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# Do People Understand Spatial Concepts: The Case of First-Order Primitives


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# Do People Understand Spatial Concepts: The Case of First-Order Primitives

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Abstract. The purpose of this paper is to examine whether people in general understand elementary spatial concepts, and to examine whether or not naive spatial knowledge includes the ability to understand important spatial primitives that are built into geographic theory, spatial databases and geographic information systems (GIS). The extent of such understanding is a partial measure of spatial ability. Accurate indicators or measures of spatial ability can be used to explain different types of spatial behavior. In this paper I first examine the relation between spatial ability and spatial behavior, then present experimental evidence of the ability of people to understand spatial concepts such as nearest neighbors (proximity), and spatial distributions. A final commentary is made about the possible difference between "common sense" and "expert" spatial knowledge, and the implications of such results for the comprehension of space at all scales.

## 1. Purpose

It is sometimes argued that instead of developing a cognitive map people develop a cognitive atlas. This atlas would contain representations of many different environments at many different scales. Depending on the purpose behind a specific problem solving task, specific components of the cognitive atlas would be accessed. The question immediately arises as to whether such a cognitive representation is simply an internalized geographic information system. A major purpose of this project is to begin examining this question by determining the degree to which selected processes involved in compiling and using cognitive maps are similar to those involved in compiling and using GIS. In particular, the project will focus on a selection of key concepts found in both cognitive mapping and GIS regardless of geographic scale. An attempt is made to determine how well the latent spatial information embedded in distributions displayed on a map can be understood and interpreted by lay people.

The larger project from which this research is abstracted continues research on the components of spatial knowledge. In particular, research is being conducted on the extent to which people understand geographic terms and concepts needed in cognitive mapping and GIS development and use. Since all such terms and concepts can be found in the domain of configurational knowledge, this will provide a focus for the research. The parent project includes the design of specific tasks: (a) to identify similarities between the processes of cognitive mapping and the processes of building a GIS (i.e. to see if correspondence occurs between the two processes or to see if cognitive maps are internalized GISs); (b) to determine the order of difficulty for completing a variety of spatial inference tasks that require the same level of understanding as is assumed in GIS functions (such as overlay, compression, pattern recognition, hierarchical ordering, recognition of spatial distribution membership, adjacency and connectivity, orientation and direction, spatial sequencing and ordering, locational designation and cue recognition); (c) to logically extend current work to include "higher order" processing such as developing an ability to overlay several discrete patterns without losing the initial information while concurrently creating new knowledge; (d) to examine the concepts of neighborhood, regions and regionalization and how they enter into spatial knowledge structures; (e) to examine the concept of spatial hierarchy, to identify how such hierarchies are formed and used by people to store and recall spatial information; and, (f) to evaluate individual abilities to recognize spatially associated geographic patterns presented in visual format. It is anticipated that much of this research will be cumulative, with the solutions to some problems depending on the prior solution of others; the research is projected over a multi-year period. This paper reports only on experiments relating to recognition of characteristics of spatial distributions.

## 2. Background

This project from which this paper is drawn examines the nature and components of configurational (survey) knowledge. Such knowledge is presumed by developmental and life span theories to be the final stage of the spatial knowledge acquisition process. Hence it incorporates all components of spatial knowledge. From the geographer's view, configurational knowledge should include the ability to identify distributions, patterns, shapes, associations and relations of phenomena in both proximal and macro environments. For the geographer it is a level of knowledge that facilitates comprehension of pattern in the distribution of natural and human phenomena over the earth's surface. Despite the ready acceptance of its necessary existence, we know little about configurational knowledge and how well people can develop it. The characteristics of this stage of knowledge as outlined theoretically by Piaget & Inhelder (1967) have been shown to occur at many stages of the life span (Liben, Patterson & Newcombe, 1981). Recently Anderson (1982) hypothesized that spatial knowledge requires only a declarative base and a set of procedural rules to allow understanding of complex spatial environments. Other research (Gale, et al. 1990; Golledge, et al. 1991) have thrown some doubts on whether this is so. The parent project aims in part to evaluate whether the integration of a declarative knowledge base with sets of procedural rules *can* produce the configurational or survey level understanding of spatial phenomena that it is assumed normal adults develop. Multiple tasks will assess the degree of integration of spatial knowledge at a variety of micro and macro scales to see if more than one level of configurational understanding exists. Based on the outcome of recent NSF funded research (Golledge, 1991, 1992) it is hypothesized that most individuals develop only a "common sense" configurational understanding of spatial phenomena, which accounts for incomplete and fuzzy cognitive representations of environments, and partly accounts for many spatially irrational behaviors. It is also suggested that people are not necessarily aware of all they "know," in the sense of not developing the necessary inference rules and logical procedures needed to obtain a full comprehension of the spatial information contained in their knowledge set. For example, one may *know* that A>B and B>C but not be aware of the logical outcome graphic research efforts. The question of scale arises in a configurational context (Kirasic, et al., 1984) with particular emphasis being placed on the difference between the immediate observable perceptual domain (small-scale) and the larger-scale environment that generally exists beyond the immediate visual field. The relative significance of active (field) versus passive (laboratory/model) experiences in obtaining configurational understanding has been discussed by Gale, et al. (1990) and Lloyd (1989a,b,c). In a series of papers, Siegel and his co-workers (Siegel & Schadler, 1977; Siegel, Kirasic & Kail, 1978; Siegel, Herman, Allen & Kirasic, 1979; Siegel & Cousins, 1983) have illustrated how conventional cartographic and surveying techniques such as triangulation, intersection, and projective convergence can be used to recover external representations of spatial layout or configurational knowledge. It is in this area that the methods and concepts of geography appear to have considerable potential in representing and understanding the nature of configurational or survey knowledge.

The major shortcoming of research activity to date is that while specific components of spatial knowledge have been identified and more light has been thrown on types of spatial knowledge, it has not yet clearly identified whether or not people in general are able to use the logic and inference needed to extend their naive spatial understanding into the "expert" domain. As geographers, we assume everyone *has* the ability to do this, and we develop methods for assisting such a transition. But often we are *not* aware of the nature of the reasoning and inferential processes that are required in as "simple" a matter as reading a map.

During the past year, NSF has funded research by co-workers James Pellegrino and myself on the following tasks:

a. *Identification of spatial distributions* of selected land-use features;
b. *Evaluation of nearest neighbor* concepts;
c. Comparison of knowledge acquired after *learning routes from maps or visual simulations of routes*; and
d. Examination of ability to *integrate information* acquired from routes into configurational understanding.

Each of these tasks is directed towards understanding the degree to which basic reasoning and inference processes can be used to solve the spatial problems we somehow handle in our daily activities. In the next section I review a selection of these tasks. As part of this review, let us now turn to a discussion of spatial abilities, spatial behavior, and spatial competence in the specific context of knowing properties of spatial distributions.

## 5. Spatial Abilities

Elsewhere, co-workers and I have discussed the nature of spatial ability (Self, Gopal, Golledge & Fenstermaker, 1992). This discussion is summarized below.

Spatial abilities include: the ability to think geometrically; the ability to image complex spatial relations at various scales, from national urban systems to interior room designs or tabletop layouts; the ability to recognize spatial patterns in distributions of functions, places and interactions at a variety of different scales; the ability to interpret macrospatial relations such as star patterns; the ability to give and comprehend directional and distance estimates as required by navigation, or the path integration and short-cutting procedures used in wayfinding; the ability to understand network structures used in planning, design and engineering; and the ability to identify key characteristics of location and association of phenomena in space. This definition extends beyond that usually found in discussion of spatial aptitude tests, but includes traditional things such as orientation and re-orientation after rotation, translation (or other transformation), perspective viewing, knowing locations, and integrating partial (linearized) information into configurational wholes.

Spatial ability is often measured in terms of achieving scores on tests such as the Differential Aptitude Test (DAT), the Thurstone test of Primary Mental Abilities (PMA), and many others (see Eliot & McFarlane-Smith, 1983). Such tests measure performance based on different tasks relating to the two main hypothesized dimensions, spatial visualization and spatial orientation. Test scores are interpreted as revealing the degree of "spatial competence" of tested subjects, and are the basis for making generalizations about differences in performance (i.e., behavior). All these measures involve laboratory testing of the presence or absence of skills. None evaluate performance outside of the laboratory test arena. None determine an individual's spatial competence in problem-solving situations in the field. It is accepted that the skills exhibited on the abstract manipulative tasks encoded in paper and pencil tests can be transferred immediately to larger-scale environmental settings and to active decision-making situations. There is some doubt that this is so, a point made previously by geographers Gilmartin and Patton (1984). My first hypothesis, therefore, is that traditional definitions of spatial ability are task dependent, are at best partial, and fall short of measuring the "spatial competence" they claim to measure.

## 6. Spatial Activities and Spatial Behavior

The restricted definition of spatial ability as incorporated into many aptitude tests contrasts with the richness of the general literature on spatial activities and spatial behavior. The term "spatial activities" includes both covert and overt activity, although it is usually interpreted in a traditional geographic way, being limited to overt activities that have observable spatial ranges (i.e., "revealed" behavior). For our purposes, however, spatial activities may include sedentary actions such as playing a musical instrument, playing chess, doing needlepoint, and so on. Activities requiring significant use of geographic space (i.e., personal relocation and movement between places) on the other hand, might involve sports, recreation, and a variety of social or want satisfying behaviors, such as shopping. The spatial skills required in many of these behaviors differ substantially. Some require visualization skills; some require visualization plus motor coordination (as in hitting a tennis ball or kicking a football). Some involve cognitive processes and physiological functioning (such as when a pedestrian explores an unfamiliar neighborhood). Other behaviors involve spatial sequencing, as might be the case in wayfinding. Consumers able to effectively use a range of shopping opportunities in a city require some understanding of hierarchical order and spatial dominance. Reading a map requires skills in symbol identification and orientation. Direction-giving requires the ability to image and verbalize information stored in memory. Drawing a sketch map may require the ability to integrate information about landmarks, routes, and neighborhoods into an organized whole contained within some bounding scheme or frame of reference (Self, et al., 1992). What is not at all obvious is how the scores on the spatial components of different aptitude tests, relate to and/or are able to predict the spatial skills necessary in many of these problem solving situations. My hypothesis is, therefore, that spatial competence is a concept that requires integration of both psychological measures of performance on spatial ability tests together with measures of performance on a range of spatial activities and/or behaviors. Few examples of this larger integrated psychological/geographical interpretation of spatial ability can be found.

The tie between spatial ability and (revealed) spatial behavior may not be immediately obvious. Co-workers Self, Gopal, Fenstermaker, and I have explored this tie elsewhere in the context of gender differences in spatial ability. I shall briefly review these ties again here. "Spatial behavior" is mostly defined as the overt act of moving from place to place. For decades geographers have discussed and built into their theories and models simple criteria for understanding such behaviors - e.g., least effort, shortest path, spatial rationality. More often than not, these assumptions do not match actual behaviors. Much literature has been written on how activities such as multiple purpose and multiple place shopping distort these simple assumptions. Much behavioral research has indicated that it is not the physical proximity of places in objective reality that is important, but rather their perceived proximity - with such a perception being measured in time or cost or distance units. In many cases choice of an opportunity is said to depend on how familiar the traveler is with possible destinations. Destinations close to anchoring nodes of home or work are often chosen over other more spatially rational opportunities because they may be more frequently experienced as part of the habitual journey to work, because the temporal scheduling of household activities prevents any other choice, or because encoding information near anchors is easier and more reliable. All these reasons rely on the ability of a person to acquire and process spatial information (e.g., locational and linkage information) from an environment, to integrate that information into a memorized spatial layout, and to undertake behavior on the basis of such acquired spatial knowledge or "cognitive map" (Self, et al., 1992)

The degree that information included in one's cognitive map reflects real world structures depends on the spatial ability of individuals to comprehend characteristics such as location, connectivity, dominance, hierarchy, proximity, region, and pattern, among others. The less one understands these concepts, the more inaccurate is the encoding of spatial information. The more errors built into the information coded and stored in long-term memory, the less accurately one can perform tasks that rely on recall, and the more error prone any consequent behaviors that rely on that recall. The question arises therefore, when attempting to understand people's use of space, as to just what features and characteristics of the spatial properties of any given environment can we expect people to be aware?

## 7. Components of Spatial Knowledge

Elsewhere (Golledge, 1991) I have examined in detail the elementary spatial components that exist in any environment at any scale, and have discussed the cognitive equivalents of such features. Briefly the components are:

a. Location of occurrences, with each occurrence having a minimal descriptor set including identity, magnitude, location and time. An additional cognitive component might be familiarity. Occurrences are often called environmental cues, nodes, landmarks, or reference points;

b. Spatial distributions of phenomena: each distribution has a pattern or shape, a density, and an internal measure of spatial variance, heterogeneity or dispersion; occurrences in distributions also have characteristics such as proximity, similarity, order, and dominance;
c. Regions or bounded areas of space in which either single or multiple features occur with specified frequency (uniform regions) or over which a single feature dominates (nodal region). In geographic space examples might be a residential neighborhood (uniform region) or a store's market area (nodal region);
d. Hierarchies or multiple levels or nested levels of phenomena, including features such as public school districts combining high, middle, and elementary schools (nested hierarchy) or the commercial structure of a city (simple hierarchy of Central Business District, Regional Center, Community Center, and Neighborhood Center);
e. Networks or linked features having characteristics, connectivity, centrality, diameter, density, including physical links such as transportation systems, or non-visual links such as telephone call frequency or migration frequency;
f. Spatial associations including spatial autocorrelation, distance decay, and contiguities; examples include interaction frequencies, or geographic and areal associations such as the coincidence of features within specific places (e.g., corn and pigs);
g. Surfaces or generalizations of discrete phenomena, including densities of occurrence, flows over space and through time (as in the spatial diffusion of information or phenomena).

Of these components, most attention in spatial cognition research has focused on the first and simplest of these features - location of occurrences represented as environmental cues, landmarks, nodes or reference points, while aptitude testing includes some shape and pattern recognition both before and after transformation. Other components of geographic space have received less attention. In the remainder of this paper I propose to partially remedy this by examining features of the second component listed above - that of spatial distributions.

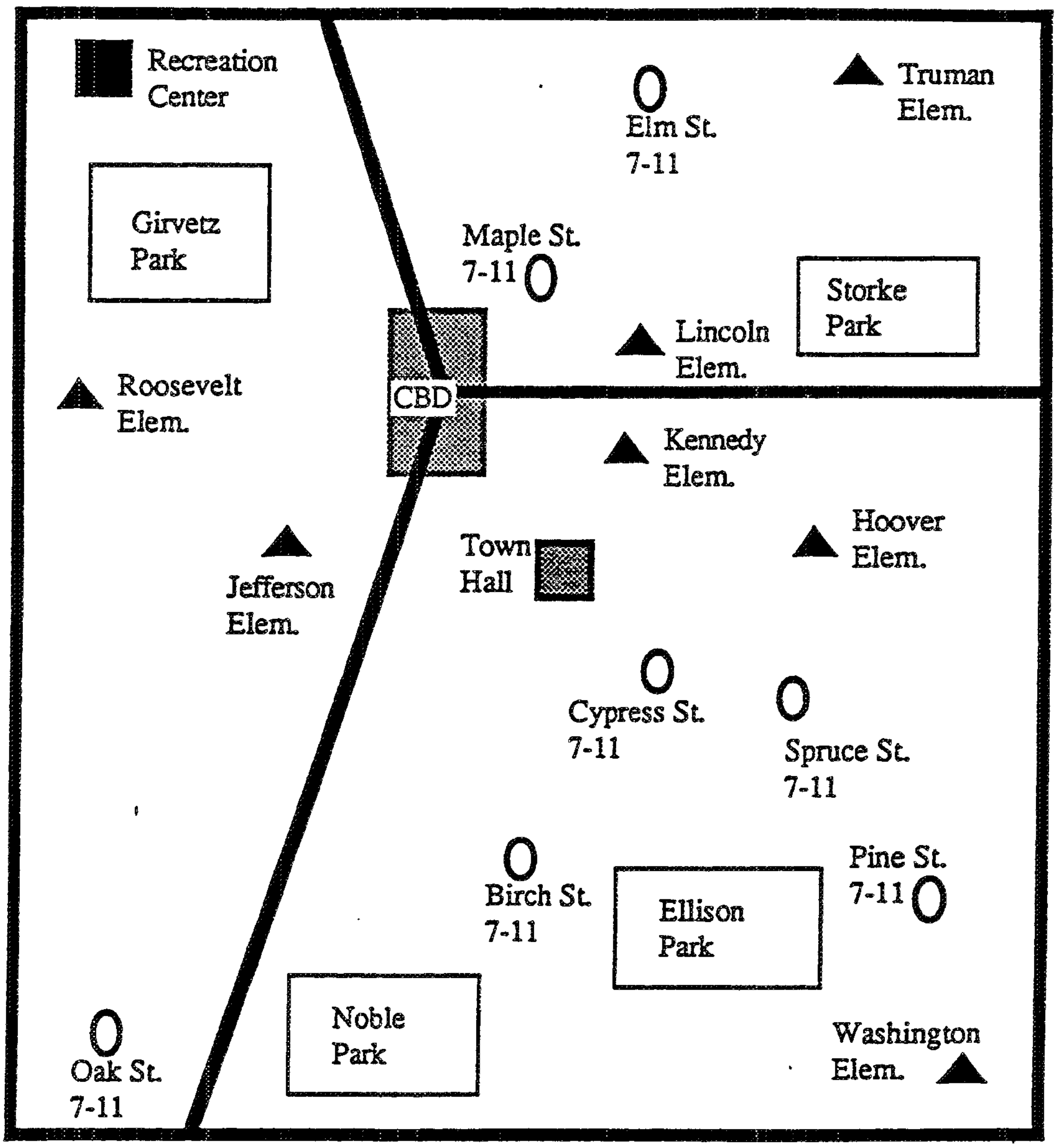
## 8. Spatial Distributions and Nearest Neighbors

In this experiment we simply wished to find out if people became aware of functional distributions (e.g., shops, schools) and their spatial properties when asked to learn about an environment. No explicit instructions were given about *what* was to be learned. We wanted to find out what information common sense examination produced. Initiating a learning process probably could produce more specific understanding, but such a procedure is more representative of a different type of inference and assumes a different set of operating procedures - (ones that I plan to investigate in a later paper).

## 8.1 Procedures

**Subjects:** Subjects were 32 adults, sixteen males and sixteen females. Each male and female group were divided equally between geographers and non-geographers. Ages ranged from 20 to 35 years.

Fig. 1. The Base Map




**Tasks:** All groups were required to study the first map given for five minutes (Fig. 1). After viewing the composite map, two initial conditions were established, one in which we focused on the distribution of stores (Condition 1); the other in which we focused on the distribution of schools (Condition 2). The 2 x 2 x 2 (condition by sex by discipline background) design was examined via ANOVA procedures.

The first task following the initial study period was investigation of the nearest neighbor concept. Each occurrence of a feature of one type (e.g., stores) was examined in turn. Subjects were given a list of the names of features in the group: Group A represented the 7-11 convenience stores and Group B were the elementary schools. These two features were chosen because they have similar population thresholds and ranges, and would therefore occur with similar frequency in an environment. Such a relationship precludes one feature from being (a priori) considered to be a more dominant occurrence. Subjects were required to choose from the list that feature that was closest (in distance terms) to the target feature. This procedure was done on a computer screen in the following manner. The name of one of the 7-11s (schools) taken from the map previously studied appeared in the center of the screen. A list of the other 7-11s (schools) was placed on the right of this feature name. The subject was then asked to remember which feature was closest to the target feature presented in the center of the screen. Response involved typing the first letter of the name of the choice made from the list of remaining features.

This task was followed by a mapping task. Again, depending on the condition they were first exposed to, subjects were asked to locate all the stores (schools) at their correct locations on a paper outline map by penciling an X on the map and labeling it with the name of the appropriate feature. The map sheet consisted of the same sized bounded area as the original map. Prior to beginning the task, subjects were placed in one of three groups - the first group was given a sheet with the boundaries and North line and no other information ("the Blank Sheet"); the second group had boundaries and North line as well as the location of two centrally located distractor cues (the Central group); a third group were given two peripheral distractor cues in addition to the boundaries and North line (the Peripheral group). Our interest here was in examining whether or not providing an additional piece of information other than a blank sheet would have an impact on the ability to perform the given task.

In the next task, subjects were tested on the distribution of the second feature - that is if at first tested on the distribution of stores, the second test focussed on the distribution of schools (or vice versa). This time the subjects were told that a feature name would appear in the center of the screen, followed by a list of the remaining feature names to the right of the target. Subjects were then asked to rank order the members of the feature list in terms of increasing distance from the target. Responses involved typing in turn the first letter of all the stores (schools) from the appropriate lists. Subjects were specifically requested to first type the letter of the feature that was closest to the target school (where closest was measured as the shortest distance away). This was the same as was done with the previous computer task. Subjects were then asked to consecutively type the letter of the school (store) that is next closest to the one shown (i.e., identifying the second shortest distance away), and the third closest, and so on. They were asked to continue until all six features had been ranked in order of distance from the target. As reinforcement they were specifically told that the last letter entered must be for the school (store) that is farthest from the target. Subjects were provided with paper and pencil check lists as scratch paper to make sure that they used features only once for each ranking task. However, in this task each feature in turn was taken as the target and all remaining features were ranked with respect to increasing distance from that target.

Following this task another map task was undertaken in which again the features for the condition were mapped in their appropriate perceived locations. The same "blank," "central," and "peripheral" conditions were used. After these maps had been collected they were then asked to perform an evaluation task in which they assessed the degree of similarity between the two distributions they had been tested on in each condition. Degree of similarity was recorded on a seven point scale anchored by the terms "not all similar" and "identical."

As a follow-up task, subjects were again shown the original map. After this map was removed they were then given a single target feature, and were asked to rank the other features in order of increasing distance away from the one presented. The procedure used was the same as before, (i.e., typing the letter of the closest school followed by letters of the next closest until the furthest was chosen). Again they were allowed to cross off names on a check list so that each feature could only occur once in the ranking. This task was designed to provide a final check on consistency of choice of both closest alternative and rank ordering.

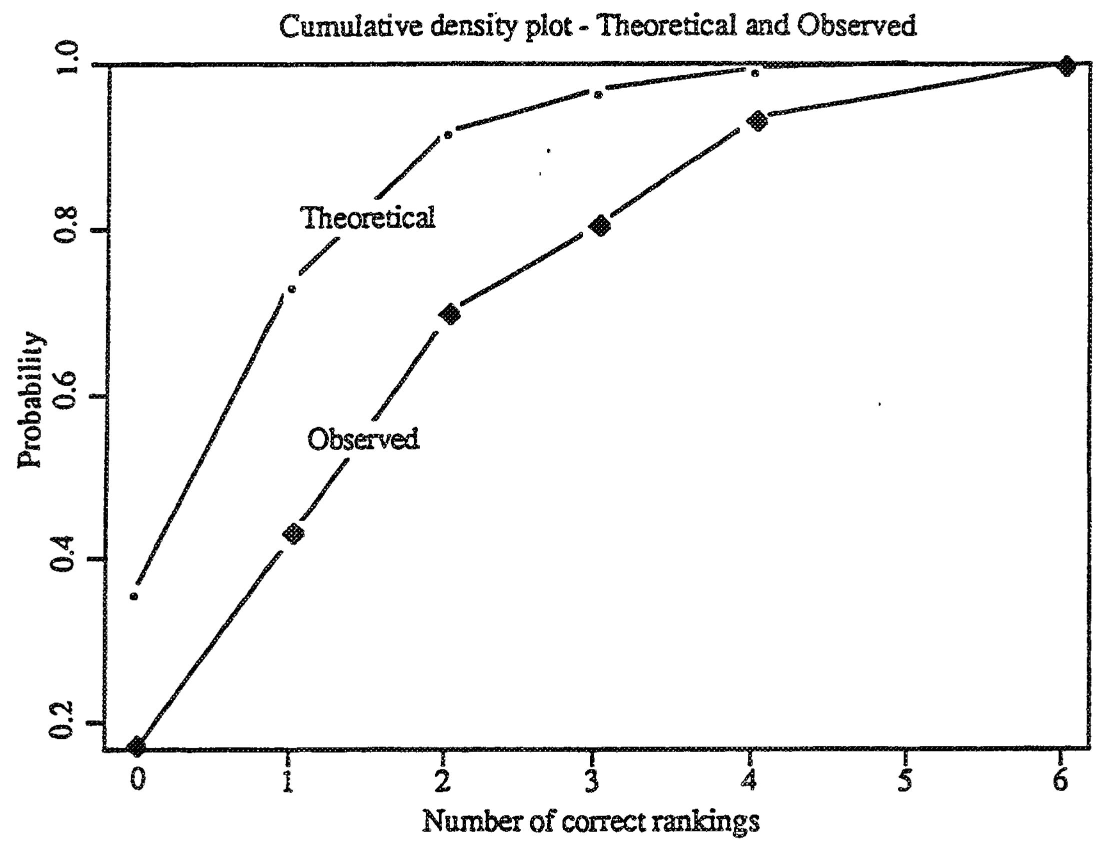
## 8.2 Results

Task 1: Closest location (first nearest neighbor). The data collected for this task consisted of the number of times the subject correctly chose the closest feature. There were seven observations for each person. A 2 x 2 x 2 ANOVA (condition x sex x geography background) showed a marginally significant main effect of group, and a significant interaction between sex and group ($F_{1,24} = 3.90$; $p > .05$). The mean number of times the first nearest neighbor was correctly identified in Condition 1 was 2.375 while for Condition 2 the mean was 3.4375. In general, Condition 2 males performed best with a mean number of correctly identified nearest neighbors of 4.25, followed by Condition 1 females having a mean of 3.0 correct times, Condition 2 females with a mean of 2.625 correct, and Condition 1 males with 1.75 correct followed. For some reason, females did better when starting with the stores while males did better when starting with the schools. Geographical background had no significant effect in this task.

Task 2: Ranking: For the ranking experiment, the data consisted of seven observations per person in which six locations other than the target were ranked each time. Again, from the 2 x 2 x 2 ANOVA there was a main effect of condition in which those working with Condition 2 (schools) averaged 2.15 features ranked correctly while the members of the other condition (stores first) had only 1.83 correct. There was a significant interaction between sex and geography background and condition ($F_{6,19} = 3.96$; $p > 0.009$) In this task, female non-geographers generally scored highest (mean correct = 2.25) followed by male geographers (mean = 2.21). Male non-geographers (mean = 1.83) and female geographers (mean = 1.66) performed worst of all. The non-geography group that did the schools first averaged 2.46 correct, while the geography group starting with stores averaged 2.04 correct; the geography schools group averaged 1.84 correct, and the non-geographers starting with stores averaged 1.63 correct.

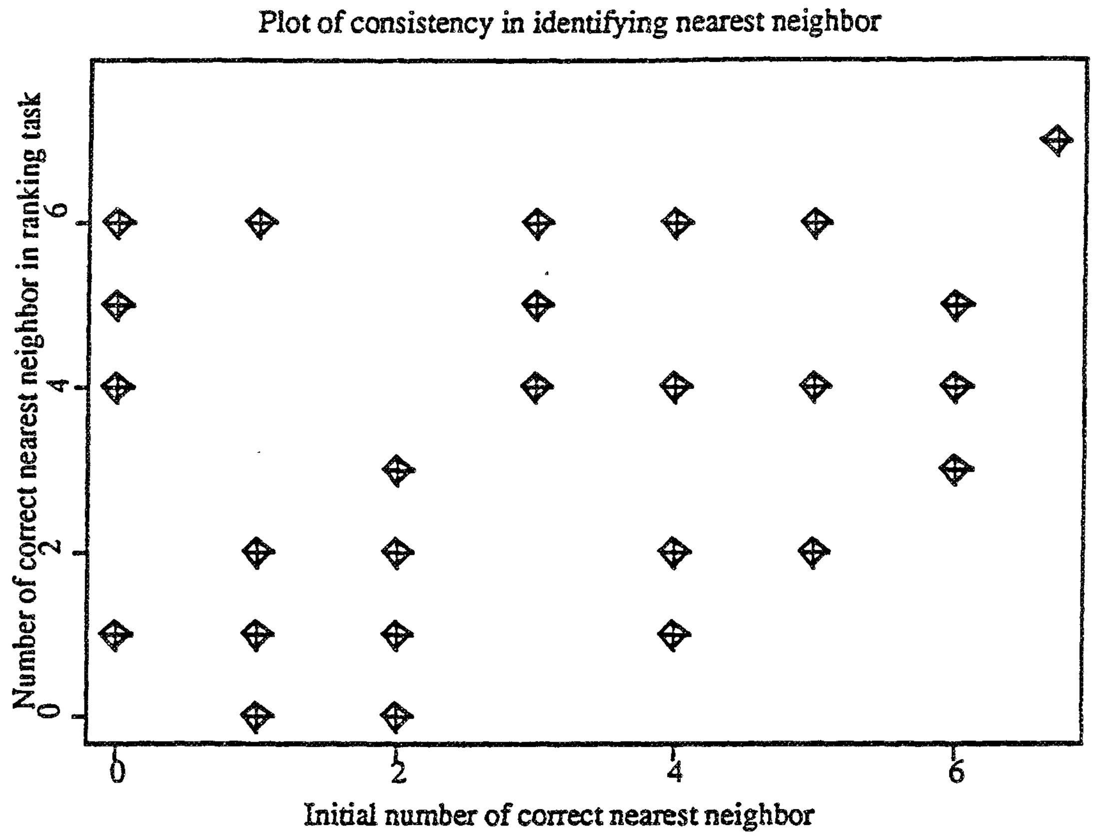
As a follow-up to this analysis, we computed a random guessing distribution which is obtained by analyzing the number of possible configurations and combinations given a task of ranking with respect to a single target location and considering all possible targets. When comparing the random distribution with an observed distribution, observed and random distributions were compared using a chi-squared statistic. The results showed rejection of the null hypothesis (i.e., no similarity) ($\chi^2$ = 1196.97; df = 5, $\alpha$ =0.90 = 9.236) (Fig. 2).

Fig. 2. Theoretical and observed cumulative probabilities of ranking k cues correctly




Another analysis focused on the success subjects achieved picking only the closest or first nearest neighbor in the six location ranking task. Here we compared performance on the single task of choosing the closest location to how they performed when ranking all locations by closeness. If subjects were consistent across tasks, the feature chosen as the closest should be the same in both cases. Results showed that there was no consistency in their ranking (Fig. 3).

Fig. 3. Relation between $R^2$ values for stores versus schools




Task 3: Map Reproduction Task: For this task subjects were asked to recreate the map pattern of either the stores or the schools following their ranking tasks. The resulting configurations were compared via bi-dimensional correlation (Tobler, 1978) to the actual mapped patterns. Bi-dimensional correlation provides a statistic somewhat similar to an r-square and has been used extensively to compare maps of point distributions (Golledge & Rayner, 1982; Gale, 1982, 1985; Richardson, 1980, 1982). The r-squares for the 32 subjects are given in Table 1.

For the store maps, 12 of the 32 subjects had r-squares greater than .60; for the schools, 10 of the 32 had correlations greater than .60. Only 6 of the 32 subjects performed consistently well on both tasks (#16, 18, 19, 21, 26, and 28). Eight others performed consistently poorly, while the other 18 had varied success from one situation to the next. In general, there was no clear pattern of consistent performance on both tasks ($r^2$ = .1818).

Table 1. Individual subject correlations between objective and subjective cue locations

| Bidimensional Regression results | | |
|---|---|---|
| Observation | Store ranking analysis R-Square | School ranking analysis R-Square |
| 1 | 0.2771 | 0.0729 |
| 2 | 0.6656 | 0.0153 |
| 3 | 0.6368 | 0.1409 |
| 4 | 0.7805 | 0.1739 ** |
| 5 | 0.8491 | 0.0261 |
| 6 | 0.7093 | 0.2180 |
| 7 | 0.0470 ** | 0.0000 |
| 8 | 0.0982 | 0.1284 |
| 9 | 0.4829 | 0.7058 |
| 10 | 0.4582 | 0.5953 |
| 11 | 0.0962 | 0.9520 |
| 12 | 0.0017 | 0.1293 |
| 13 | 0.0834 | 0.2838 |
| 14 | 0.3372 | 0.0389 |
| 15 | 0.2822 | 0.8290 |
| 16 | 0.8760 | 0.7781 |
| 17 | 0.0129 | 0.0325 |
| 18 | 0.8760 | 0.8999 |
| 19 | 0.9469 | 0.9603 |
| 20 | 0.0550 | 0.3003 |
| 21 | 0.8571 | 0.7526 |
| 22 | 0.3566 | 0.3159 |
| 23 | 0.2823 | 0.9406 |
| 24 | 0.4146 | 0.4700 |
| 25 | 0.0240 | 0.0292 |
| 26 | 0.9375 | 0.6177 |
| 27 | 0.6697 | 0.2406 |
| 28 | 0.9313 | 0.8998 |
| 29 | 0.0420 | 0.0254 |
| 30 | 0.4439 | 0.0779 |
| 31 | 0.5607 | 0.2178 |
| 32 | 0.0117 | 0.0038 |

** Observation has missing coordinates.

## 9. Discussion

The overall results from these experiments were not particularly encouraging. First it appeared that even simple first order geographic primitives such as the idea of pair proximity or nearest neighbor, is not necessarily well understood in the complex map situation tested here, whether or not the distribution which is examined is embedded in a map including other information. Since both configurations of stores and schools had exactly the same internal spatial relations, with one merely being locationally displaced and rotated ninety degrees in the plane, the evidence shows first that the two distributions were not regarded as being similar, and that even performing common tasks on each distribution produced significantly different results. Our attempts to examine whether or not there was a gender basis in terms of this particular spatial ability showed no significant differences overall. Similarly our attempts to evaluate whether those trained in geography or non-geographers could perform better on these tasks also showed no significant differences.

Other information that can be gathered from this study includes examination of whether locations are imaged as being in the correct region (e.g., as defined by the road system on the map), and whether or not the point patterns of the cues have any common interpretation. One reason for a lack of good performance on the cue location reproduction task for example might be that people regionalized the initial map and that this interfered with their ability to comprehend the functional distribution as a single entity. Since the schools and stores can be regionalized differently, this would again account for the lack of observed similarity between distributions.

Another reason for the lack of ability to recognize distribution features and similarities may lie in the choice of labels for each location. For example when debriefing subjects, some claimed it was "easier" to remember details of the stores because they were all associated with tree names and remembering which trees were located near one another was easier than remembering which schools (named after Presidents) were near each other, particularly since many people learn presidents' names in temporal order and the spatial arrangement followed no clear temporal sequence. But, even these explanations fail to explain the significant differences between better performance using schools first for men and stores first for women.

Another intriguing feature was the lack of difference between geographers and non-geographers. We presumed that geographic training would produce a greater ability to recognize spatial distributions and their characteristics. We could not support this hypothesis.

The question remains then, how effective are people at recognizing spatial distributions of like phenomena? The answer appears to be "not very effective." But, is this true only for naive subject? Can we, through repeated trials, dramatically improve people's ability to recognize and interpret this fundamental component of geographical space? How can this skill/ability be taught? Must it be part of all training for spatially aware professionals, including those designing and using GIS? And, to what extent is this skill/ability needed when undertaking spatial analysis at any scale? Can we be sure that interpreters of spatial data will get all relevant information *without* such training? And, is the ability to recognize a distribution and its documentation an integral part of spatial knowledge that should occur in any aptitude or ability test? These and many other questions arise automatically from studies such as the above, and point the way to an important area of future research for all interested in space and territory at geographic and other scales.

## 10. Summary

Practical needs have lead to the investigation of a variety of methods and techniques for describing spatial relations. They have also raised important questions as to what sets of spatial relations are the most fundamental, and the most important to include in an environmental knowledge base. In today's GIS, for example, many queries are based on some form or another of spatial concepts (Dangermond, 1983; Peuquet 1984). It is essential both to understand what those concepts may be and how people are able to interpret or understand them. For example, we need to be aware of and be able to describe spatial objects standing alone, in sequence (chain) or list form, or regionalized. The lack of a comprehensive theory of spatial relations has been identified by the NCGIA as a major shortcoming and impediment to further GIS development (NCGIA, 1990). The problem inherent here is one of determining which spatial relations should be identified, how to define them, and to understand their various semantic interpretations.

What are the consequences of this research?

1. Even simple spatial concepts may not be well comprehended by many people (e.g. nearest neighbor; shortest path; location, orientation, and direction).
2. The spatial terms we freely use to "help understand" the distribution of phenomena and the interactions between them are not widely used or understood (e.g. nearest neighbor; "distance decay," distribution of a function; region).
3. Without specific prompting (or teaching), people may be unaware of spatial characteristics of an environment (e.g. may not appreciate that like functions form a spatial distribution and that properties of distributions may be similar or different).
4. That the "naive" or "common sense" understanding and use of spatial information and spatial relations is error ridden, naive, and very incomplete, resulting in misconceptions and misunderstandings (e.g. which are closer? which way is shorter?).
5. That many of the criteria that geographers use in models to comprehend and explain spatial relations and spatial properties are *not* the ones typically used in common sense spatial problem solving.
6. To handle spatial problems appropriately, there is a need for an expert language base, expert concept and model building, and an expert training/teaching program capable of using appropriate language, interpretative and manipulative skills. There is, in fact, a need for a distinct spatial discipline designed to handle these functions: Geography is such a discipline, but it has developed on a set of assumptions about people's abilities to understand spatial relations that may be woefully incorrect. We need to know more about the skills and abilities required in spatial thinking and problem solving, and this knowledge must be examined at all spatial scales and under both active and passive experimental conditions.

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