issues. Cognition need not be linked with immediate behavior and therefore need not be directly related to anything occurring in the proximate environment. Consequently, it may be connected with what has passed (or is past) or what is going to happen in the future.

However, this distinction falls short of establishing a clear dichotomy. We agree with Levy that the difference between perception and cognition is one of degree and focus (1970, p. 251). Both refer to inferred processes responsible for the organization and interpretation of information, but perception has a more direct sensory referent than cognition. Cognition is the more general term and includes perception as well as thinking, problem solving, and the organization of information and ideas. A more useful distinction from a spatial point of view is offered by Stea (1969). He suggests that cognition occurs in a spatial context when the spaces of interest are so extensive that they cannot be perceived or apprehended either at once or in a series of brief glances. These large-scale spaces must be cognitively organized and committed to memory, and contain objects and events which are outside of the immediate sensory field of the individual. This scale-dependent distinction, intuitively acceptable to a geographer, also suggests that we are concerned with the nature and formation of environmental cognitions rather than with briefer spatial perceptions.

ATTITUDES, PREDICTIONS, PREFERENCES, AND COGNITIVE MAPS

The processes of perception and cognition that lead to predispositions to behave in certain ways toward object classes *as they are conceived to be* are termed *attitudes*. The parallels between the concepts of cognitive map and attitude are marked. For example, we assume that knowledge of an individual's cognitive map is necessary to predict his spatial behavior: a similar claim has been made in psychology with respect to attitudes. Yet as Fishbein says:

> After more than seventy-five years of attitude research, there is still little, if any, consistent evidence supporting the hypothesis that knowledge of an individual's attitude towards some object will allow one to predict the way he will behave with respect to the object. (1967b, p. 477)

He rejects the argument that the lack of confirmation of the hypothesis is due to an incorrect operational definition of the terms involved, since continual revisions of measuring instruments have brought no success. Instead, he suggests that the conceptualization of an attitude and its hypothesized links with behavior are faulty, and replaces the holistic concept of an attitude with a formulation containing three components: *cognitions* or beliefs, *affect* or attitude, and *conations* or behavioral intentions.

Fishbein claims that the fact that affect, cognition, and action are not always highly correlated necessitates this more complex typology (1967a, p. 257). The belief component of Fishbein's model is relevant to our definition of a cognitive map. He distinguishes between beliefs concerning the *existence* of an object and about the *nature* of an object, both of which are expressed in probability-improbability dimensions. Significantly, Boulding refers to the *image* (or cognitive map) as being subjective knowledge which "largely governs my behavior (1956, pp. 5–6)."

However, this governing relationship may be both indirect and highly complex. In such a light, work on the perception of environmental hazard and individual locational behavior must be reevaluated. For example, the questions that Kates (1967, pp. 72–73) developed in his study of storm hazard on the Eastern seaboard of the U.S.A. measure the structure and content of belief systems. Through the verbal content of people's responses, Kates attempts to infer the reasons for people choosing to locate in potentially hazardous areas. However, Fishbein points out that attitudes, beliefs, and expressed behavioral intentions are frequently brought into line with actual behavior. Consequently, Kates' approach contains problems of causal relations and inference, since the perception of the hazard may have been adjusted, or *rationalized*, so that it conforms with past behavior (i.e., the decision to locate). In other words, if a behavior can be specified, an attitude can usually be postdicted.

Finally, we must distinguish among attitudes, preferences, and traits. In comparison with attitudes, preferences are usually considered to be: (1) less global—often directed to a specific object rather than a class of objects; and (2) less enduring over time—more subject to change than relatively stable, permanent attitudes. When a given attitude pervades a wide variety of objects over a considerable period of time, it becomes a *personality trait*. Craik has suggested the existence of environmental traits:

> Individuals not only exhibit characteristic styles of relating to other persons, such as "dominant," "assertive," "deferent," and so on, they also display enduring orientation toward the physical environment. Designed to identify the individual's conception of himself in reference to the natural and man-made physical environment, an inventory of environmental traits would

permit the declaration: "I am the sort of person who reacts in these ways to the molar (large scale) physical environment." (1970a, p. 86)

Hypothetically, one could construct a scale from preference through attitude to trait, increasing in both inclusiveness and duration of the cognitive, conative, and affective components.

These discussions indicate the depth of confusion that exists concerning the key concepts of perception, cognition, and attitude. Part of the confusion is due to obvious interrelationships; for example, cognition is assumed by many to be the major component of perception (Langer, 1969) although affective and conative characteristics are present as well. Similarly, there is interplay between an attitude and the way an object is perceived. Boulding argues that "for any individual organism . . ., there are no such things as 'facts.' There are only messages filtered through a changeable value system (1956, p. 14)." This lack of conceptual clarity is a major problem in an area already overburdened with tentative and unrelated conceptual infrastructures.

The Nature and Functions of Cognitive Maps

To understand more fully what cognitive maps are, how they are formed, and how they work, we need answers to three basic questions: (1) What do people *need* to know? (2) What do people *know?* (3) How do people *get* their knowledge?

WHAT DO PEOPLE NEED TO KNOW?

Given an individual with the limitations specified earlier and a spatial environment with complex characteristics, there are two basic and complementary types of information that he must have for survival and everyday spatial behavior: the *locations* and the *attributes* of phenomena. Cognitive maps consist of a mixture of both. Since location and attribution are properties of objects as well as of phenomena, we must also know what an "object" is.

Locational information is designed to answer the question, Where are these phenomena? and leads to a subjective geometry of space. There are two major components to this geometry, *distance* and *direction*. Distance can be measured in a variety of ways, and we are surprisingly sensitive to distance in our everyday behavior. The claim that "it takes you only half an hour to go and get it" will perhaps receive the reply that "it's too far to go." We think of distance in terms of time cost, money cost, and the more traditional measures, kilometers and miles. Knowledge of distance—the amount of separation between pairs of places and pairs of phenomena—is essential for planning any strategy of spatial behavior. Geography, for example, has developed a series of models of human spatial behavior which depend upon the individual's sensitivity to distance variations and upon his assumed goal of minimizing the distance traveled either by himself or by his products.

Direction is no less important in the geometry of space, although we are less conscious of directional information. We take direction more for granted than we perhaps should. It is only when we cannot find a map in the glove compartment of the car and become lost that the need for directional information becomes acute. The person who "gives" directions by pointing vaguely and saying "it's over there" is no more helpful than one who says "it's on the left"—we need to know *whose* left.

By combining distance and direction we can arrive at locational information about phenomena, but not necessarily the same as that provided by the Cartesian coordinates of cartographic maps. For example, suppose that we wish to visit a drive-in movie theater—what do we need to know? First, we need to know where we are—this means "keying" our cognitive map to our current location. We need to know where the movie theater is, which, at this spatial scale can be accomplished in two ways. Either we know where the theater is *in relation to* where we are now and consequently can select the easiest route to get there, or we know its location *relative* to some other place whose location is known—thus it may be "about five minutes' drive past the Suburbsville Shopping Center." Second, we need to know how far away it is, how to get there, and how long it will take to get there.

Thus, locational information is not as simple as it might appear. We must store many bits of distance and direction data to operate efficiently in a spatial environment, a process involving relatively accurate encoding, storage, and decoding. Use of locational information in formulating a strategy of spatial behavior, however, requires a second type of information: that concerning the *attributes* of phenomena.

Attributive information tells us what *kinds* of phenomena are "out there," and is complementary to locational information, indicating *what* is at a particular location and *why* anybody would want to go there.

An attribute is derived from a characteristic pattern of stimulation regularly associated with a particular phenomenon which, in combination with other attributes, signals the presence of the phenomenon. A concrete example will clarify this definition. Imagine that at the end of the search process specified in the drive-in theater example you are confronted with something that you "recognize" consisting of a large open space surrounded by a wall with an enormous screen at its far end, a small building at a break in the wall, and lots of teenagers driving in and out in cars. Obviously, it is the drive-in movie theater that you were searching for, and the screen and teenagers can be considered attributes of the phenomenon "movie theater." You can interpret the pattern of stimulation (visual in this instance) as indicating a series of attributes that, in this combination, signal the presence of a drive-in theater.

We can divide attributes of phenomena into two major classes: (1) descriptive, quasi-objective, or denotative; and (2) evaluative or connotative. The attributes listed as signaling the presence of the drive-in all belong to the first type, while attributes such as "reasonable prices," "good shows," or "easy to get to" are evaluative or connotative. Here, we are separating attributes which are affectively neutral (descriptive) from those which are affectively charged (evaluative). This process of evaluation involves a relationship between a phenomenon and its potential role in the behavior of the experiencing individual.

What is the relationship between an attribute and an object? An object is identified and defined by a set of attributes and bits of locational information. However, what is an object at one spatial scale can become an attribute at another. Consider the following sequence: at an interurban scale we might view cities as objects with population density, built-up area, and level of industrial growth as examples of attributes; at an intraurban scale, we could consider shopping centers as objects with number of stores and number of different types of retail functions as attributes; at an intracenter scale, the stores become the objects; and finally, at the intrastore scale, the offerings of the store become attributes. The scale of analysis of the problem at hand defines what is an object and what is attributive and locational information.

WHAT DO PEOPLE KNOW?

If we compare a cognitive map with a base map of the real world (whether it be an aerial photograph, a cartographic map, or a scale model), we find that *cognitive* mapping does not lead to a duplicative photographic process with three-dimensional color pictures somehow "tucked away in the mind's eye," nor does it give us an elaborately filed series of conventional cartographic maps at varying spatial scales. Instead, cognitive maps are complex, highly selective, abstract, generalized representations in various forms. As Kates and Wohlwill (1966) argue, we must realize that "the individual does not passively react or adapt to the environmental forces impinging on him, but brings a variety of cognitive activities to bear—expectancies, attitudes, even symbolic elaboration and transformation of the world of reality—which come to mediate and modulate the impact of the environment on him (pp. 17–18)." We can characterize cognitive maps as *incomplete, distorted, schematized,* and *augmented,* and we find that both *group similarities* and *idiosyncratic individual differences* exist.

The Incompleteness of Cognitive Maps. The physical space of the real world is a continuous surface which we have come to understand through a classic geometrical framework, that of Euclid. Even though the amount of the earth's surface within our immediate visual range is limited, we are told that the surface is one of approximately continuous curvature. There are no gaps or bottomless voids, and the Flat Earth Society to the contrary, we cannot fall off the edge. There is always something at the "back of the beyond." Yet all cognitive maps depict discontinuous surfaces. Seemingly, some areas of the earth's surface do not "exist" when existence is defined

by the presence of phenomena in the subject's cognitive representation. Carr and Schissler (1969) show how the knowledge of approach routes to a city extends only as far as the visual range attainable from the highway in the journey to work, a finding also apparent in the work of Appleyard, Lynch, and Myer (1964). On a smaller scale, Ladd (1970, pp. 90–94) indicates that black children do not represent certain sections of the neighborhood environment in their cognitive maps.

However, before we accept the discontinuous nature of cognitive maps, we must question the nature of our evidence, particularly negative evidence. As Crane (1961) observes in a provocative review, Lynch's (1960) maps of Boston omitted the city's then most prominent feature, the John Hancock Building. Yet it is difficult to accept that residents did not know of its existence; they chose not to represent it externally on their *drawn* cognitive maps. The reason for this omission may be related to the distinction between denotative and connotative meaning. Although the phenomenon may *denote* something to the individual, it may have no *connotative* meaning; that is, it may play no significant or valued role in the person's behavior. In addition, we frequently find that cognitive maps are distorted so that the size (scale) of represented phenomena, especially in the drawings of young children, indicates relative connotative significance. Therefore, we must be careful in interpreting the absence of phenomena from cognitive maps as reflecting cognitive discontinuity of space.

Distortion and Schematization. By the *distortion* of cognitive maps, we mean the cognitive transformations of both distance and direction, such that an individual's subjective geometry deviates from the Euclidean view of the real world. Such deviations can have major effects upon the patterns of spatial use of the environment. In terms of distance distortions, Lee (1962; 1970) has indicated that, given two urban facilities equidistant from an urban resident, one located on the downtown side is considered closer than the one which is away from the city center. If people are sensitive to distance, consequent spatial behavior patterns will be dependent upon such distance distortions.

Far more significant, and as yet little understood, are the results of *schematization.* By schematization we mean the use of cognitive categories into which we code environmental information and by which we interpret such information. We are, as Carr (1970, p. 518) suggests, victims of conventionality. This conventionality may be expressed in two ways. The first involves the use of those spatial symbols to which we all subscribe and which we use both as denotative and connotative shorthand ways of coping with the spatial environment. Thus, we all understand (or *think* we understand) the intended, value-loaded meanings of "Africa the Dark Continent," "Europe the Center of Culture," "Behind the Iron Curtain," and "The Midwest as the Heartland." Symbols (often mythological), such as the Western route to India and the search for the Northwest Passage, have had major effects upon the course of history. In general, such symbols deal with large spatial areas and are subscribed to by a large part of the population.

However, there are other symbols dealing with geographic entities at many scales; geographic entities which owe their cogency and importance to their mere existence—even to rumored existence. In the aggregate, such entities have been termed the "invisible landscape" (Stea, 1967). As images, these elements are perhaps the most purely symbolic. Included are certain National Parks and Wilderness Areas (of importance to many people who never have and perhaps never will see them); national landmarks such as the Statue of Liberty, once (and perhaps still) *the* symbol of the United States; New York's theater district, for those inhabitants of "The City" who never have gone there and never will go; and even, for some, New York City itself. It could be argued that even though many people do not want to go into New York, it is still important for New York to maintain its image because the same people want to locate around it. "Suburb of *what?*" is perhaps not an insignificant question.

A second aspect of schematization or conventionality involves the very limited set of cognitive categories or concepts that we have developed in order to cope with information derived from the spatial environment. As we were recently told, "Once you've seen one slum, you've seen them all." Are all older center-city areas "slums" to middle-class whites or do they have more sophisticated cognitive categories? Our understanding of the semantics (or the vocabulary) of cognitive maps is remarkably limited.

The controversy over linguistic relativity suggests that there are cross-cultural differences in the ways in which spatial information is coded. Such barriers are not only cross-cultural. Burrill (1968), a geographer studying an Atlantic coast swamp area, found that "swamp" meant a complex, multi-attribute feature to local residents; to Burrill it was a simple, single attribute feature. Communication using the term "swamp" was impossible because of this difference in meaning. Similarly, Downs (1970) assumed that a neighborhood shopping center would be a clearly defined and commonly agreed upon spatial unit, with the edge of the commercial area defining the shopping center boundary. However, residents of the area recognized four distinct subcenters.

A modern counterpart of Dick Whittington's belief that the streets of London were paved with gold may have been the belief of Blacks, Puerto Ricans, Appalachian Whites, and other disadvantaged people that they could find "a piece of the action" in the cities of the Northeastern United States, their desire to share in "the good things of modern society," and their trust in the willingness of those who had "made it" to help them. The gap between such beliefs and reality is almost painful (Brody, 1970). Yet another example of the ways in which people cope with spatial information

comes from studies of environmental hazard evaluation: Burton and Kates (1964) indicate the unrealistic nature of people's estimates of the probabilities of hazards. Thus, the Los Angeles earthquake of 1971 has not served as a warning to Californians. Building continues, house sales continue—apparently the "lightning will not strike twice" mechanism is operating in spite of warnings that even more severe earthquakes can be expected in the near future.

Augmentation. Another characteristic of cognitive maps is *augmentation.* There is some indication that cognitive maps have nonexistent phenomena added as embroidery. Ancient cartographers abhorred voids and filled blank spaces with fictitious rivers, mountain ranges, sea monsters, and possible locations of Atlantis. A respondent in Appleyard's (1970) study of Ciudad Guayana drew in a railway line on his map of the city because he felt that one must exist between a particular pair of points. Such distortions may be highly significant, but we know little about their causes, and nothing about their eradication.

Intergroup and Individual Differences in Cognitive Maps and Mapping. Superimposed upon the overall relationship between cognitive maps and the real world are significant intergroup differences in the specific ways in which identical or similar spatial environments are construed. The underlying group perspectives are the result of a combination of three factors. First, the spatial environment contains many regular and recurrent features. Second, people share common information-processing capabilities and strategies. The capabilities are associated with the innate, physiological parameters of human information processing while the common strategies are learned methods of coping with the environment. Third, spatial behavior patterns display similar origins, destinations, and frequencies. These factors in combination yield intergroup differences in cognitive maps. Lucas (1963) indicated that the perceived spatial extent of a wilderness recreation area in the Northeastern United States was defined differently by various subgroups of users and by those who were responsible for its administration. Tindal (1971) studied the spatial extents of home ranges among black children in urban and suburban contexts, and found the spatial extent to be correlated with age and sex.

The individual differences among cognitive maps emerge primarily from subtle variations in spatial activity patterns, variations which can have striking effects on such maps. Ladd (1970) cites the case of two brothers who produced surprisingly different cognitive maps of their neighborhood. Such idiosyncracies are particularly notable in verbal descriptions of cognitive maps—the choice of visual details shows tremendous variation from subject to subject.

In answer, therefore, to the question "What do we know?" we can conclude that we see the world in the way that we do because it pays us to see it in that way. Our view accords with our plans for use of the environment. In other words, differences between the "real world" and cognitive maps based on it serve a useful purpose in spatial behavior. Koffka (1935, pp. 28; 33) expressed this idea well:

> Let us therefore distinguish between a *geographical* and a *behavioral* environment. Do we all live in the same town? Yes, when we mean the geographical, no, when we mean the behavioral "in". . . . Our difference between the geographical and the behavioral environments coincides with the difference between things as they "really" are and things as they look to us, between reality and appearance. And we see also that appearances may deceive, that behavior well adapted to the behavioral environment may be united to the geographical.

People behave in a world "as they see it"—whatever the flaws and imperfections of cognitive maps, they are the basis for spatial behavior.

HOW DO PEOPLE GET THEIR KNOWLEDGE?

We have postulated a set of basic characteristics that our knowledge of the spatial environment should possess, and we have indicated the characteristics that our knowledge (or cognitive map) actually possesses. Some of the differences between these two sets of characteristics can be attributed to the ways in which we *acquire* spatial information. What are the various information processing (or sensory) modalities? What are the basic sources and types of spatial information? How does our knowledge (or stored information) change through time? How do we know that cognitive maps exist?

Sensory Modalities. In our studies of cognitive maps, we have overlooked the *range* and *number* of sensory modalities through which spatial information is acquired, and have ignored the integrative nature of cognitive processes related to spatial information. The visual, tactile, olfactory, and kinaesthetic sense modalities combine to give an *integrated* representation of any spatial environment. The modalities are complementary despite our intuitive belief (and linguistic bias) that visual information is predominant. For example, Manhattan tower-dwellers often know the local Horn and Hardart or Chock-Full-O'Nuts restaurants through the smell of their famous coffee being brewed. Dock areas of cities are memorable because of the distinctive sounds they emit; the sea has a distinctive smell; certain streets, because of cobblestones or frequent railway line crossings, have a certain texture. Thus, the quality of distinctiveness or memorableness is not solely the result of the way the environment looks. Some blind people (Shemyakin, 1962) remember the various paths they traverse through the city by the different feel of each path. Held and Rekosh (1963) have demonstrated that sensory-motor interaction with the spatial environment is necessary for correct perception, for experiencing the world "as it really is."

Direct and Vicarious Sources of Information. Sources have differing degrees of validity, reliability, utility, and flexibility. Direct sources involve face-to-face contact between the individual and, for example, a city and information literally floods the person from all of his sensory modes. He must be selective in what he attends to, but can choose to repeat certain experiences, with such variations as making a given trip in the opposite direction or at a different time of day. Above all, he is "learning by doing" via a trial and error process. Reinforcement and checking are continuous: erroneous beliefs about locational and attribute information are rapidly corrected by feedback from spatial behavior.

Vicarious information about the city is by definition secondhand. It is literally and metaphorically "seen through someone else's eyes." This is true of a verbal description, a cartographic street map, a T.V. film, a written description, a color photograph, or a painting. In the mapping context these modes of representation, though similar in function, are different in form because they display different signatures. In each case, the information is selected by and transmitted through a set of filters that necessarily distort the information, generally in a way useful to the individual in his present context—for example, a travel brochure for a potential vacationer or a street map for a newcomer to an area. The result of this filtering is an incomplete representation which varies with both the individual and his group membership, especially since the individual is also comparing this new data with more familiar information and with a set of expectations.

We are all aware of the difference between image and reality when the travel brochure and the vacation resort do not match, or when a friend's color slides and the place he has photographed appear to bear little resemblance to each other. Many paintings are notably "impressionistic," selecting and highlighting some characteristics of a scene over others. A street map may be useful to a local resident or to someone who can "read" maps; but map reading is a learned skill, and we may not be able to translate from the signature of the street map back to the spatial environment.

However, although we can distinguish between active and passive information processing, they are only typological descriptions of a continuum. The two information-processing strategies operate simultaneously and continuously. Steinitz (1968), in discussing how an individual derives meaning from his spatial environment, makes it obvious that meaning develops as a result of both active and passive modes of information processing.

Both modes share a characteristic which distinguishes them from *inferential* information. Both active and passive information processing are tied to stimuli coming from the spatial environment. Inferential information is indirectly tied to the spatial environment, and results from symbolic elaboration, embroidery, and augmentation. Two examples will indicate how an initial stimulus or set of stimuli can trigger a chain of prior associative processes in the individual's memory, resulting in inferential information. Consider a person driving past a city block of poorly-maintained houses, their paint peeling and streets littered with paper and garbage. Frequently, these stimuli are sufficient to set off a stereotyped chain of thought that conjures up lower class people, probably black, on welfare, with a high crime rate. These inferred characteristics are transferred or generalized to encompass not just the particular block but the whole surrounding area. A second example of the same inferential process is the advertisement advising us "to come to sunny Florida." At this point our cognitive representation (or stored and processed information) comes into play, and we associate (or infer) a whole set of characteristics about vacations (or living) in Florida.

Thus, we have three types of information available to us at any point in time. Each has distinct characteristics, validity, and utility. For example, first impressions based upon what "hits you between the eyes" are notoriously incorrect, especially if they are accentuated by invalid chains of inferences. We all know that "things are not what they seem to be" and that we "should always look twice." We recognize the roles of the foregoing three information types in our everyday language and wisdom—they are also crucial in understanding the bases of cognitive maps.

A Terminology for Change

To this point, our whole discussion of cognitive mapping has been static—concepts of learning, time, and change have been omitted. In our approach to the question "How do we get our knowledge?" we can no longer avoid a thorny philosophical and theoretical issue. First, we must clarify the terminology and concepts necessary to tackle the issue, and second, suggest a typology of change.

We acquire the ability to know things about the environment through the process of development. *Development* must be distinguished from (1) *change*, which represents any alteration in structure, process, or events; (2) *simple accretion*, or growth by addition (typical of nonorganic structures); and (3) *progress*, implying change directed toward a given goal or set of goals, usually positively valued, such that the resultant change is regarded as an improvement. Development clearly includes change taking place over a considerable period of time; such change is assumed to be irreversible in the normally functioning individual, and, to the extent that it results in increased differentiation and complexity, is also regarded as progressive. Development encompasses both *growth* (the organic equivalent of accretion) and *maturation*. Maturation is sometimes used to refer to developmental changes due to hereditary factors, or to those changes that inevitably

occur in normal individuals living in a suitable environment. Maturation and learning are to some degree interrelated in behavioral development; some maturation appears to be a necessary though not sufficient prerequisite for learning to commence, while further maturation, in certain respects, is dependent upon the successful acquisition of capability for learning.

What effects (or learned changes) can spatial information induce? Boulding (1956) suggests three possibilities: no effect, simple accretion, and complete reorganization. The "no effect" case is the most frequent in the normal adult: the information simply confirms what he already knows (i.e., the cognitive map). Thus, for example, the necessary turns on the way to the Suburbsville Shopping Center have no effect on his cognitive map because he knows the route. The successful shopping trip to the Center has no effect on his attribute information because he already knows that it is a good place for shopping. Most of the spatial information that we receive, although essential for the successful use of the environment at any point in time, has no effect on the stored knowledge or cognitive map.

A Typology of Change: Accretion, Diminution, Reorganization

The simple accretion case relates to minor changes in the cognitive map. Thus, for example, the *route* to the drive-in movie theater is learned during the trip there and back. Also the individual begins to form an *evaluation* of the movie-theater—is it good or bad, cheap or expensive, easy or difficult to get to? Both locational and attribute information are added to the cognitive map: a simple additive change has occurred through learning. As an example of the alternate change, deletion, consider what happens when a street previously used becomes one way: an alteration in route selection is required. If a store previously used in the Suburbsville Shopping Center closes down, an alternative outlet for purchasing those goods once supplied by that store becomes necessary.

Diminution develops directly from deletion. There is no need to assume that cognitive maps undergo only *progressive* change such that we increasingly approximate the asymptote of economic man's perfect knowledge (or accurate representation). Either through the passage of time or through maturation, we forget—the amount of information available through the cognitive mapping process diminishes. If a long period of time elapses before we try to drive to the movie theater again, we may have forgotten the route and where to make the appropriate turns. All stored knowledge is subject to this time decay: we need to repeat a spatial experience in order to "remember" the route in the future. This is in line with our earlier argument that "learning by doing," with its associated processes of feedback and reinforcement, is vitally important.

Diminution may also be an adaptive process. Appleyard (1969a and b;

1970), in his study of adjustment to the new Venezuelan city of Ciudad Guayana, found that people initially enriched their cognitive maps with a mass of detailed information about the city. However, over time their cognitive maps lost detail (became "improvised") as they required less information to use accustomed paths and to "live" in the city. We must not lose sight of the limitations upon the human capacity to cope with information, as discussed by Miller (1956) in his now famous "magic number 7 ± 2" paper. Given our limited capacity to store and handle information, diminution may be an adaptive process ensuring that "excess" information is lost but important information retained.

Maturation can also lead to diminution and forgetting: as the person ages, the capacity to remember and perform certain tasks diminishes (Pastalan and Carson, 1969). Whether this is an inability to retrieve the stored information or decay of the storage mechanism is irrelevant to our argument: the effect is the same. Thus, diminution is a parallel but opposite process to simple accretion.

The most dramatic changes in cognitive maps are the result of total reorganization. Boulding (1956) suggests that images are relatively resistant to change in their overall nature. It requires an accumulation of contrary evidence before a complete reorganization can occur. For example, the realization that the Earth is spherical among those people who initially considered it to be flat came slowly and only as the result of a massive accumulation of evidence. The most frequent spatial example of such a complete reorganization is to be found in long-distance human migration and subsequent residential site selection, largely the result of vicariously received information. Even the latter is often of doubtful utility, since having been once installed in a new environment, one's expectations and hopes can be markedly altered by new spatial information inputs (see Brody, 1970).

We have examined some aspects of our cognitive maps and how they came to be. We know that they are modes of structuring the physical environment, that "blooming, buzzing confusion" which surrounds us at birth and that we must later sort out in order to survive. Much of the support in contentions concerning their existence is behavioral, stemming from introspection and anecdotal evidence, but the "harder" experimental data is beginning to emerge, even, quite recently, within neurophysiology. Thus, the face of cognitive mapping is growing clearer—only the features have yet to be fully filled in.

2

Cognitive Maps in Rats and Men

EDWARD C. TOLMAN

I shall devote the body of this paper to a description of experiments with rats. But I shall also attempt in a few words at the close to indicate the significance of these findings on rats for the clinical behavior of men. Most of the rat investigations, which I shall report, were carried out in the Berkeley laboratory. But I shall also include, occasionally, accounts of the behavior of non-Berkeley rats who obviously have misspent their lives in out-of-State laboratories. Furthermore, in reporting our Berkeley experiments I shall have to omit a very great many. The ones I *shall* talk about were carried out by graduate students (or underpaid research assistants) who, supposedly, got some of their ideas from me. And a few, though a very few, were even carried out by me myself.

Let me begin by presenting diagrams for a couple of typical mazes, an alley maze and an elevated maze. In the typical experiment a hungry rat is put at the entrance of the maze (alley or elevated), and wanders about through the various true path segments and blind alleys until he finally comes to the food box and eats. This is repeated (again in the typical experiment) one trial every 24 hours and the animal tends to make fewer and fewer errors (that is, blind-alley entrances) and to take less and less time between start and goal-box until finally he is entering no blinds at all and running in a very few seconds from start to goal. The results are usually presented in the form of average curves of blind-entrances, or of seconds from start to finish, for groups of rats.

All students agree as to the facts. They disagree, however, on theory and explanation.