There has been considerable interest within cartography in the cognitive processes associated with cartographic communication. Mental imagery is thought to be an important part of cognition. It has been determined that such internal images have structural and functional properties similar to maps and may be used in answering questions based on information derived from maps. The long term function of maps in the process of cartographic communication is modelled in the form of a human geographic information system – analogous to similar computer systems.

The Mental Image in Cartographic Communication

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A great deal of controversy has traditionally surrounded the existence and functional role of mental images in human thought. Defined as an internal representation similar to sensory experience but arising from memory, the construct of mental imagery has a tortuous history in science. Recent technological innovations, however, have enabled researchers in cognitive psychology (a branch of psychology concerned with mental phenomena) to externalize mental events in ways not previously possible. As a result, new empirical findings about mental imagery have emerged. This paper examines what has been learned in cognitive psychology about the mental image and how this construct may be applied in cartography, particularly the study of cartographic communication.

An interest in internal or mental phenomena within cartography is not new. In recent years, there has been a recognition by many cartographers of the importance of cognitive processes in the study of cartographic communication. Cognition is generally defined as the "intelligent processes and products of the human mind."[1] Neisser defines cognition as "all the processes by which a sensory input is transformed, reduced, elaborated, stored, recovered, and used."[2] Cognition includes such mental activities as perception, thought, mediation, reasoning, problem solving and *mental imagery*. Various recent cartographic studies have helped define this new 'cognitive' emphasis in cartography.[3]

The word image is also not new in cartography. Robinson and Petchenik,[4] for example, use the term in the general sense in examining the distinction between graphic and verbal symbolism. Referring to image in this general form, they conclude that the image is the "most comprehensive form in which spatial arrangement can be encoded or transmitted" and that the "potential of image development is the most elegant attribute of the map."[5]

The implication of the image as a mental phenomena is apparent in other cartographic studies. Petchenik,[6] in attempting to define the difference between general purpose and thematic maps, points out that "thematic maps point to a 'distribution-as-thing,' and the knowledge of internal spatial variation (is/is-not, more/less) of a constructed space is the goal." She continues: "for thematic map usage, then, primary meaning lies in the image that is constructed." Olson[7] proceeds a step further in associating the word "image" with a mental phenomena. In elaborating on the importance of the concept of a "mental construct" in cartographic communication, Olson points out that this construct could be an image. Olson states: "If we consider our mental conception of the border of Canada, one example of a construct for which the map as stimulus has played an important role, our mental construct might well be termed an image . . . ."[8]

In psychology, the mental image is strictly defined as an internal representation similar to sensory experience but arising from memory. A mental image may therefore exist in several sensory modalities and we may speak of auditory, olfactory, etc., mental images. The type of mental image that is referred to here, and the type that has been the focus of most psychological investigations, is the "visual mental image."

Once seen as one of the most important concepts in understanding human behaviour, mental imagery faded as a serious subject for investigation in psychology with the growth of behaviourism in the 1920's.[9] According to behaviourism, theories are only valid if they rest on physically observable parameters. Processes that occur between stimulus and response (thought) are not directly observable and therefore irrelevant for the behaviourist. The behaviourist viewpoint was first elaborated by John Watson who believed that imagery was subsumed by "subvocal thinking" consisting of measureable laryngeal movements (behaviour). Finding no proof of imagery, he argued that all thoughts are verbally coded and that the experience of imagery is merely the verbal rehearsal of a scene.[10]

The study of imagery has revived in recent years due to a widespread appreciation of the limitations of behaviourism and recent methodological advances which have enabled researchers to externalize mental events in more objective ways. Images are now viewed by some cognitive psychologists as data-structures in human memory consisting of both a "surface representation" (the experienced image) and an underlying "deep representation."[11] A present concern in cognitive psychology is discovering how images serve as repositories of information, how they are used in spatial reasoning, and in answering questions.

The recent findings concerning mental imagery would seem to have important implications to cartography. The concept of an internal image itself leads to fundamental questions in cartography that concern both map construction and map reading. How does an image serve in the process of designing a map? To what extent does a cartographer 'see' a finished product in his mind? What is the function of internal imagery in map use? Finally, where does the image 'fit' in the cartographer's conception of the cartographic communication process?

In the following discussion of imagery, studies in cognitive psychology will be reviewed that have been used to both verify the existence and determine the functional properties of mental images. We will find that images may not simply be "pictures in the head" but rather that the imaging process is much like an internal form of cartography (involving generalization, etc.). The second section will attempt to outline the significance of these findings to the study of cartographic communication. It is shown how maps and images are fundamentally related, and mental images are modelled in the framework of human geographic information system. To properly appreciate mental imagery, however, we must have some appreciation of human memory for which, of course, imagery is but one product. We begin with a cognitive conception of human information processing.

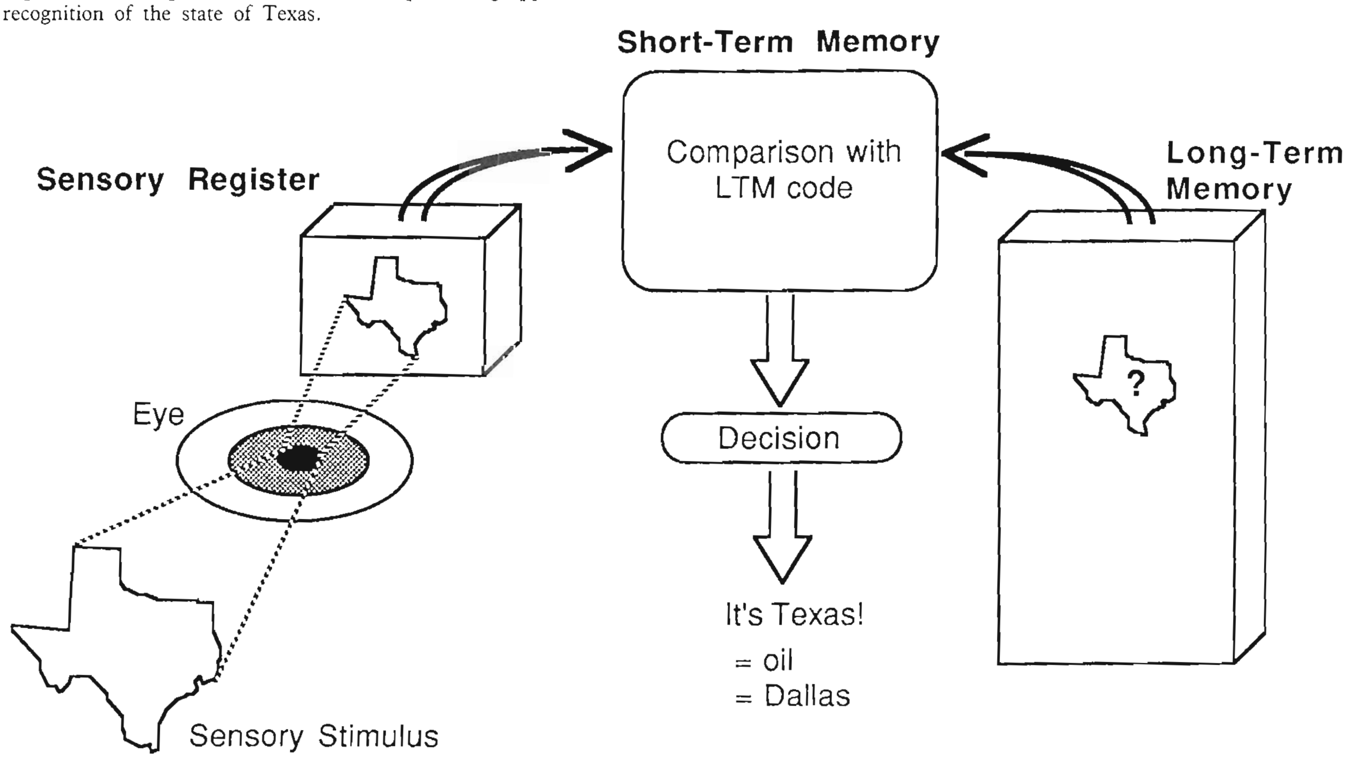
I. INFORMATION PROCESSING AND MENTAL IMAGERY

In cognitive psychology, human information processing is often conceived as a series of stages, each characterized by a limited amount of information processing. Three memory stores are generally referred to – the sensory register, short-term memory (STM) and long-term memory (LTM). "Control processes" such as attention, pattern recognition, and rehearsal are thought to move information between the different memory stores. Figure 1 depicts the mental processes that are believed to occur in recognizing the shape of a state.

According to the stage-model, information processing begins at the sensory register which is thought to hold information in sensory form for a fraction of a second, long enough for it to be initially recognized.[12] The visual sensory register, also called the "icon,"[13] may be thought of as a type of physical image and various experiments have verified its existence. The initial control process of attention simply refers to the human capability to 'tune-in' certain sources of information and reject all others. Pattern recognition converts raw sensory information into something more meaningful by matching information in the sensory register to previously acquired knowledge stored in long-term memory. One theory of pattern recognition proposed by Selfridge[14] suggests that a pattern is recognized in a series of hierarchical stages by "demons" who work on a pattern by breaking it down into subcomponent features (see Figure 2).

Information which has been registered, recognized and attended to may be sent into short-term memory (STM). Information is held in STM for longer periods by a process called rehearsal which serves to both recycle material in STM so that information does not decay, and to transfer information about rehearsed items into long-term memory. Very little is known about long-term memory. One theory suggests that LTM is an essentially permanent storehouse – nothing is ever lost. Forgetting, it is argued, is a retrieval problem where the appropriate links to a piece of knowledge are disrupted.[15] Another theory suggests that information in LTM is stored in a form compatible to sensory perception to facilitate the complicated process of pattern recognition.

Figure 1. The stage model of information processing applied to the recognition of the state of Texas.



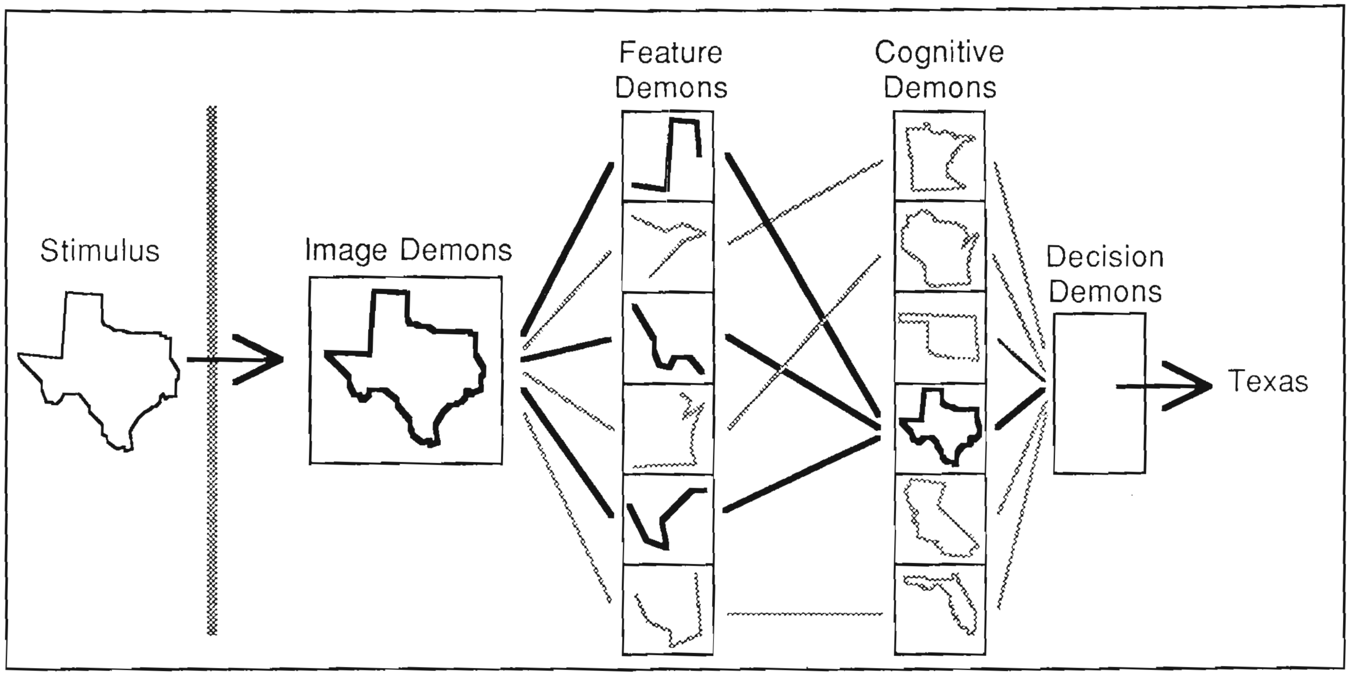


Figure 2. Selfridge's Pandemonium model of pattern recognition applied to the recognition of a state.

Evidence for Mental Imagery – The question of the code representing information in short- and long-term memory (collectively termed non-sensory memory) is currently the topic of debate in cognitive psychology.[16] A great deal of evidence has accumulated in recent years suggesting that analog representations in the form of visual codes or images may be one component of memory. Studies in cognitive psychology dealing with visual codes in memory are of three general types: (1) those indicating the existence of visual codes in memory; (2) those attempting to show individual differences in the use of these codes; and (3) those attempting to define properties of these codes.

Existence of Visual Codes in Memory – Studies suggesting the presence of visual-image codes in human memory are so numerous that it is impossible to review them all here. In one of the first of these studies, Posner *et al.*[17] found that visual codes seem to be used in the comparison of letters. He showed that physical matches between letters such as A–A are more quickly determined than non-physical matches such as A–B and A–a (in milliseconds using a reaction timer). Posner concluded that identical letters can be judged the same based on their *physical images* (i.e., subjects are capable of comparing shapes without having to name them). The "mental rotation" experiments conducted by Shepard and Metzler[18] are often cited as evidence of imagery. In this study, the reaction times were measured for subjects to decide whether two rotated three-dimensional figures depicted the same three-dimensional shape. Shepard and Metzler found that the time to make the judgements increased linearly with the difference in angle between the two objects. They concluded that subjects were rotating the visual image of one figure into congruence with the other and the farther the objects had to be mentally rotated, the more time was required for the decision.

One interesting line of research concerning the existence of mental images has suggested a difference between visual and linguistic memory.[19] Numerous researchers[20] have verified the effectiveness of images in mnemonic systems and verbal learning. Paivio[21] postulates that visual imagery and verbal symbolic processes represent alternate coding systems in memory. Paivio showed that the image evoking value of nouns, called imagery concreteness, (i.e., "apple" leads to more concrete image than "distance") correlates highly with the ability to remember. It seems that words coded under both image and verbal mediators will be more easily remembered than words which are only verbally coded since more 'links' exist to those words in memory.

Individual Differences in Imagery – The second line of research associated with mental images concerns individual differences in imagery. Various experiments using a self-report testing technique have shown such differences.[22] However, the self-report testing method has been criticized because there is no way to be sure that people know what an "image" means or that everyone sets their criterion to the same level in assessing images. The available data, therefore, do not warrant the development of a theory proposing individual differences in imagery. (Such a theory would be particularly troublesome to cartographers who must generally assume that people possess similar mental resources).

Properties of Mental Images – Determining the properties of mental images represents the third and most interesting line of research concerning imagery. One of the foremost investigators in this area has been Stephen Kosslyn who theorizes that mental images are like displays on a graphic computer-terminal or cathode-ray tube (CRT) on which graphic displays can be generated. In this view, imagery consists of two major parts: 1) the "surface representation" is the quasi-pictorial entity that we experience and 2) the "deep representation" is the information in memory from which the surface image is derived.[23]

As proposed by Kosslyn, the CRT metaphor of mental imagery has several structural components. Among them (a) images have analog properties, i.e., preserve relative interval distances between their component parts; and b) mental images have limited spatial extent. The theorized components of imagery have been demonstrated through various experiments.

In experiments involving visual scanning, the time to search for certain objects or scan between objects in images was used to determine whether images have truly analog properties. In one of these experiments, a fictional map with seven locations (house, well, tree, lake, etc.) was presented to subjects. To assure that subjects formed an accurate image of the map, people were asked to indicate the seven locations on a blank piece of paper. When finished, the piece of paper was placed over the map and subjects noted their errors. This procedure was repeated until the subject was accurate to within 0.25 of an inch of the actual locations. Next, subjects were asked to image the map and mentally 'stare' at a named location. Another name was presented and the reaction measured for the subject to mentally scan to the object. It was found that the time to scan increased linearly with the distance to be scanned.[24] It was concluded that images, like maps, depict information about interval spatial extents.

If images have a limited spatial extent, then one can also assume that parts of "subjectively" smaller objects would be harder to see than subjectively larger objects. A procedure was devised in which size was manipulated indirectly by asking subjects to image "target" animals, such as a rabbit, as if they were standing next to either an elephant or a fly. Kosslyn assumed that if an image takes up a fixed amount of space and most of this space is taken up by the elephant, then the adjacent scaled image of the rabbit should be subjectively small. Accordingly, if a rabbit is scaled next to scaled image of a fly, then the rabbit should seem much larger. The results of the experiment showed that people required more time to see parts of animals imaged next to the larger animals. Subjects said they had to "zoom in" to see the properties of the subjectively smaller images. Kosslyn concluded that a selection of features had occurred in the original (before "zooming") image. In other words, a generalization of features was apparent in the original smaller image.

To summarize, in the cognitive framework, perception and pattern recognition are closely linked with memory and since pattern recognition occurs so quickly, many cognitive psychologists believe that the representations in memory have sensory qualities. Much evidence has accumulated in recent years for analog representations in the form of mental images. Kosslyn likens such images to displays on cathode-ray tubes and has shown that images have many of the spatial properties we would expect. The results of various experiments strongly indicate that images are functional representations in human thought.

II. MAPS, IMAGERY AND GEOGRAPHIC INFORMATION PROCESSING

Maps and mental images share the quality of being spatial representations, leading one to suspect that the interaction between the external map and the internal image may be an important area of research in cartography. In the following discussion, an attempt is made to (1) define the relationship between maps and images, (2) describe the overall importance of maps and resultant mental images in thought processes, and (3) explain the possible role of map derived mental images in thought and long-term memory.

Relationship between maps and images – The results of various experiments in psychology may be taken to indicate that mental images bear many structural similarities to maps, as physical images. For example, in Kosslyn's experiment involving the scaling of objects at different apparent sizes, it was determined that when objects are displayed at smaller sizes (rabbit next to elephant), fewer details are evident than when they are imaged at larger sizes. In other words, mental images seem not to be copies of sensory impressions like "pictures in the head" but rather they are intellectually processed and generalized representations, much like maps. The cause-and-effect relationship is unclear and deserves more investigation. Perhaps experience with maps and pictures provide the rules for image formation or alternatively maps can be viewed as an outward expression of a basic human capability for mental imagery.

Maps, Imagery and Thought Processes – Both mental images and maps seem to share unique properties that make them intellectually useful and distinctive from other forms of communication. They both seem to be products of a "spatial thinking" and dependent on the process of arranging objects in space.[25] The question remains as to how images are used in thought processes.

A fundamental distinction is generally made in cognitive psychology between linguistic or propositional symbolism and presentational or graphic/visual symbolism. As described previously, these two types of symbolism seem to be characterized by different memory processes. Robinson and Petchenik in making this distinction, point out that language is a sequential medium and the reader "must relate his visual stimuli to a system of sounds and meanings . . .". "The map percipient, in contrast, can and does enter the graphic array at any point; he can stop at any point; and often he relates the visual stimuli to other visual stimuli rather than to a system of sounds."[26]

This distinction between linguistic (propositional) and graphic symbolism is central in cognitive psychology and leads to some interesting conceptions of how images are actually used. Kosslyn,[27] for example, suggests that the relative speed of processing of the two kinds of representations, images and propositions, determines which is used to answer a question. One can think of "demons" working in both the image and proposition domains, each attempting to answer a given question as fast as possible. For example, in answering whether Volkswagen Beetles have tyres, a propositional file may be used since VW's are cars and cars have tyres. On the other hand, consider what happens when one decides whether VW Beetles have vent-wing windows (little triangular windows at the front of the door). It is unlikely that this information is explicitly noted in the propositional file associated with Volkswagen Beetles. Thus, one

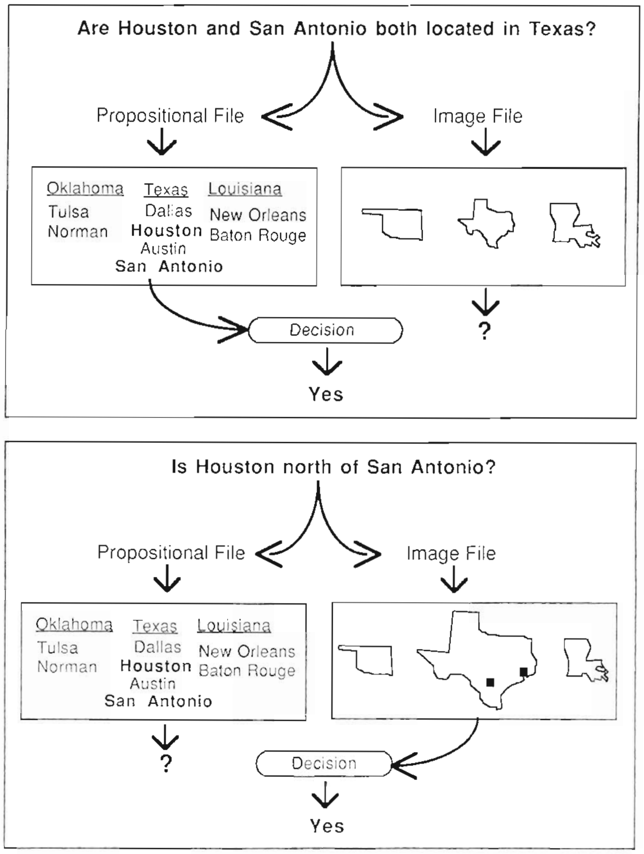


Figure 3. Answering questions using propositional and image information.

may have to mentally image the car in order to retrieve the information.[28]

This same example can be put into geographic terms. For example, the question of whether Houston and San Antonio are both in the state of Texas may be most quickly answered by consulting a propositional file. However, with the question of whether Houston is north of San Antonio, one may have to consult an image file of the state of Texas (see Figure 3). This suggests that whenever "some previously unconsidered spatial relation (which hence is unlikely to be encoded propositionally) is queried, and this relation is implicit in the encoded image,"[29] then one uses an image to answer a question about the relation (see Figure 3).

The Human Geographic Information System – The above example indicates that images may serve an important role in answering map-related geographic questions. In order to elaborate on this aspect of the image, it is useful to model the function of imagery as part of a human geographic information system (HGIS) analogous to similar computer systems. The model allows us to understand the function of imagery in relation to cartographic communication.

The concept of the Geographic Information System (GIS) has developed since the late 1950's in association with the computer handling of geographical data. The general function of an automated GIS is to acquire, store, manipulate, and display geographical data for decision-making.[30] Maps constitute the primary source material and GIS's are usually characterized by a conceptually important and basic distinction between so-called image data and descriptor data (see Figure 4).

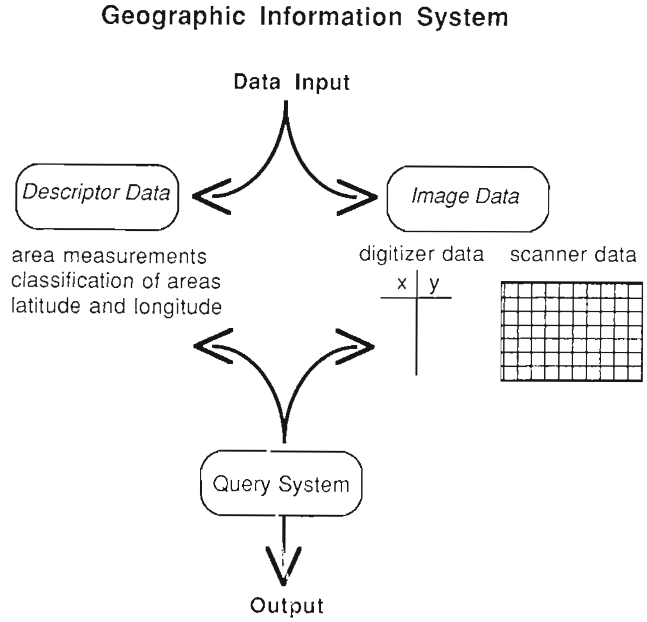


Figure 4. Components of a Geographic Information System.

The image data set is created by digitizing or scanning maps. The descriptor data set will usually consist of textual information such as area measurements, the classifications of areas and longitude-latitude indications. Information is requested through a collection of library routines that query the system.

Humans, of course, perform these same functions as a part of every day life. A person's every movement is, in some way, dependent upon the input, manipulation and display of spatially coded information. It is the spatial functioning capacity of every individual and, particularly, his capacity to use maps to conceive of space beyond his own direct experience, that allows each individual to be thought of as a 'geographic information system' (see Figure 5).

Many structural similarities can be seen between the computer GIS and its human counterpart. The HGIS may also be divided into hardware and software components. The structural and control features of human information processing such as the sensory register, short- and long-term memory may be seen as constituting the hardware of the human system while control features of attending to a stimulus, recognizing patterns and rehearsing information may be viewed as its software. In addition, the HGIS also seems characterized by a basic distinction between image and descriptor (image and propositional) data.

While the computer and human GIS may be se seen to have certain structural similarities, their capabilities differ significantly. The computer GIS, for example, is characterized by a concern for accuracy and the ability to execute various statistical manipulations. Perhaps the most striking difference between the two is the relative passivity of the computer system. Information must be carefully entered into the computer and is then stored on separate files. In contrast, the human will process almost any kind of geographic information and does not store the information as separate entities but makes associations between newly entered and previously acquired information. Compared to the computer, the human is very active in acquiring information and particularly

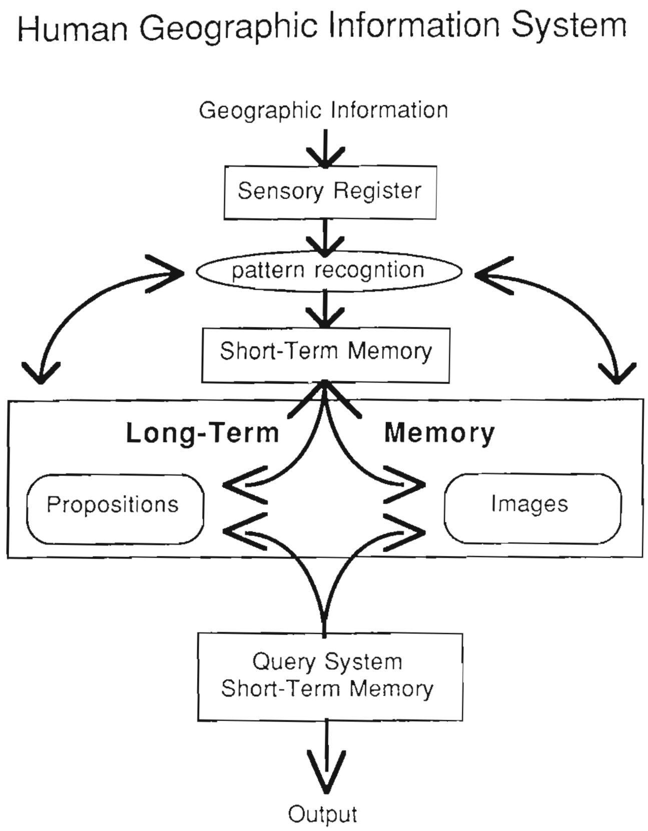


Figure 5. Components of a Human Geographic Information System.

adept at recognizing meaning and creating associations.

The active nature of human information processing is apparent from evidence that suggests that a great deal of locational information is coded into long-term memory without attention or conscious awareness.[31] This phenomenon has been often noted. For example, we might remember the location of an article in a newspaper without intending to do so or the location in a notebook of an answer to a question without remembering the answer. Although it is possible that we may attend briefly to this sort of spatial information, it is unlikely that we intend to remember it. Many kinds of information about words or objects – their color, orientation, location – may be briefly registered, perhaps even attended, but are not necessarily coded into long-term storage. We may conclude that the human mind is probably an extremely active – if, at times, unconscious – encoder of spatial information.

The mental retrieval of map-image information is also accomplished with relative ease. When confronted with questions concerning the relative size of Minnesota and Wisconsin, the similarity in shape of Vermont and New Hampshire or the location of Paris within France, the human system responds with relative ease. If the question constituted a "previously unconsidered spatial relation,"[32] then it is very likely that an internal image is consulted to answer the question. Even if the question had been previously considered, the answer may have been more easily retrieved from the image representation since that particular bit of propositional knowledge may have been too deeply embedded in memory. It seems probable that the mind is a storehouse of images, from which previously unconsidered spatial information may be derived.

The basic significance of the HGIS model to cartography is that it allows us to consider the long-term aspects of cartographic communication. Map reading is not a one-time, isolated activity as is suggested by many models of cartographic communication. Much of the information derived from a map is in image form and may be used long after the map has *ceased* to be a visual stimulus. The process of map communication, therefore, continues in the absence of the map. It follows that one of the major concerns of every cartographer is to create maps that will facilitate the creation or formation of long-term mental images.

III. CONCLUSION

The mental imagery and HGIS constructs both suggest many areas of research in cartography. An understanding of these constructs would certainly be beneficial in the education of both cartographers and of map users. For example, differences in the quality of map construction among different people may be explained by a differing reliance on internal imagery.

In the area of map use, research may indicate that people who are more accustomed to mental imagery may use maps more often. Research may also find that our educational system does not encourage the use of mental imagery. Acceptance of mental imagery as a functional part of human cognitive development may result in a greater use and understanding of maps by all groups of people.

Perhaps the most interesting line of research related to the constructs of imagery may be the evaluation of the image-quality of maps. It is certainly reasonable to suggest that maps differ in their ability to create a mental image in the mind of the map-user. It is this aspect of maps, and particularly differences in the image-creating quality of maps caused by different forms of mapping and symbolism, that deserves particular attention.[33]

However, not all information that we derive from maps is in image form. It is perhaps best to think of the totality of this information as a mental-construct[34] which would encompass both non-image (discursive-propositional) and image information. But, it should be remembered that maps distinguish themselves from other forms of communication because of their spatial-image qualities. Only by understanding this aspect of maps can we move closer to understanding the true nature of the cartographic communication process.

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Ordnance Survey – Photogrammetric Services

Ordnance Survey at Southampton have taken delivery of Laser-Scan's LAMPS automated mapping software for the editing of photogrammetrically captured digital data. The software will run on a Digital Equipment Corporation (DEC) VAXstation/GPX with a second workstation provided by a Ramtek 4225 display.

Data will be input to the workstations from stereo digitising systems and will be output in standard Ordnance Survey Transfer format for transmission to other OS systems in Southampton or the field.

These two new LITES workstations bring the total of Laser-Scan 'seats' at Ordnance Survey to 23. This includes 13 LITES and 8 OLDS (on-line digitising systems) in the Cartographic Division where they provide the majority of the digital flowline. Some of the monochrome workstations now being upgraded to high resolution colour displays, were also supplied through Laser-Scan.

"A CRY FROM THE HEART!"

1. Quite a number of membership subscriptions are still outstanding for 1987. Reminders have been sent to those members concerned and it would greatly ease the work of the Membership Officer (Ken Atherton) if these subscriptions could be paid as soon as possible.

2. Many members who pay their subscription by Standing Order have yet to return the new Banker's Order form which was issued with Newsletter No. 4/86. This means that the old subscription rate (£8.00) has been paid, through their banks, to the old account at Maybush, Southampton. Now that the Society's bank account has been moved to Nailsea, Avon, Ken is having great difficulty in identifying these subscriptions. If you know you have paid your Standing Order but have not received either a blue membership card for 1987 or a request for the outstanding balance to make up the new subscription rate please contact Ken as soon as possible.

3. As a reminder, the new subscription rates for 1987 are:
   Corporate .... £100.00 *per annum*
   Junior .... £8.00 *per annum*
   Ordinary (Inland & Overseas) £15.00 *per annum*
   There is also an optional Airmail service for members overseas for an additional £5.00 *per annum*.

4. If you have any queries regarding membership the Membership Officer's address is:

Ken Atherton
12 Elworthy Drive, Wellington
Somerset TA21 9AT
England
Telephone: 0823 47 3965