The role of maps in spatial knowledge acquisition

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Considerable emphasis is placed on map work in geographic instruction. In what can be viewed as a complementary effort, cartographers have devoted substantial attention to investigating map symbolisation and design decisions that influence communication effectiveness of the small scale thematic maps that are typical in geographic texts. Much of this effort, however, was modelled on related work in behavioural psychology. As a result, the emphasis was not on how learning from a map is accomplished, but on how to alter a stimulus (the map) to produce a desired response (e.g., judgement that city A has twice the population of city B). This research has provided an objective basis for some map design guidelines (e.g., grey scales for choropleth maps [Kimerling, 1985] or appropriate type styles for children’s atlas maps [Gerber, 1982]). Left unanswered, however, are questions such as what kinds of information can be acquired from maps, how does the process of learning from maps work, how can this process be facilitated through instructional strategies, and what are the similarities and differences between spatial knowledge acquisition from maps and directly from the environment?

The process of learning from maps is attracting increasing attention (e.g. Shimron, 1978; Thorndyke and Stasz, 1980; Lloyd, 1989a; Lloyd, 1989b). Much of the work thus far, however, has been done by psychologists who have considered maps to be just one of several stimuli used to investigate cognitive processes underlying knowledge acquisition. A primary goal of this paper is to synthesise some of this psychological research and place it in the context of spatial problem solving and geographic instruction. Selected examples of geographic research into learning from maps are also considered in the context of current cognitive theories. An emphasis on the process of learning from maps leads to very different research questions and methodologies than does an emphasis on map communication effectiveness. As an example, the paper concludes with a brief account of a classroom experiment dealing with the impact of maps, and the process of map compilation, on regional images.

KINDS OF SPATIAL KNOWLEDGE

The role that maps play in spatial knowledge acquisition is likely to vary with the kinds of knowledge that a person is trying to acquire (or the kinds of knowledge that a teacher is trying to communicate). To understand the role of maps in spatial knowledge acquisition, then, we must first consider the characteristics of that knowledge. Kinds of spatial knowledge have been distinguished on the basis of the spatial extent of features (point, line, and area), the function that those features might have for environmental behaviour (e.g. landmark, node, path), and the level of cognitive processing required (i.e. discrete fragmentary information about places and their connections or integrated knowledge of overall spatial relationships).

Lynch’s (1960) identification of landmark, node, path, edge, and district is probably the best known system for categorising spatial knowledge. Lynch’s feature categories, are distinguished primarily on the basis of dimension, but the landmark-node distinction is one of function. Some authors have suggested that there is little difference between landmarks and nodes (that landmarks all serve the function of nodes) and that an edge is part of the district that it
is associated with. Categorisations into place, path, and domain (Norberg-Schultz, 1971) have, therefore, been suggested as adequate.

In both of the above categorisation systems, the object categories can have attributes associated with them such as colour, income, etc. Spatial objects can also be linked to attitudes towards those objects (e.g. scenic route, dangerous neighbourhood, etc.). Empirical evidence suggests that both attributes of and attitudes towards objects in cognitive representations may be stored independently of the objects themselves (Pezdek and Evans, 1979).

Although the above systems of specifying spatial knowledge are useful in studying both urban images and the cues used in navigating, they focus on what is known rather than how the knowledge is acquired. An alternative system of categorising 'environmental' knowledge was suggested recently by Golledge and Stimson (1987). This system is closely tied to developmental theories of spatial knowledge acquisition. In it, three categories of knowledge are recognised: declarative, procedural, and configurational.

With minor additions to their definitions of each, these three categories of knowledge result in a logical grouping for spatial knowledge in general that puts emphasis on the sequence of knowledge acquisition and the extent to which that knowledge can be interrelated.

By declarative knowledge, Golledge and Stimson are referring to knowledge about objects and places. Their concern is with learning the environments in which behaviour takes place. The objects and places they refer to, therefore, are things that can be directly perceived. For spatial/geographical knowledge in general, we need to expand the definition of declarative knowledge to include places at any scale of analysis. All places ranging from landmarks in a city to continents of the world should, therefore, be included. Declarative knowledge about places, then, includes both the spatial attributes of places that allow them to be recognised (e.g. shape of a building or continent) and the aspatial attributes that allow the place to be characterised (e.g. a building's function or the dominant agricultural products of a region). From a perspective of geographic education, declarative knowledge is fundamental to the study of regional geography (e.g. recognising subnational to multinational regions as places, and knowing what goes on there). Most of the research directed to the process of acquiring declarative knowledge, however, has emphasised local scales such as the city or even the neighbourhood.

Procedural knowledge is characterised by Golledge and Stimson (1987) as wayfinding knowledge, or that knowledge required to move about within an environment. With an emphasis on the process of navigating, 'paths' from Lynch's system are replaced by 'routes'. The assumption is that not just linear features are stored, but a sequence of decisions about how to get from one place to another (e.g. Kuipers, 1978; Golledge et al., 1985). This point of view is supported both theoretically and empirically by Garling, Book, and Lindberg (1984, 1985) and their hypothesis that the formation and execution of travel plans is a major source of environmental information.

Procedural knowledge is considered to be at a higher level of cognitive development than declarative knowledge. For children, according to this Piagetian developmental approach, the ability to acquire and use this kind of knowledge appears at a later stage of their cognitive development. Some evidence exists that a similar developmental sequence from discrete place to route knowledge occurs for adults who encounter an unknown environment (e.g. Moore, 1976; Golledge and Stimson, 1987). In addition, computational models of environmental knowledge acquisition have recently been created based on this hypothesised developmental sequence (Gopal, Klatsky, and Smith, 1989).

At the highest level of cognitive processing is configurational knowledge. It is here that understanding of spatial relationships occurs. In Piagetian terminology, the ability to develop configurational knowledge for children is dependent upon having reached the concrete operational stage of development. Again, there is considerable evidence.
that acquisition by adults, of environmental information about an unfamiliar place, is a gradual developmental process that begins with selective, fragmentary information, to which further information is added over time until an integrated cognitive representation is achieved (Coulcelles et al., 1987). Recent evidence suggests that this process occurs even for those with impaired vision (Klatzky et al., 1990). In relation to geographic education, configurational knowledge includes knowing the relative location of places (e.g. where Johannesburg is within Africa or where the Falkland Islands are in relation to Argentina). Beyond this, however, spatial knowledge at this level allows geographic patterns to be identified, relationships between patterns to be noticed, and hypotheses about spatial association to be developed.

MAPS AS SOURCES OF SPATIAL INFORMATION

The process of environmental learning was labelled 'cognitive mapping' by Downs and Stea (1973, p. 9) and defined as "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." The product of this process was termed a cognitive map, but will be referred to here as a cognitive representation to avoid implications of the term map in relation to possible cognitive structures.

There has been considerable debate among psychologists concerning the form that cognitive representations take. The three points of view initially taken are described by Lloyd (1982) as radical image theory (see Kosslyn, 1980), conceptual-propositional theory (see Pylyshyn, 1981), and dual coding theory (see Paivio, 1969). The distinction among the theories is whether imagery plays a role in the coding, storage, and retrieval of spatial information, and if so, what role does it play. The strongest original proponent of radical image theory (Kosslyn) has modified his approach to treat images as something that are created in working memory as part of the spatial information retrieval process (Kosslyn et al., 1988). Considerable evidence exists to suggest that both verbal information and imagery can be part of these working memory representations (Lloyd, 1989a).

Cognitive representations, whether in the form of images, propositions, or both, may be derived from direct experience with the environment, from media such as travel brochures and maps, or from a combination of these sources. In the case of large regions (e.g. the Midwest of the United States of America) our cognitive representations are often solely the result of media. In more limited environments, such as a city, our initial spatial information may come from a map prior to actual experience with the environment. That cognitive representations can be generated from maps has been demonstrated by a number of authors (Garling, Lindberg, and Mantyla, 1983; Peterson, 1985). Evidence exists that representations generated from maps can be picture-like (Levine, Jancovic and Pallj, 1982), can be scanned for information (Kosslyn, 1980; Lloyd and Steinke, 1985), and that, as discussed below, even song held cognitive representations of regions (i.e. regional images) can be altered by information obtained from maps.

Past studies have demonstrated that map users' abilities to learn a map are affected not only by map design elements such as value contrast among features (Eastman, 1985), but by map feature presentation strategies that control how much of a map a person can view at one time (Shimron, 1978; Ford 1985; MacEachren, 1992). In addition, evidence provided by Thordyke and Stasz (1980) indicates that learning can be improved by directing map users to apply a specific learning strategy (e.g. the use of imagery).

A number of authors have suggested that a cognitive representation obtained from a map may differ substantially from a representation for the same area derived from direct environmental experience (Evans and Pezdek, 1980; Thordyke and Hays-Roth, 1982; McNamara 1986). Thordyke and Hays-Roth (1982), for example, argue that information acquired from a map is stored as images that can be scanned and measured like a physical map. Such images could include both declarative and configurational knowledge. In contrast, they contend that actual environmental experience produces procedural knowledge stored as propositions from which problem solutions can be computed.

Most attempts to specifically consider cognitive representations derived from maps, in contrast to studies of map symbol interpretation, have not been by cartographers. Six related issues have been addressed: (1) the importance of mental visualisation as a problem-solving tool and the role of maps and other graphics in assisting visualisation, (2) simplification of information obtained as part of the encoding and/or retrieval strategy, (3) hierarchical organisation of that information, (4) a tendency for use of map information to be influenced by the orientation of the source map, (5) the influence of structural components of the map (e.g. a grid street network versus no street network) on the representation obtained, and (6) the influence of different learning strategies on what is obtained and how accurately. Highlights from this research relevant to geographic instruction and spatial problem solving (e.g. trip planning, wayfinding, region delineation, pattern comparison) are reviewed below.

Visualisation

Visualisation is both a human ability to develop mental images (sometimes of relationships that have no visible form) and the process of rendering concrete visual representations designed to assist this mental visualisation process (MacEachren and Ganter, 1990). Research into the history and philosophy of science provides evidence that visual imagery has contributed to major scientific discoveries (Hadamard, 1954; Shepard, 1978). Shepard, for example, cited Faraday's and Maxwell's use of imagery in their initial conceptions of electric and magnetic fields, Einstein's emphasis on visual over verbal thinking, and Kekule's visual images that led to his discovery of the structure of benzene.

Following from work on the role of mental imagery in creative thinking, there has been corresponding attention to the use of diagrams as concrete visual representations that prompt the mental imagery needed for understanding problem situations and creative thinking about those situations (Beveridge and Parkins, 1987). Larkin and Simon (1987) have even provided a formal comparison of the efficiency of diagrammatic representations over sentential (i.e., verbal) representations in solving mathematics and physics problems. In relation to efficiency, Larkin and Simon (1987) state that "... diagrams and the human visual system provide, at essentially zero cost, all the inferences we have called 'perceptual.'" Faraday's contemporaries used the term 'intuition' to describe something quite similar to...
Larkin and Simon’s ‘zero cost’ information (Shepard, 1978). Arnhem (1985) also emphasises intuition as a component of visual thinking that operates like a ‘gift from nowhere’. Both mental images and diagrammatic representations appear to share advantages that allow this apparently ‘free’ access of information by humans. In relation to diagrams, Larkin and Simon (1987) cite the following advantages: (1) they group related information together, thus limiting search time, (2) location is used to group information about single elements, and (3) they support large numbers of perceptual inferences, which are extremely easy for humans. These observations are clearly applicable to maps as well.

Similarly, advantages for learning about or understanding relationships have been demonstrated for test supplemented by relevant illustrations over text alone (Levin, Apgin, and Carney, 1987). Gilmartin (1982) has even suggested that maps may allow female students to overcome male students’ potentially superior abilities at mental visualisation. In a test of comprehension of text that described geographic relationships, she found that the addition of maps with the text resulted in an increase in performance for female students, but not for male students. The hypothesis given to explain these results was that the male students had been able to visualise the distributions and their relationships from the textual description alone. The female students, on the other hand, apparently found this task more difficult, but were able to visualise the relationships when a map was provided.

Peterson (1985) has demonstrated that maps vary in their ‘pattern quality’ and, therefore, in their ability to stimulate the formation of a mental image. In a later paper, Peterson (1987) goes on to suggest that many geographic problems can be answered by drawing on either image or verbal information, a contention also made by some psychologists and termed dual coding theory. The principle underlying this theory is that information can be processed simultaneously in the image and verbal domains. The response to a particular query will be provided from the domain in which a solution is reached most quickly. Maps with weak image producing properties, therefore, may result in more reliance on verbal knowledge, while strong images will result in the reverse.

It is quite clear from research in cartography (e.g. Lloyd and Stea, 1976) and cognitive psychology (e.g. Paige and Simon, 1966; Larkin and Simon, 1987) that maps and other graphic displays only assist interpretations when the user knows the appropriate method for taking advantage of them. People apply a ‘schemata’ that is used to direct their perception and to organise their interpretation of what is perceived.

“Perceptual schemata are plans for finding out about objects and events, for obtaining more information to fill in the format. One of their important functions in seeing is to direct exploratory movements of the head and eyes.” (Neisser, 1976).

We can see in an illustration only what we know to look for (i.e. what the schemata allows us to see). The schemata applied is often dependent upon how the information is presented to us and at what scale (Anes and Mann, 1984).

Duncker’s problem provides a dramatic illustration of the influence that selection of a particular schematic has on problem solving (Howard, 1983). In one version of this problem, the subject is presented with a drawing of a table upon which are a candle, a pack of matches, a small box full of thumb tacks, and two loose thumb tacks next to the box. The subject is told to devise a method for mounting the candle vertically on a nearby plywood wall. STOP and consider this problem for yourself before reading further. If the subject does not immediately arrive at the problem solution, a variation of the drawing is presented in which the tacks are scattered next to an empty box. Even without the illustration, your own mental visualisation skills should now allow you to solve the problem.

The point of the above example is that different forms of information presentation can lead to different hypotheses or problem solving strategies, or to such a strong fixation on one view of the data that the correct solution or interpretation cannot be derived. With a box full of thumb tacks, the box is ignored and thinking is guided towards how the tacks can be used to attach the candle directly to the wall. The empty box with tacks next to it, on the other hand, leads to the ‘insight’ that the box is significant and that the problem can be solved by first tackling the box to the wall, then putting the candle in it. An interesting cartographic question, that follows from this example is whether the simple highly generalised maps that seem to be advocated for geographic texts will necessarily help spatial problems solving. By removing all of the local variation and ‘extraneous’ details, we present a single schematic and might be removing the possibility for alternatives so devised. Tuft (1989), in his recent book, Envisioning Information, argues strongly for high information density in graphics so that key relationships are present to be discussed.

Simplification

No matter how much or how little detail is presented, humans seem to have a tendency to simplify it. Arnhem (1966), for example, suggests that humans form ‘visual concepts’ or ‘visual categories’ that characterise what we perceive in such a way that we are able to recognise subsequent similar (built different) objects or forms. Canter and Tagg (1975) hypothesised the use of simplifying structures that could enable a person to recall and use their cognitive representations of cities more readily. In a study using a sketch mapping methodology, Sanders and Porter (1974) found that their student subjects had a tendency to represent the shape of Africa as a regular geometric form.

Tversky (1981) has provided evidence for similarities in the way information derived from both the environment and maps is simplified in the encoding and retrieval process. She proposes that in order to orient and anchor figures in space, heuristics based on principles of perceptual organisation are applied. The two heuristics suggest are rotation (shift of the natural axis of a figure to correspond with the frame of reference) and alignment (the gravitation of figures toward each other).

To test the alignment hypothesis, Tversky asked student subjects to give compass directions between six to ten pairs of cities. She hypothesised that students, as a simplifying heuristic, would align North with South America and North America with Europe. This shift would lead to judgements placing South American cities farther west than they actually are and European cities farther south. This is exactly what was found. In a second experiment, the rotation hypothesis was supported for San Francisco Bay, with most subjects having rotated the major axis to a straight north-south orientation. In a final experiment with artificial maps, in which all location knowledge was the direct result of map study, both the alignment and rotation hypotheses were confirmed.

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Recently, Lloyd (1989) identified similar rotation and alignment heuristics for cognitive representations of urban environments developed by both navigation within the environment and map reading. Further support for simplification as a cognitive strategy was obtained by Howard and Kerst (1981) for both known locations and studied maps. Their results indicate a tendency to remember a rectangular region as more nearly square. Cognitive representations derived exclusively from a map, however, exhibited less distortion towards a simpler form than those from direct environmental experience. A lessening of the simplification effect was also demonstrated for the familiar local environment after brief map study.

Evidence for application of simplification heuristics as part of the memory process is also available for thematic maps (MacEachren, 1982). In a test of memory for three-through eleven-class choropleth and isoplech map patterns, subjects were asked which of two regions had the higher overall population density. Results of this area comparison task indicated that regardless of the number of categories on the map presented, subject responses were based on memory for only high, medium, and low population regions.

**Hierarchies**

Another generalizing procedure demonstrated for cognitive representations derived from both maps and the environment is hierarchical organization. Stevens and Coupe (1978), for example, examined subjects' knowledge of direction among geographical locations in North and Central America and locations on hypothetical maps. Their results indicate that spatial relations for locations within the same superordinate region (e.g. cities within a state) are stored directly, while those for locations in different regions are computed based on knowledge of the relative positions of superordinate regions.

A relationship has also been found between response time to verify distance and direction judgements for inter-cluster but not intra-cluster locations (Maki, 1981). The between-cluster times were significantly faster indicating that judgements were being made at a higher level in the hierarchy (i.e. between the superordinate regions).

Hirtle and Mascolo (1986) have demonstrated that organisation of map locations into regions or clusters in a cognitive representation can be influenced by the labels given to the locations, with functionally related places grouped together. Their results, in contrast to previous work (e.g. Pezdek and Evans, 1979), are cited as evidence that verbal and spatial information are not encoded independently. Semantically related locations appear to be grouped in memory, and remembered as being closer together than semantically unrelated locations. These clusters are shown to occur whether or not there are physical barriers present. This suggests that geographic regions defined by common attributes can be as clearly remembered and understood as regions defined by physical barriers such as mountains or oceans.

In a series of experiments in which memory for object location in a room was compared to a map of the layout, McNamara (1986) concluded that similar hierarchical clusters were used. Spatial priming was analysed using reaction time data. Locations in the same regions were found to prime each other (i.e. speed response to questions) more than locations in different regions. Results were interpreted as support for a partially hierarchical rather than a strongly hierarchical model. A partially hierarchical model for spatial memory suggests that regional information is coded in memory in a nested hierarchy, but that some information redundancy also occurs. Some, but not all, spatial relations between places in different regions within the hierarchy will be stored explicitly.

**Orientation**

Cognitive representations derived from maps have been demonstrated to be linked to the orientation (in terms of cardinal directions) of the map studied (Levine, Jankovic and Plait, 1982). In comparison, cognitive representations derived from direct environmental experience have been shown to be orientation free (e.g. distances and directions are remembered equally quickly and accurately regardless of direction from one location to the other).

Evans and Pezdek (1980) used response time for determining relative position accuracy for triads of USA states or buildings on campus. Reaction times for the state triads increased as a function of the degree of rotation of states from their orientation on a north at the top map. No rotation effect was found for the buildings. In a second experiment, subjects unfamiliar with the campus learned building locations from a campus map and completed the same test. A rotation effect corresponding to that for the state location case was found.

Four possible reasons for the difference in representations derived from maps and from the environment have been suggested: (1) maps are viewed simultaneously while actual environments are generally experienced in several partial encounters (Thordyke and Hays-Roth, 1982), (2) maps are viewed from one perspective while the environment is experience from many (Evans and Pezdek, 1980), (3) for representations derived from the environment, the perspective of the representation is from within (i.e. as if you could imagine being in the environment at one location while considering the distance and direction to another location), rather than from above as it is for a learned map (Thordyke and Hays-Roth, 1982; Evans and Pezdek, 1980; Presson and Hazelrigg, 1984), and (4) map learning is a secondary or indirect spatial activity while experiencing the environment is a primary or direct spatial activity (Presson and Hazelrigg, 1984).

If hypotheses one or two are correct, it should be possible, through interactive computer map presentation systems, to overcome the orientation bias inherent in geographic information learned from a traditional static map. In contrast, should hypotheses three or four prove correct, much more sophisticated visual simulation systems would be required to eliminate orientation bias in geographic information obtained from sources other than direct experience.

An intriguing question that should be addressed is the role of map projections in tying our understanding of global relations to a fixed view. It was certainly with this danger in mind that Richard E. Harrison developed his famous series of novel world views during World War II. In the USA as elsewhere, there are growing efforts to improve geographic education. Much of this effort thus far is stimulated by and directed to the lack of place knowledge demonstrated by USA students. We may be able to use this demand for teaching place name geography to develop methods for learning spatial relations that are based on presenting the world from multiple rather than single perspectives.

**Map Structure**

Map structure can be manipulated by choice of base
information or symbolisation strategies. The presence or absence of a street grid, for example, was shown to influence recall of landmarks (Kulhavy, Schwartz and Shana, 1982). The college students who participated in that study remembered fewer map features when the map included a street grid than when it did not, but they were able to correctly locate more of the features that were recalled. Eastman (1985), in a related study, examined the presence or absence of political borders and transportation features, as well as visual contrast among linear features, as potential factors in how point locations are clustered in memory. He found that presentation formats had an effect on region delineation, but not on the hierarchical nature of the memory structure itself. Together these findings indicate a potential role, on instructional maps, for reference grids as an organising structure. Although co-ordinate systems are an abstract concept that younger children may have difficulty with, other kinds of regular grids may prove to be helpful organisers. Directing attention to them as such may help to introduce the more abstract co-ordinate reference systems presented later in the curriculum.

Elements of map structure that impede formation of accurate cognitive representations have also been investigated. Taylor and Hopkins (1975) suggested that map ‘clutter’ was the single greatest problem in map design. Map ‘clutter’, in the form of number of cities along routes was investigated by Thorndyke (1981) in relation to route distance estimates. Estimates were found to increase in proportion to city number. A related aspect of map structure, ‘complexity’ has been investigated for memory of small scale thematic maps (MacEachren, 1982). Complexity of the mapped distribution was found to impede map memory for both choropleth and shaded isopleth maps. In addition, general patterns were remembered less accurately when learned from the choropleth maps, which were demonstrated to be more complex.

Learning Strategies
Learning strategies for mapped information have been considered from two perspectives, the effects of specific tasks on learning, and the control of learning strategies through map segmentation and sequencing. Stanford (1980), in considering mapwork tasks, has focussed on the relative merits of directed map search versus free search. He has found that leaving children to their own devices to explore a map, at a pace and with a strategy they select themselves, results in dramatically better success in mapwork skills. There is the possibility, of course, that this result would differ if different instructions were given for directed search.

In a related study, Kimner and Wood (1987) compared two learning tasks in relation to memory for topographic maps. Two subject groups answered a series of questions using a topographic map. One group dealt with questions directed specifically to the contour depiction while the other answered questions about other map information (i.e. distance and co-ordinates). Those who focussed on elements of the map not related to the terrain depiction did not remember the terrain pattern (only 11% could pick the map that they used from a set of five similar maps). The group of students who were directed to answer questions about the contours, however, did much better (65% picked the correct map). These results suggest that directed search or specific map use tasks can lead to an accurate cognitive representation of a mapped region, but only if the tasks are narrowly focussed on key spatial patterns.

In what has been the most complete study of learning strategies published to date, Thorndyke and Stasz (1980) considered the following questions: (1) are there large individual differences in map learning performance, (2) do map learners use diverse study procedures, (3) what distinguishes good and poor learners, and (4) are different learning strategies employed by experienced and novice map learners. In their initial experiment, verbal protocols were obtained from subjects concerning their attentional focus, study heuristics, and evaluations of their learning process. For the eight subjects in this experiment, three ‘experienced’ and five ‘novice’, they found no clear difference between the experienced and novice learners; possibly due to limitations in the number and choice of subjects. They did, however, identify three common elements of the good learners’ strategies: (1) segmentation and systematic focus on subsets of information, (2) conscious use of learning techniques, and (3) consistent and accurate self-evaluation of learning progress. Segmentation and focus on subsets of information correspond to the underlying premise of developmentally based theories of spatial learning; that learning proceeds from local uncoordinated knowledge to a global co-ordinated representation. Eastman (1985), as discussed above, used graphic means to induce different regionalisations, and concluded that the groupings induced did not affect map memory except in the case of one map that encouraged several conflicting regionalisation strategies. In an experiment where labelled landmark locations were learned, functionally related verbal labels were found to be a stronger influence on clustering of point locations than were spatially induced associations (Hirtle and Mascolo, 1986).

In a route segmentation experiment, Hanley and Levine (1983) demonstrated that if two interconnected routes were learned independently, they could be organised into a co-ordinated representation. For the simple (three segment) routes in their study, however, the coordinated representation was learned more easily from a complete map. This suggests that there is a lower threshold or unit size for memory ‘chunks’ below which further segmentation interferes with, rather than aids, acquisition of information.

A number of studies have forced subjects to use a segmentation strategy for map learning by providing map information as a sequence of parts of layers. Shimron (1978) compared two segmentation strategies and found that spatial segmentation of a schematic map, by presentation as separate regions, results in more accurate memory than separation into functional layers (i.e. cities, highways, etc.) Kulhavy, Schwartz, and Shana (1982) provide evidence that it is the regionalisation itself, rather than segmenting of information for sequential presentation, that aids learning. Their three test groups were each presented with a regular street grid to which point features were added in six stages. For one group the stages consisted of conceptual sets (e.g. sports, plants, etc.), for the second group spatially segmented sets were used, and the third group was presented with six random sets. For all three groups, the reference grid appeared to aid learning. No significant differences among groups was found, an indication that the street grid provided a frame of references that was more dominant than any effects due to segmentation.

COGNITIVE MAPPING, MAPWORK, AND REGIONAL IMAGES:
A CLASSROOM EXPERIMENT

Downs and Stea (1977) contend that cognitive mapping is "the way in which we come to grips with and comprehend
the world around us'. This is thought to be the case, at least in part, because one aspect of cognitive mapping is to provide an organising structure, or spatial schema, for relating information acquired from a myriad of sources (Cox and Zannaras, 1973; Downs and Stea, 1977). Spatial schema, or frames of reference, are clearly used in everyday spatial decision making, and they frequently exhibit a regionalised hierarchical structure.

One product of cognitive mapping is the development of regional images, a form of declarative knowledge that includes both spatial and attribute components. Regional images seem to be a logical outgrowth of the human search for structure in spatial information and the tendency to simplify and hierarchically organise that spatial information. As evident in the psychological research cited above, political divisions such as states impose a hierarchical structure on positional knowledge. Cox and Zannaras (1973) hypothesised that subnational regions for which no official boundaries have been delineated (e.g. the South or Midwest) exert the same influence.

For regional images, as well as more local cognitive maps, the existence of separate locational and attribute components have been recognised for some time. Cox and Zannaras (1973) referred to 'locational' and 'non-locational' attributes of places, while Downs and Stea (1973) distinguished between 'locational' and 'attributive' information. As discussed above, some psychological research dealing with local scales (from neighbourhoods down to rooms) has demonstrated that verbal information can influence spatial grouping and, therefore, memory for position.

It is clear from a geographic perspective that there must be distinct spatial and attribute components of regional images, but that these components are strongly interdependent. If certain bounds are specified for a region (by a government agency or the media) these bounds will influence the expectations about that region's characteristics. Alternatively, if a region is strongly associated with particular characteristics, assumptions about where these characteristics are prevalent will have an effect on where the region's boundaries are assumed to be.

For a number of years in both a map use and a map making course I have used a map compilation exercise to introduce the concept of regionalisation to students. In addition to its pedagogical goals, student performance on the exercise has allowed some aspects of the role of maps in regional image formation to be examined. What follows is a brief description of the exercise and an analysis of its results in the context of the above discussion of spatial knowledge acquisition from maps.

Student performance on this exercise has permitted two contrasting possibilities concerning spatial and attribute components of regional images to be compared. Regional images may be tied to locations for which individuals develop a conception of the attributes (i.e. a visually-based image, possibly linked to a location by memory of a map or photograph). Alternatively, regional images may begin as an assemblage of shared attributes, and the location of the region then viewed as where these attributes correspond (i.e. a propositionally-based image). As geographers we typically take the latter approach when identifying cultural, economic or political boundaries. Popular regional conceptions, however, may be more dependent upon a general location identified on maps or in the media, with attributes only guessed at, as with the 'Sun Belt' in the US (Browning and Gester, 1979).

The classroom exercise developed focuses on a different subnational region of the USA each term. Several regions have been used, the most interesting of which is the Midwest. This is a region that all of the students know about, but one for which the Colorado students tested were expected to have varied opinions. It is a region for which both residents and outsiders hold widely disparate views concerning its location and attributes. The goal of the analysis reported here was to determine the locational stability of the Midwest image when students were faced with evidence, in map form, that the attributes thought to characterise the region were not concentrated in the anticipated location.

**Experimental Procedure**

Students for whom assignments are analysed were enrolled at the University of Colorado. They were, therefore, living in what previous studies indicate is an ambiguous area, in terms of Midwestern versus Western affiliation. Three hypotheses are addressed. (1) Colorado students, due to their location at the western periphery of the region, have a Midwest image with a western core (i.e. centred in Kansas or Nebraska), but the attributes they associate with the region are concentrated to the east of that core area (because they share the same agricultural perspective on the region held by people across the country). (2) A simplification heuristic results in symmetrical images that are aligned with a central meridian passing through the center of the USA (due to a literal interpretation of 'Mid' west). (3) Work with published maps of Midwestern attributes (as judged by the students) will result in an eastern shift in their image of its location to match the location of attributes they find on published maps (an indication of a attribute or propositionally-based image).

39 students in a map use course were provided with an A4 sheet containing only the border of the conterminous US. They were asked to outline (draw a border around) the part of the country that they identified as the Midwest. In addition, they were instructed to include elements appropriate to their definition of 'the Midwest', such as state boundaries, cities, and rivers. They were then asked to create two lists, the first of the most significant Midwest characteristics, the second of characteristics that were definitely not Midwestern.

The sketch map and list of attributes characterising the Midwest was produced during the first week of the semester. As a course project over the next two weeks, the students were to select the three or four Midwestern and non-Midwestern attributes from their lists that best characterised the region, and to use resources available in the library and map collection to locate published maps of these attributes. The students transferred information about each attribute from their source map to a standard base map provided to them. The individual attribute maps were then used to compile two composite maps, one of Midwestern and one of non-Midwestern attributes. These composite maps depicted areas where no attributes were present, where only a single attribute was present, where two attributes overlapped, and where three or more attributes overlapped.

Once completed, students were asked to briefly discuss their image of Midwest location in relation to the inclusive and exclusive factors depicted on their two composite maps. They were specifically asked to describe any 'inconsistencies' between the sketch and composite maps, and to provide any reasons that they could for these inconsistencies.
Ten weeks after completing this assignment, students were asked to produce a second sketch map. As with the first, this map was prepared during the lecture period, with no opportunity to consult their first sketch, or any other sources. Comparison of this second map to the earlier one provides a measure of the impact that the attribute map compilation exercise had on the location component of the students’ Midwest images. 32 of the original 39 students completed second sketches. Analysis was, therefore, limited to these 32 respondents.

Analysis
Data were compiled using a grid overlay with units of 100 mile resolutions. For both of the two sketch maps produced by all subjects, each 100 x 100 mile cell was classified as Midwestern if 50% or more of the cell fell within the bounds drawn on the map, or non-Midwestern (if less than 50% of the cell was within the bounds). For each subject’s composite map of Midwestern attributes, a similar coding was done. In this case each cell was assigned a value of 0 through 3 to indicate the number of attributes occurring in that cell. (Examination of the composite maps for non-Midwestern factors indicated that a significant percentage of students deviated from the instruction in listing and compiling this information. The maps of non-Midwest attributes, therefore, were not considered in the analysis.)

As a first step in the analysis, aggregate choropleth grid cell maps were produced for the first and second sketch and for areas in which two or more Midwestern attributes corresponded (Figure 1). As anticipated, the Colorado student’s initial Midwest is centrally located and roughly symmetrical. The region’s core is centered over western Iowa, but not as far west as Shortridge’s (1985) aggregate results for students from across the USA. The hypothesis of a more eastern location for region attributes appears to be supported, as does an eastern shift in location on the second sketch. Particularly for the area of 70% or greater agreement, the second consensus Midwest provides a better match to the consensus on attribute location (a coefficient of areal correspondence that was calculated increased from 0.55 for the first sketch to 0.71 for the second). As seen in the summary map (Figure 2), this improvement is due largely to elimination of sections of the country on the north, north-west, and south-west fringe of the original Midwest image.

In addition to considering group data, changes in Midwest location from the first to the second sketch were examined for individuals (Figure 3). The average area contained within the Midwest bounds decreased (from 850,500 to 729,000 square miles), becoming more similar to the area for which two or more attributes correspond (607,500 square miles). In addition, the second sketch exhibits a small, but statistically significant increase in correspondence with the composite attribute map (the mean coefficients of areal correspondence are 0.44 and 0.53, respectively with a pairwise t-score of -4.314 indicating a probability of less than 0.001 that the difference is due to chance). The location core for individuals was relatively stable. Centroids calculated for the sketches indicate an average shift of only 54 miles between the first and second sketch. The second location centroid was an average of 26 miles closer to a weighted centroid for the attribute composite.

Discussion
A number of authors have measured and compared the contents of regional and global images for people of differing education, age, and cultural backgrounds (e.g. Raitz and Ulick, 1982; Shortridge, 1985, 1987). Little as has been discovered, however, about the structure of regional images, how they are formed, and how to stimulate the cognitive regionalisation process.

The results described above add to the evidence that cognitive representations of space include both attribute and location components. A simplification heuristic of the type described by Tversky (1981) was clearly identified. The students’ images of Midwest location were initially more symmetrical and centrally located than they were following map work. The change in region location following compilation of attribute information supports a hypothesis that verbal information can dominate spatial information in cognitive representations. This result is in agreement with Hirtle and Mascolo’s (1986) evidence that semantic clustering in memory can dominate spatial clustering.

For the students who completed this exercise, the mismatch between attributes and location was often dramatic. Unless faced with the contradictions, however, an individual can easily remain unaware of them, and use the regional image as if it was internally logical. The result could range from disappointment about choice of a vacation site to financial failure due to an inappropriate business location decision.

Presentation of a systematic regionalisation procedure allowed students to identify areas of correspondence for attributes that they associated with the Midwest, and to identify discrepancies between the region as defined by their sketch and composite attribute maps. This procedure, coupled with a tendency to accept maps as correct, produced significant long term changes (of at least ten weeks duration) in the locational component of the student’s Midwest image. It is equally apparent from the individual map comparisons (Figure 3), that some students had a location (visually)-based image and were not swayed by the evidence of their composite map. Although not tested, it can be assumed that the students who retained a location that did not match their attribute maps have probably changed their minds on the Midwest’s dominant attributes.

Figure 2. Summary map showing areas of 70% or greater agreement for the 32 subjects. Greater correspondence between the second sketch of Midwest location and the location of Midwest attributes is achieved by omitting some of the areas initially thought to be part of the Midwest.
Figure 3. Individual results. Each map depicts a subject's initial Midwest sketch with large dots and the area of the second sketch with the striped pattern. The grey outlined area encloses those locations where two or more attributes overlapped.

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CONCLUSIONS

The experimental exercise described is one example of a change in approach that I believe is needed in how maps are used in geographic instruction and integrated into geographic problem solving. Given a specific problem to investigate (e.g. planning for urban growth, citing of a nuclear power plant or diffusion of AIDS), a typical past strategy was to attempt the development of single, graphically 'optimal', representations. In fact, much cartographic research over the past three decades has been devoted to the search for optimal symbolisation. In the case of geographic regions, boundaries have been depicted as if they really exist. Today, with computer mapping and information systems increasingly available in the classroom, we are not limited to a single geographic interpretation or form of presentation. We can instead provide, and compel students to consider, alternative interpretations of information. This strategy can prevent the student from adopting a single, possibly misleading schema that would be applied to other problem solving. An intriguing area of research, therefore, is to determine the influence that a set of varied views of the same spatial distribution has on hypothesis generation or problem solving efficiency.

The suggestion that we need human-map interaction tools designed to incorporate multiple views and facilitate pattern identification has been made in a previous paper (MacEachren and Ganter, 1990). Outside of geography and cartography there seems to be rapid growth in interactive scientific visualisation tools that allow change of viewing perspective (from 3D views to 2D cross sections) and interactive manipulation of display variables such as time frame, data classification, and colour assignments. For maps there are microcomputer packages that allow nearly instantaneous change among choropleth, graduated circle, and dot maps (e.g. MapMaker by Strategic Mapping, Inc.) and at least two systems have been developed for interactive manipulation of data class ranges on choropleth maps (Yamahira, Kasahara and Tsurutani, 1985; Ferreira and Wiggins, 1990). No effort appears to have been made thus far, however, to assess the impact of such tools on problem solving (e.g. risk assessment, planning decisions, political districting, etc.) or hypothesis formation.

When the cognitive process that are the foundation of learning from maps are investigated, many additional exciting avenues for research become apparent. Cartographic research based on an understanding of those cognitive processes is potentially more relevant to geographers and how they use maps, than is perceptual research dealing with symbol detection, discrimination, and interpretation. Thinking of learning from maps as a gradual developmental process moves us away from the fallacy of viewing the cognitive map user as a container into which we pour information. Considering how people learn about space and how they deal with the spatial aspects of their environment on a daily basis will allow us to devise maps, and map presentation strategies, that facilitate thinking and problem solving rather than to memorising.

In addition to tackling the problem of regions, what they are, and how we learn about them, the more general question of regionalisation and sequencing as spatial information presentation strategies should be investigated. Monmonier's (1990) concept of 'atlas touring' and Miller and Modell's (1988) Great American History Machine offer intriguing examples of the potential afforded by recent computer advances. We now have the tools to dramatically change our approach to teaching and communicating geographic knowledge with maps. We must, however, proceed with caution because we are just beginning to understand the implications of the new technologies for how we think and solve problems.

REFERENCES


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