# COGNITION IN CARTOGRAPHY

Barbara Petchenik
Newberry Library

The essence of what I have to say today is well summed up in these words from Rudolf Arnheim's book, Art and Visual Perception:

> All perceiving is also thinking,
> all reasoning is also intuition,
> all observation is also invention.

These ideas are related to certain fundamental issues in map reading and map perception that I should like to consider under the broad title, Cognition in Cartography.

A considerable amount of perceptual research within the general framework of behavioral psychology has been conducted by cartographers during the last ten or fifteen years. However, as one reviews the findings of this research in connection with problems encountered during the normal process of making maps, it doesn't seem to add up to much. No whole theory or set of principles, greater than the sum of the small component parts, has emerged. Similarly, analytical attempts to deal with the notion of map reading have not led to any theoretical structures from which principles that would assist in the details of map design can be deduced. Clearly, map reading is more than just the cumulation of a number of simple perceptual comparisons of symbol size or value. Perhaps it is time, in recognition of this fact, to shift our thinking from the details of empirical research, from psychophysical studies, etc., to a concern with the broader assumptions that underlie the conduct of such research, and to the possibility that certain shifts in those basic assumptions might be of some value to cartography. Whitehead has characterized science as, "the union of passionate interest in the detailed facts with equal devotion to abstract generalization." We need to be concerned always with both levels of research activity.

During the last few years, a number of significant theoretical shifts have occurred in disciplines influencing cartography, especially in the field of psychology. As I see it, these shifts bear on cartographic research in a number of important ways. The assumptions underlying the work of experimental psychologists for the past 40 years or so have been essentially reductionistic rather than wholeistic, and behavioral rather than dealing with mental processes. In reductionistic-behavioral research the only legitimate means for developing theory is by using inductive techniques. But in psychology, as in cartography, the experiments accumulated and the specific details proliferated, while no coherent and comprehensive whole theories emerged. In addition, some researchers were personally uncomfortable about the explicit omission of any reference to the internal thought processes that form such an important part of any individual's experienced reality.

The important shift that has occurred in psychology is away from an emphasis on strict behaviorism, and toward an emphasis on thought processes, toward what has come to be called cognitive psychology. Intellectual processes are now a legitimate topic of concern and are receiving considerable attention from both theoretical and empirical points of view. Evidence for this shift is contained in books such as that edited by William Chase, Visual Information Processing, where he says in the introduction: "If there is a single organizing theme in this book, it is the mind's eye, or the contents of the mind's eye -- images." The terminology employed attracts the cartographer's attention, for the notion of "cognitive mapping" appears frequently in the psychological literature. The term suggests that there might be something in it for us, and indeed, I believe there is.

While cartographic researchers have concentrated on the perception of individual map symbols or on limited comparisons among symbols, the problem of map reading extends far beyond such concerns. But the notion of map reading itself has not yet received as much attention as it should have. The real problem is this: How does a map user develop internal, personal knowledge of relations among things in space on the basis of viewing a sheet of paper covered with ink marks? How, in common language, does one read a map?

This question takes us far beyond the simple symbol size comparisons that were appropriate at an earlier, more limited level. It is a question that in a broader sense is of interest to many other disciplines -- to the communication theorist, the perceptual psychologist, the reading specialist, the anthropologist, and the artist. Ultimately, it is the problem of the epistemologist, interested in the nature of all knowledge and in the knower.

Cartographers have often analyzed the map reading process with concepts and terminology developed originally for other purposes. We are all familiar, for example, with the information theory metaphor and its vocabulary of "channels" and "redundancy" and "noise." Such concepts were developed by electrical engineers concerned with the transmission of electrical impulses along wires. From it the conception of knowledge being transmitted as some sort of sealed packet, carried unaltered from transmitter to receiver, emerged. Fortunately, this concept is being discarded in favor of another, quite different conception.

This new approach conceives of communication as the process wherein thought originating in one human mind is converted by that mind into physical forms according to rules developed by the culture in which he lives. These symbols are then apprehended through eye or ear by the person for whom the message was intended, and from them he constructs in his own mind the meaning originally formulated in the message sender's mind. In this view, the physical means of communication such as language and maps, do not carry meaning, but rather, they trigger or release it. The psychologist Weimer puts it this way:

> The strong claim of the constructive cognitive theorists ... is that there is no meaning or knowledge in language per se. Stated another way, the claim is that language does not carry meaning in sentences, but rather triggers or releases meaning (i.e., occasions understanding)

> that is already in the head. Unless a hearer can generate a context which renders a sentence interpretable, the sentence has no meaning at all.

In other words, for there to be successful communication the receiver of a message must be able to construct meaning from the physical stimulus in essentially the same way that the originator of the meaning constructed it. It is unlikely that the thoughts in the two minds will be exactly the same in form, although both are necessarily related to the physical form of the message.

It is useful to view this interactive process with terms developed by Piaget to characterize all organism-environment transactions, that is, the words "assimilation" and "accommodation." Piaget likens the process of acquiring knowledge from the environment to that of the ingestion of food by the organism, where there is a transformation from something external to something which becomes an intrinsic part of the organism. The food which the organism ingests must be assimilated to the nature of the organism -- it must be made smaller by mechanical means, it must then be acted upon by digestive chemicals, etc. The action which takes place on the object is called assimilation, and in the process of interaction the object itself is changed. On the other hand, certain changes must also take place in the organism, for not only does he change the assimilated object, but the object changes him as well. He may have to open his mouth wider to ingest, his stomach must expand to take in new food, he must produce digestive juices, etc. This process whereby the organism changes as a result of the transaction is called accommodation. The metaphor is a convenient one for analyzing the interaction between knowledge and the knower. It makes rather obvious the over-simplification inherent in the concept of communication as the transmission of information along a one-directional linear path.

As a result of these new assumptions about the active and interactive nature of communication, we can conclude several things. We must be concerned with meaning in cartography to an extent far greater than that to which we have been in the past. If the function of a map is to trigger meaning, then meaning becomes all-important. We must determine what the meaning of a map is, and how research could take account of such meaning.

These are difficult questions, with which other disciplines are also concerned. Quoting the psychologist Weimer again, he says:

> No matter where one goes in psychology there comes a point at which one runs straight into an insurmountable wall that is, conceptually speaking, infinitely high and wide. All we can do is look up and see that written on the wall are all the problems of the manifestations of meaning.

It is useful to compare the problems associated with map meaning to the problems involved in spoken and written language. Considerably more has been written about the latter topics, and there would seem to be some application of this material to maps.

For a good many years, researchers in the field of reading and linguistics approached the problem of the acquisition of knowledge from printed symbols with the idea that meaning was assembled on a unit-by-unit basis in linear sequence. One began with small units, such as letters and words, and then built up to the larger units of sentences and paragraphs. But while this view has been essentially discarded, a replacement has not yet been completely worked out. A new view does see the eye-brain interaction as not necessarily linear, but rather complex, and utilizing processes that allow the apprehension of the visual stimuli of printed text at several levels simultaneously. Meaning seems to come from an all-at-once grasp of the relation of the stimulus to the reader's previous knowledge structures, rather than from a bit-by-bit build up. We have all had the experience of glancing at a paragraph or page in order to quickly derive meaning, with no recollection whatever of individual letters, words, or sentences. Meaning goes beyond particular forms.

Yet there is an interesting and important contrast of text with maps in this regard. While the sounds and images of normal language are of no consequence in themselves and do not usually affect the meaning, this is not the case in mapping. The marks that make up the map have character and implicit meaning of their own, quite apart from their earth-surface referents. This character-of-their-own is what has received the most attention in cartographic research dealing with map perception and reading. In the terminology of some current cognitive research, there has been a concern with the characteristics of map marks or symbols as "brute things." This is defined by Bransford and McCarrell in the book, Cognition and the Symbolic Processes, thusly:

> ... knowledge of entities arises from information about their relations to other knowledge, and that knowledge of relations distinguishes a meaningful object from a 'brute thing.'

This "other knowledge" must, of course, be brought to the map by the map reader in order that the spatial symbols he sees take on spatial meaning. There is little the cartographer can do to control this, but there are things he can do to facilitate the development of such relations, if we think about the matter at all. For example, we all know how much easier it is to tell "where something is" on a map if we can see shapes that we recognize -- and we also know how quickly such familiar shapes can be lost with larger and larger scales, or with tighter and tighter cropping of the map area. Perhaps it would be well for us to have some idea of "most recognized shapes" at particular scales. Or perhaps there are ways in which map information can be given more meaning through linkage with verbal language -- through titles, legends and captions that relate what is seen to other things already known. These are just some of the ways I can think of to help the map reader move from the level of sensing brute objects to that of spatially meaningful symbols.

The meaning of maps is consequential spatial arrangement; it is the fact that objects isolated in real perceptual experience are put into relation with one another on the surface of the map. Cartographers are not concerned fundamentally with the nature of objects per se, but rather with a particular set of relations among those objects. The reader must reconstruct these relations in his mind for the map to have meaning.

Piaget has shown quite clearly that the knowledge of relations in space is not a given, but is rather constructed gradually with experience over a long period of time. He is not the only one with this point of view, of course. Bertrand Russell has written:

> People who never read any psychology seldom realize how much mental labour has gone into the construction of the one all-embracing space into which all sensible objects are supposed to fit. Kant, who was unusually ignorant of psychology, described space as "an infinite given whole," whereas a moment's psychological reflection shows that a space which is infinite is not given, while a space which can be called given is not infinite.

This seems an appropriate point to stress a major emphasis of this presentation: cartographers interested in fundamental research, the outcomes of which are intended to increase map utility, cannot feel that they are sufficiently well grounded to conduct such research unless they are familiar with the more basic cognitive research now being conducted by psychologists. Cartographic research should be more than superficial manipulation of questionnaires and correlation coefficients; those cartographers pursuing it must clarify certain basic issues having to do with the very nature of knowledge itself. In this view epistemological cartography is not a peripheral concern -- it is the heart of the matter.

One interesting point has been made recently in cognitive psychology, having to do with the question of the form in which knowledge exists in the mind. In the past, some have argued for verbal encoding, others for imagery, still others for a combination of the two. It is now being proposed that ultimate knowledge, Michael Polanyi's concept of "tacit knowledge," has neither form, and in fact, may have no form at all. Knowledge appears to be pure structure, pure relation, and at the most basic level we all know a great deal more than we can tell, that is, than we are able to convert from tacit to explicit form. It seems that we can convert portions of our vast stores of tacit knowledge to various explicit forms, upon demand. Sometimes there is a preference for imagery, at other times a need to express our thoughts in words. Knowledge seems to take on form for the purposes of communication, rather than for internal thought processes.

It is difficult to "picture" knowledge if it indeed lacks form as this conception suggests. Yet a simple cartographic illustration of how knowledge exists without specific form should clarify the situation. We may know where certain places are, or how certain areas are arranged, even though we have not actually seen them and have only derived such knowledge from maps. Yet if we were asked to describe the graphic characteristics of the maps from which we derived the knowledge, it is unlikely that we would be able to recall line weights, type styles, or colors. Yet we know the relations that were depicted, regardless of the form of the original marks. Once we assimilated those marks and converted them into tacit knowledge, they lost their form. However, we can retain the relations of interest to us, that is, the structures of the maps from which they were obtained.

So far cartographic research in map reading has not penetrated at all deeply into matters of this sort. In fact, comparing what has been done in map reading with what has been done in text reading, it seems fair to say that what has been done with maps in the way of symbol perception, is to total map reading, as typeface perceptibility studies are to reading comprehension research. We really lack a word that describes the apprehension of spatial knowledge from maps, a word that would compare to "comprehension" for text.

It is scarcely encouraging to find, however, that in the matter of textual comprehension reading experts are far from agreeing about the ways in which comprehension can be defined or measured in empirical terms, or even exactly what the nature of comprehension is. It may be that with increased emphasis on meaning, we are moving toward a realm where not everything can be defined and observed and measured in completely objective fashion. But it would surely profit us to know something of the nature of such limitations, and assuredly, this is something we do not yet know enough about.

It might be well to consider another basic matter at this point, and that is, the definition of the word "perception." It may be that for this new view of communication the word "perception" needs to be newly defined, or perhaps even eliminated. Part of the problem in using the word at all is that in the past it has been used without adequate definition or constraint. David Stea writes:

> Unfortunately, perception and cognition have been employed in a confusing variety of contexts by psychologists and other social scientists ... 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.

He continues:

> 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 ... Cognition need not be linked with immediate behavior and, therefore, need not be directly related to anything occurring in the proximate environment.

Yi-Fu Tuan says something similar and makes an important point:

> A percept is sustained by the information in the environment; we see what is before us. An image, on the other hand, is something we see when the environmental stimuli do not appear to justify it ... When percept and image are examined closely, however, they can be shown to differ in degree rather than in kind.

In these two views, which are consistent and complementary, perception no longer forms a separate class of human activity, isolated from thinking or feeling or judgment. Rather, it is a portion of a continuum along which human responses to stimulation can be ranged, from the simplest apprehension of raw sensation to the intermediate level of perceptual processing to the most complex of the higher cognitive operations. Percepts differ from thought and ultimate meaning only in the level of complexity of cognitive processing that is taking place.

Although the fact is largely ignored in cartographic research, the spatial knowledge that is acquired in the course of ordinary life is multi-sensory in nature. The map, of course, is one part of the input that is visual, so if a map user is to relate knowledge encoded in his total store with that acquired from the map, he may be relating two quite different things. Kinesthetic sensation, for example, must be equated with visual sensation aroused by the map. As Stea says:

> A cognitive spatial representation (or image) depends upon more than visual input -- it is an integrated, multimodal representation.

Or Bertrand Russell puts it this way:

> The first thing to notice is that different senses have different spaces. The space of sight is quite different from the space of touch; it is only by experience in infancy that we learn to correlate them ... The one space into which both kinds of sensations fit is an intellectual construction, not a datum.

In short, the map produces visual sensations that must interact with previously stored knowledge that resulted from multi-sensory cognition, which may not be stored in either spoken or imaged form.

If the cartographer hearing this review of recent approaches to cognitive processes as they relate to map use feels that there may be some truth or utility in them, he might consider what they mean in two ways: one, as they affect the ways he makes and improves maps, and two, as he devises research to provide information to be used in making and improving maps. Several directions are implied in these concepts.

First, if we assume that a map is not lifted intact from the paper by the eye and carried unchanged into the brain, and if the map becomes meaningful only in relation to previous knowledge of the user, then we should probably know something about that knowledge which is brought to bear on the map. Certainly when we communicate with words we have a preconception of what our hearer knows and how that knowledge will interact with and make meaningful what we are saying. We are betting that the words we speak will trigger a shared meaning in our listener's mind. Similarly with maps; we must interest ourselves not only in clarifying the spatial message we intend to convey with a map, but also in assessing the cognitive resources the map user brings to bear on the problem of reconstructing space from this image.

This will be a difficult order, even though some research has been conducted in recent years that might seem to bear on this situation. The words "mapping" and "map" appear in both the psychological and geographic literature, with the usual prefixes being "cognitive" with mapping and "mental" with map. When examined carefully, however, these concepts are disappointing in the cartographic sense. "Cognitive mapping" is a metaphor that refers to the mental process whereby unorganized external stimuli are converted to organized knowledge structures, in a manner that resembles the way a cartographer selects, abstracts, and organizes information from a complex, unstructured milieu and arranges it in coherent fashion on the map surface. The use of this metaphor in psychology serves to point up the very basic nature of mapping -- so basic that it is convenient to use it as a metaphor for all knowing.

The term "mental maps" would seem to offer us much more -- it sounds as if it should refer to the sum total of all spatial knowledge that any individual carries about with him in the form of tacit knowledge and potential spatial images. Unfortunately, this is not at all what the term has come to mean in geographic literature, though few besides the perceptive Yi-Fu Tuan have bothered to make the careful distinction he does in this quote:

> Under the influence of Peter Gould and Thomas Saarinen, among others, geographers tend to see mental maps primarily as 1) cartographic representations of how people differ in their evaluation of places, and 2) freehand maps that people can draw -- outlines of city streets and continents.

In an article in which he reviews the Gould and White book, Mental Maps, Tuan also says:

> So far as I can tell, the mental maps of this book are opinion and information surveys represented in cartographic form.

He adds, in telling fashion,

> I don't think enviro-preferential maps throw much light on the psychology of perception and cognition ...

and I thoroughly agree with him.

Another person who has penetrated the superficiality of the way the term "mental map" is used in geography is Stea, and he writes in Image and Environment:

> Another area of research ... is that of environmental dispositions and preferences. Unfortunately, this latter area was entitled at one time 'mental maps' thus causing others to believe it a part of spatial cognition.

In this same book, Stea also clarifies the relationship between spatial knowledge and all other knowledge in this way:

> The structure underlying the spatial map of the world that people carry around in

> their heads is not different from the structure that underlies all cognitive processes ... In this framework a spatial cognitive map might be viewed as a special case of cognitive maps in general. It is more likely, however, that spatial maps are not neatly separated from other sorts of cognitive structures.

It would be a mistake to imagine that human spatial knowledge is carried around in the head in the form of a stack of map-like images, for, as stressed before, much of it is not even visual to begin with.

We find, then, that there is practically no research that is relevant to the question of the nature of the map user's personal spatial knowledge. Perhaps this is an impossible task. If it begins to appear likely that each person is unique in the mental baggage he brings to the task of map reading, what is the poor cartographer to do with a map that is to be circulated among thousands of viewers?

What he should probably do is forget for the moment the research that emphasizes idiosyncratic spatial knowledge and recall the fact that explicit knowledge comes in a variety of forms, and that some of these forms are arbitrary and prescribed for anyone who wishes to function successfully in the cultural forms of a particular society. When dealing with formal means for communication, such as words or maps or mathematical symbols, we assume that most viewers are familiar enough with them so as to constrain the meaning each one can have to a greater or lesser degree. Only in Alice in Wonderland can words mean whatever the speaker wants them to mean. If people know nothing at all of maps, the map maker no longer has any responsibility for the possible failure of any one map to communicate adequately. But even if this does free the cartographer from the impossible task of making self-explanatory symbol systems, there are many ways in which he can facilitate the transfer of information via the map. It is important to clarify, partly through intellectual analysis and partly through empirical research, which aspects of the map are part of a societal agreement or contract, and which are truly subject to the cartographer's control.

In the concern with testing individuals to determine what they see or think about particular map symbols, the fact that certain aspects of mapping are totally arbitrary has been too often ignored. If there is no reason at all to expect that some aspect of the map can be interpreted in any way other than by the rules of the mapping game, then there is no need to find out how various subjects think it should be interpreted. I recall, for example, some of the research that has been done in testing various color schemes that show elevation changes. The assumptions on which it was done were not logically clarified to the point where it should have become apparent that, for the most part, readers' responses to certain questions are of no consequence. It is analogous to conducting a survey to find out whether or not the letters C-A-T look like what they mean. It has simply been agreed that they will mean what they mean in our culture, and there's an end to it.

This is equally true of many aspects of mapping. A Canadian artist, Joe Bodolai, wrote perceptively in a special issue of artscanada that dealt with maps and mapping:

> A map can also be said to be somewhat like a contract in that it is a document of agreement about the nature and distribution of phenomena in space. Mapping is an effort not to eliminate point of view but to socialize it, even to conventionalize it ... When a map is used a reversal of the map-making process takes place. Reason informs perception and makes the field of vision meaningful.

In summary, we do need to know how map users see particular things and how the meaning assigned to these things varies among individuals. But it is important to distinguish between those aspects of research that are related to variations about which the cartographer has the potential for doing something, and those about which he can do nothing because they are pre-determined by the rules of the formalized communication system. Much of the research in the Stea and Downs book, Image and Environment, for example, is interesting as it shows how individuals vary in their conceptions of space. But there seems no way to make such information directly relevant to map making. Insofar as mapping is a scientific activity, a comment made by Bertrand Russell is relevant:

> Scientific knowledge aims at being wholly impersonal and tries to state what has been discovered by the collective intellect of mankind.

It is important for cartographers to understand this distinction between individual and collective intellect.

In concluding, I turn for the first time to the theme of this conference, that is, to the matter of computer-assisted cartography. How, you may be wondering, can this theoretical and wide-ranging exposition of recent trends in cognitive psychology have any relation to computers? In quite an obvious way, I think. When the computer is utilized in one way or another to produce a map, the human cartographer must tell it exactly what to do. Therefore, he must know exactly what he does to make a map, and then be able to code these procedures in explicit, step-wise forms for the obedient machine to replicate. The difficulty in this seemingly simple process is that much of what goes on in cartography is not explicitly understood, particularly at the level of the nature of the human knowledge transfer that is involved. The relation between computers and the topics I've discussed should thus be clear; if we are to instruct machines to do rapidly what we can only do slowly by other means, then we must have clear insights into the nature of the tasks we are undertaking and speeding up. These insights must be based on a knowledge of the perceptual-cognitive characteristics of the human being, and on a firm understanding of the meaning of maps. A human being can operate successfully himself, in the domain of mapping or elsewhere, on the basis of poorly understood tacit knowledge. But for the computer all tacit knowledge must be clothed in explicit forms. If, as mentioned earlier, we know a great deal more than we can tell, then there may be absolute limits on what we can know in a form that can be conveyed to the computer.

What the implications of this approach for specific research topics are, I don't yet know. I simply have this initial, mildly disturbing sensation that the notions introduced here are important, and will become more so in the years ahead. In her novel The Years, Virginia Woolf wrote:

> The steps from brain to brain must be cut very shallow ... if thought is to mount them.

The structure of those steps, as they are used to communicate spatial information from one brain to another is important to us; for the sake of all of our map users, we'd like to know if we could make them shallower and easier to climb.

REFERENCES


1. Bodolai, Joe, "Borderlines in Art and Experience," artscanada (31), 1974, pp. 65-81.

2. Chase, William G. (ed.), Visual Information Processing, (New York: Academic Press), 1973.

3. Downs, Roger M. and David Stea (eds.), Image and Environment: Cognitive Mapping and Spatial Behavior, (Chicago: Aldine Publishing Company), 1973.

4. Russell, Bertrand, Our Knowledge of the External World as a Field for Scientific Method in Philosophy, (Chicago: The Open Court Publishing Company), 1914.

5. Russell, Bertrand, Human Knowledge: Its Scope and Limits. (New York: Simon and Schuster), 1948.

6. Tuan, Yi-Fu, A Review of Peter Gould and Rodney White, Mental Maps, in Annals of the Association of American Geographers (64), 1974, pp. 589-591.

7. Tuan, Yi-Fu, "Images and Mental Maps," Annals AAG (65), 1975, pp. 205-213.

8. Weimer, Walter B. and David S. Palermo (eds.), Cognition and the Symbolic Processes, (Hillsdale, New Jersey: Lawrence Erlbaum Associates), 1974.