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Time and Space in Route Preference

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1.0 Introduction and Background

It is only in the last few decades that geographers have become aware of their special skills and knowledge systems for understanding space in domains other than objective physical reality. As this awareness has grown, however, it has become more and more obvious that spatial knowledge is much more than the sensing or description of landmarks, routes and areas in an internal representation of environment.

In behavioral geography attention in past decades has been focused on the idea first of "mental maps" and later cognitive maps. The term mental map defined a mapped preference surface (Gould, 1973). To compile these surfaces, subjects were asked to rank order areal units such as states, cities, countries, in order of preference according to some criteria such as desirability for living. The ranked orderings were then cartographically summarized using isolines of equal attractivity. The resulting contour map highlighted regions of great desirability and showed gradients from these to the troughs or pits of lower desirability. While these were interesting visual summaries of people's preferences, usually constructed such that they covered very large areas such as countries, they proved to be of little use as explanatory or predictive devices. This lack of use dissolusioned some researchers who then arrogantly pronounced the "death" of behavioral geography - for they had not the wit or the imagination to go beyond this setback. Even today we continue to read pronouncements from those unable or unwilling to understand behavioral geography, that it is an unproductive backwatger in the stream of geographic research (Cloke, Philo & Sadler, 1991). Although Timmermans andwe have elsewhere disputed these claims and have provided much evidence to the contrary (Golledge & Timmermans, 1990, Timmermans & Golledge, 1990), our profession still hears from doomsayers and psuedo-academics who, lacking the skill and knowledge to undertake serious behavioral geographic research, attempt to dismiss it, substituting the latest fad (be it Marxism, Post-Modernism, or Realism) as "the" guiding light for creative geographic research and thought.

In this paperwe continue the well-established tradition of behavioral research in a spatial context. Emphasis is placed on human actions, feelings, preferences, and attitudes in the context of an everyday activity - selecting a path and following it between known and given origins and destinations.

Extending beyond the initial idea of a mental map, geographers later adopted the notion of a cognitive map or cognitive configuration as an external representation of environmental information retrieved from memory. This information was collected either directly via techniques such as sketch mapping or verbal descriptions of places, by verbal descriptions or mapping of routes, or more indirectly by attempting to recover the latent spatial structure contained in long-term memory via an indirect judgment process used in conjunction with non-metric multidimensional scaling (Golledge & Rushton, 1972).

Much of the behavioral geographer's interest has been in explaining patterns of and reasons for human spatial behavior. The cognitive map was assumed to be an internalized Geographic Information System (GIS) in which different strata or levels of information could be compressed, combined, manipulated, and interpreted. Thus, when asked to make judgments about proximities of individually perceived landmarks that may not have previously been considered together as a holistic system (e.g., public buildings, monuments, recreational areas, grocery stores, freeway segments etc.) each individual would first invoke a function that would focus on location, and then estimate proximity, similarity or preference in terms of, say, a scale value. It was these scale values that were manipulated via external measurement techniques to produce latent spatial structures or configurations of environmental cues. The same process guided development of distributions of phenomena. It was assumed that once recovered, these external representations would give insights into how people behaved - for they were the best representation of the information available regarding what spatial data was stored in memory. It was considered essential to determine this because volumes of geographic research had shown a lack of coincidence between overt spatial behavior and measurements made on hypothesized explanatory variables in objective reality (e.g., Euclidean distance measures between places, time transforms of actual route distances separating places, and so on). This latter literature is far too large to attempt to review here, but overviews can be obtained from many introductory human geography textbooks, and from recent reviews by Golledge and Timmermans (1990) and Timmermans & Golledge (1990).

The cognitive map as an internal geographic information system did become the analytical tool that the preference surface (mental map) had failed to become. Cadwallader (1979) pointed to the increased reliability of gravity models based on cognitive information rather than objective information for predicting human movement such as consumer behavior or migration. Smith (1983) used the cognitive map concept to anchor a selection of models aimed at understanding how residential site selection decisions were made. More recently, Phipps & Clark (1988) used concepts of cognitive mapping to build computer simulations of decision processes and the sets of behaviors involved in choosing new home sites. Timmermans, van der Heijden & Westerveld (1982) have similarly used cognitive mapping concepts in their studies of consumer spatial behavior. In other research, externalizations of cognitive maps have been used in both individual and group contexts to discover locational accuracy and to throw light on the type of distortion and fuzziness that one can expect when spatial information is stored in and recalled from long-term memory (Buttenfield, 1985; Gale, 1982;

Richardson, 1982). This latter work surfaced only after a significant treatise by Tobler (1976) which discussed the geometry of mental maps. He suggested that location errors and the spatial variance or fuzziness associated with remembering sets of locations could be recovered and mapped cartographically using error ellipses. Such ellipses provided indexes that could then be incorporated into explanatory models of human behavior. Case studies of the use of such measures to help explain movement patterns of populations (such as those who are mentally retarded) can be found in Richardson (1982) & Golledge, Rayner & Parnicky (1980). But, while locations and landmarks proved adequate origins, destinations, and decision points for incorporation into long term memory as anchor points for cognitive maps, much less attention has been focussed on the links between them, the paths actually travelled between origins and destinations, and the reasons for choosing such paths. In this paper we concentrate on these features.

A fundamental geographic concept is spatial separation; the elemental term used to describe this is *distance*. Whereas distance in geographic space is usually well specified in terms of one or another of the standard geometries (usually Euclidean), there is still considerable speculation as to whether or not any one particular distance metric should be used in cognitive spaces (Baird, Wagner & Noma, 1982; Golledge & Hubert, 1982; Montello, 1991).

Distance is the bond that links places together or separates them in both cognitive and geographic space. When an anchor point or line or area is identified, we look at what is nearby. Geographic law suggests that things close to each other will be more alike than those farther apart and that there will be regularity to this decay of similarity over distance that can usually be expressed by a Pareto curve or simple negative exponential function. So we look for linked occurrences, "nearest neighbors", or things "in the neighborhood." In geographic space we can identify nth order nearest neighbors; but in cognitive spaces can we even identify one nearest neighbor? When we rank order environmental features according to paired proximity, for example, we are in fact performing a distance ordering function of the nearest neighbor type. Many people can perform proximity rankings satisfactorily. However, when an estimate of distance is required from one place to all others, performance deteriorates. Perhaps it is the additional geometric implication that intrudes to diminish performance capacity. But certainly when qualitative distance (e.g., "proximity") is used to estimate first nearest neighbors, competent performance can be expected, whereas the same success is not achieved using quantitative distance measures (Golledge, 1992). What is it then about distance that makes it so fundamentally comprehensible in geographic space but so much more difficult to comprehend in cognitive space? Both geographers and psychologist must explore this question further. We explore it further here by giving people path-finding tasks and then examining spatial and temporal measures to see what latent criteria people use to make these decisions.

2.0 Some Comments on Recognizing Spatial Properties

In both the natural environment and the transformed, or built, environment, understanding comes not only from knowing what is where, but also how different things are linked and fit together. As we pointed out previously, this includes higher level concepts such as hierarchy, surface, association, connectivity, pattern, and so on. For example, with the exception of Gärling, Böök, Lindberg, & Arce (1990), psychologists have neglected the role of height or relief in examinations of spatial phenomena. In contrast, the geographer commonly represents spatial interactions, movements, or even the basic distribution or pattern of phenomena (e.g., land rents orpopulation density) as surfaces. These are sometimes represented in two dimensional form (e.g., contour lines representing physical relief) and sometimes represented as three dimensional surfaces (e.g., spatial distribution of population densities or a surface representing flows through space and time). As more attention in the geographical world is focused on presenting spatial data as a Geographical Information System (GIS), the tendency to use three dimensional graphs and surfaces to represent such data is increasing. In addition, the nested hierarchical structures of functional arrangement over space has produced powerful geographic theory (e.g., central place theory) which is visually represented as an overlapping two dimensional nested hierarchy. Given this enriched way of looking at environments and the data contained in them, one can postulate that geography is a spatial science and the geographer is an expert with a specific set of techniques and representational devices to unpack information contained in the spatial domain. The gap between the expert knowledge structure and the common sense understanding of environment and its more restricted and impoverished knowledge structure then becomes obvious.

It is not at all obvious that most people are aware of many components of the spatial system in which they live. While decades of research on developmental theories of spatial learning and cognition provide strong evidence that the *ability* to comprehend spatial information in configurational or survey level terms exists, much evidence also appears to indicate that this knowledge is difficult to articulate and externally represent. This leads me to suggest a differentiation between common sense knowledge, and an expert level of spatial knowledge. The common sense knowledge is primarily what is tapped when we examine sketch maps, proximity judgments, or slide or video recall and recognition procedures, or when we ask for verbal directions to routes between known or unknown distinations (i.e., it is what individuals *appear to know* about a place). More often than not, analysis of the externally represented information indicates numerous distortions and errors. But sometimes in follow-up discussions, it is obvious that the individual knows more than they are able to express. One suggestion is that they have neither the training, nor the technical language to express the sets of spatial associations, relations, connections, networks, paths, hierarchies and regions that are contained within their knowledge structures. we would suggest that the science of geography has at its core the explicit aim of giving people such understandings. Geography provides an established technical language for discussing spatial concepts. It contains numerous models that define the properties of spatial distributions, spatial networks, spatial interaction patterns, and spatial hierarchies (Anselin, 1988; Clark & Hosking, 1986). Learning the language and unpacking the essence of the concepts (as well as providing many examples of their existence from the everyday environment) provides the tools for understanding the level of environmental knowledge that one develops through interaction, association and experience.

The essence of this overview has been to show that people are not always aware of how or why they do things in spece. Wayfinding and navigation in particular are activities that are often pursued without a great deal of conscious thought, either in the pre-planning or the active phase. Although people might refer to a map (or have someone else, such as a friend or the AAA) describe a route for them, there is little research that shows what criteria are normally used, or even if one bothers to think about the rationale behind another's route suggestions.

3.0 The Route Choice Experiment

Not only do we select and follow a limited set of paths through the complex networks in which we live, but we have developed many models capable of finding solutions to these path selection problems (e.g., linear programming; traveling salesmen; shortest path). The question is, however, are these the criteria used by humans to solve their own movement problems - or are they methods best suited to mathematical or computer determination of optimal paths through networks to ensure economic efficiency of flows, but yet using criteria of which people in general are unaware, or are incapable of using? Are we in effect engaging in ecological fallacy, building models suited to commercial or fleet routing then extending them to cover disaggregate or aggregates of individual behavior? The question asked here is whether or not the criteria used in travel behavior models are real and relevant (not useful for explaining human travel choice behavior), but only artifacts useful for obtaining normative statistical or mathematical solutions? To examine these questions we now turn to outline and describe experiments undertaken to discover the relative significance of criteria used for navigation and wayfinding in a variety of environmental conditions.

4.0 Subjects

Subjects consisted of 32 adults, 16 women and 16 men. Most were students. Ages ranged from 20-35 years of age. Half of both male and female subjects had geographic training consisting of five or more college level geography courses.

5.0 Experimental Design and Procedures

Tasks: General information about the task environment was provided by sets of regular and distorted grids on which were located a set of specified locations..An initial task was to evaluate the degree to which subjects were able to integrate information obtained from a network so as to simulate travel between two or more routes and to be able to produce orientation and directional judgments between places experienced on different routes. It was also determined how well subjects could fill in knowledge gaps so they can give directions from places on one route to places on other routes. The ability of the subjects to take or describe shortcuts between places on different routes has been examined in other papers (Gale, et al., 1990).

It is hypothesized that route knowledge incorporates a series of sequentially linked landmarks or choice points starting with an anchor point and followed by subsequent points whose significances are influenced by a decision making process. Allen (1981) examined the effect of segmentation in route knowledge acquisition, assuming that "Route" information may be organized as a series of subdivisions bounded by distinct environmental features. A component of survey level knowledge is that perspective may be an important part of the cognitive mapping process. This task, therefore, examined how instructions to take a particular perspective on an environmental learning problem influence decision making (i.e. rouute choice. Note that in general it is assumed that the more experience we have with a given environment, the richer is the amount of landmark and path integration that can take place in order to produce understanding (Kirasic, et al., 1984; Gärling, et al., 1986). It is, however, suggested that the development of survey level knowledge (i.e. an integrated cognitive map) of a complex large scale environment from direct experience is a "bottom-up" process in which learning is driven by data accumulation, usually via travel through the environment. In this process one must deduce the overall structure from the relations one is able to determine between individual components (i.e. landmarks, routes, and areas). Kuipers (1978) has presented evidence that this integration process proceeds slowly as information is acquired piece by piece about an environment. by exploring it. As opposed to this piecemeal development of survey level knowledge, it has been hypothesized that such knowledge can be learned quickly from a "top-down" perspective via access to overall environmental summaries such as maps, where all the landmarks, paths, and spatial associations and relations between them are simultaneouslly perceptually available (Golledge, 1992). Similarly, we have suggested here that map learning increases knowledge of orientation and provides a frame of reference for the totality of environmental information that is sometimes difficult to develop via other types of experience (Golledge, 1992).

6.0 The Tasks and Task Environments

In this first task we examine a variety of routes that people select through given environments. Initially, subjects were given a series of maps on which two locations were marked. These maps consist of simple regular grids. Three different routes were laid out from a common origin a to common destination (Figures 1a, b, c, d). Subjects were asked to imagine that they lived in a town built around the grid network shown on each map, and to imagine that moving from the origin to the destination represented a daily trip-making activity. They were asked to decide which of the three routes they would take. In this first task the routes allowed them the choice of taking the longest leg first, the shortest leg first, or a stepwise route that approximated a diagonal join between origin and destination (supposedly simulating perceived least effort or least time). Given the regularity of the grid, however, each route was exactly the same distance and varied only in its configurational properties. Maps and routes were configured so that trips were undertaken either as one travels away from the body (i.e., South to North in conventional coordinate terms) or towards the body (i.e., North to South). Different configurations of a diagonal path were provided while actual distances were kept constant, but only the simplest forms are examined here.

A second task involved increasing the number of nodes connected by paths. Again, routes were configured so that travel took place either away from or toward the body (Figure 2a, b). In part two of this task the regular grid was altered to be more irregular. This environment had nonorthogonal and intermittent intersection blockages.

Figure 1(a)

Map Grid - A in Sth - 2 Locations Step Diagonal

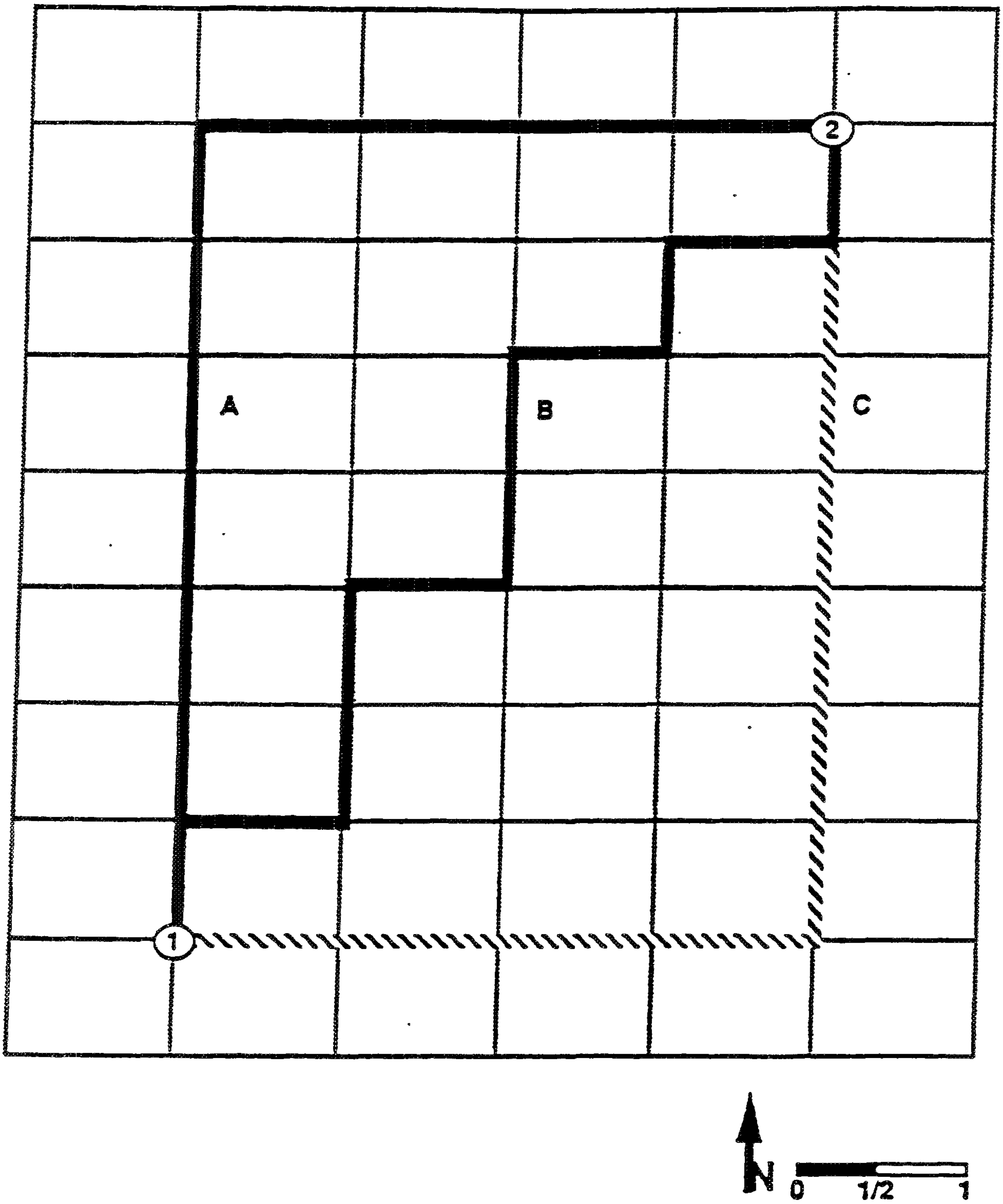


Figure 1(b)

Map Grid - A in Nth - 2 Locations Step Diagonal

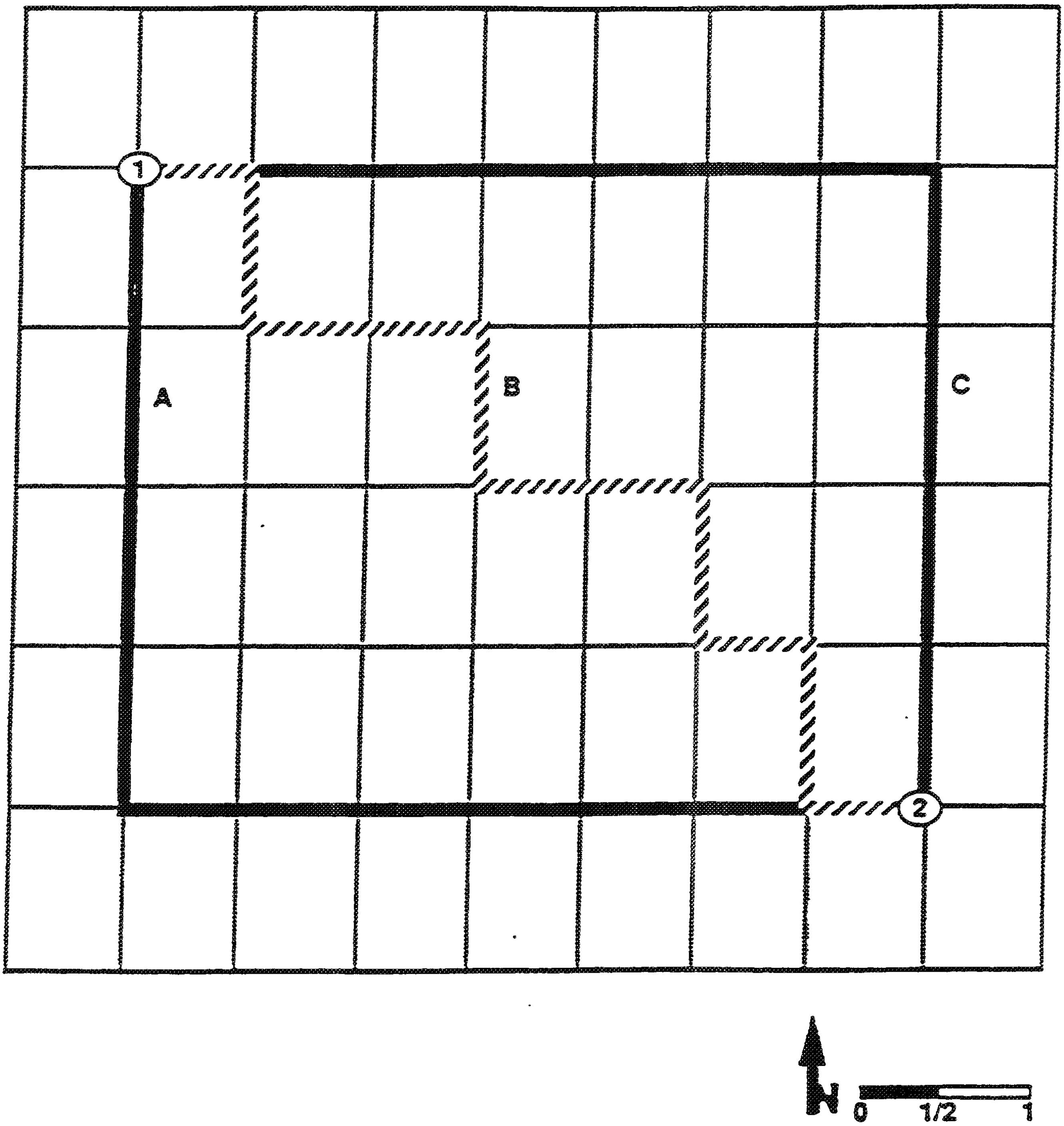


Figure 1(c)

Map Grid - A in Sth - 2 Locations Angle Diagonal

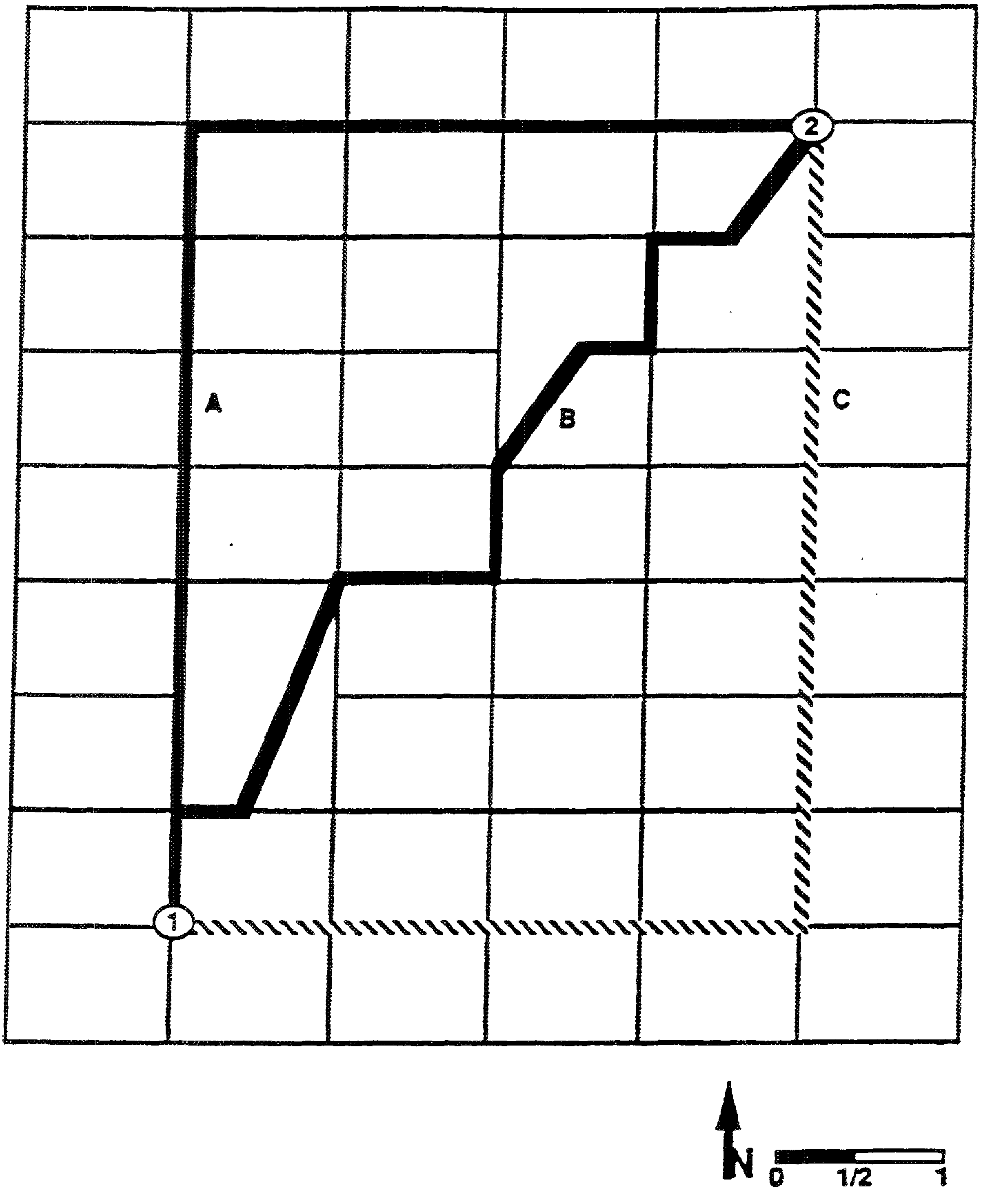


Figure 1(d)

Map Grid - A in Nth - 2 Locations Angle Diagonal

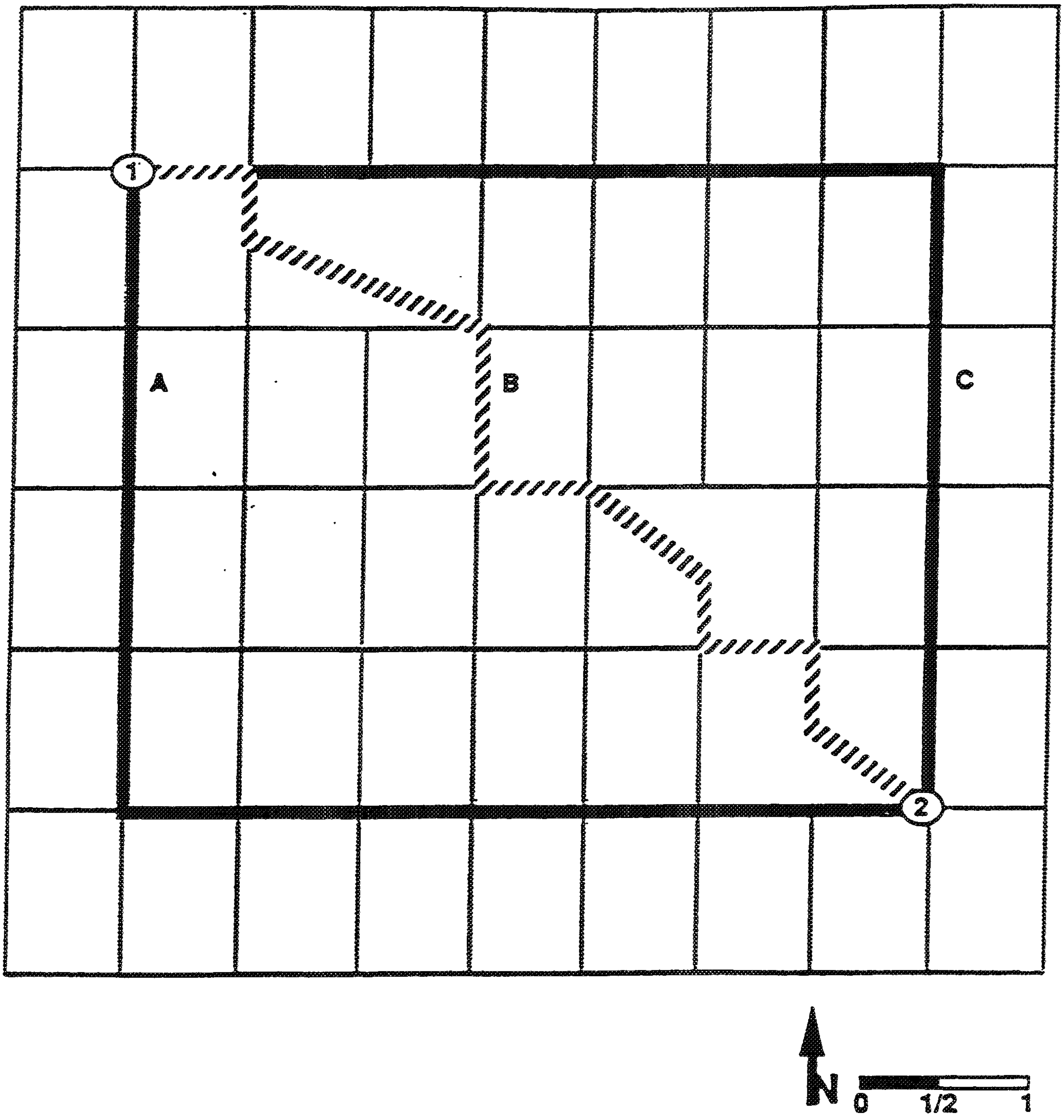


Figure 2(a)

Map Grid - A in Nth with Diagonals

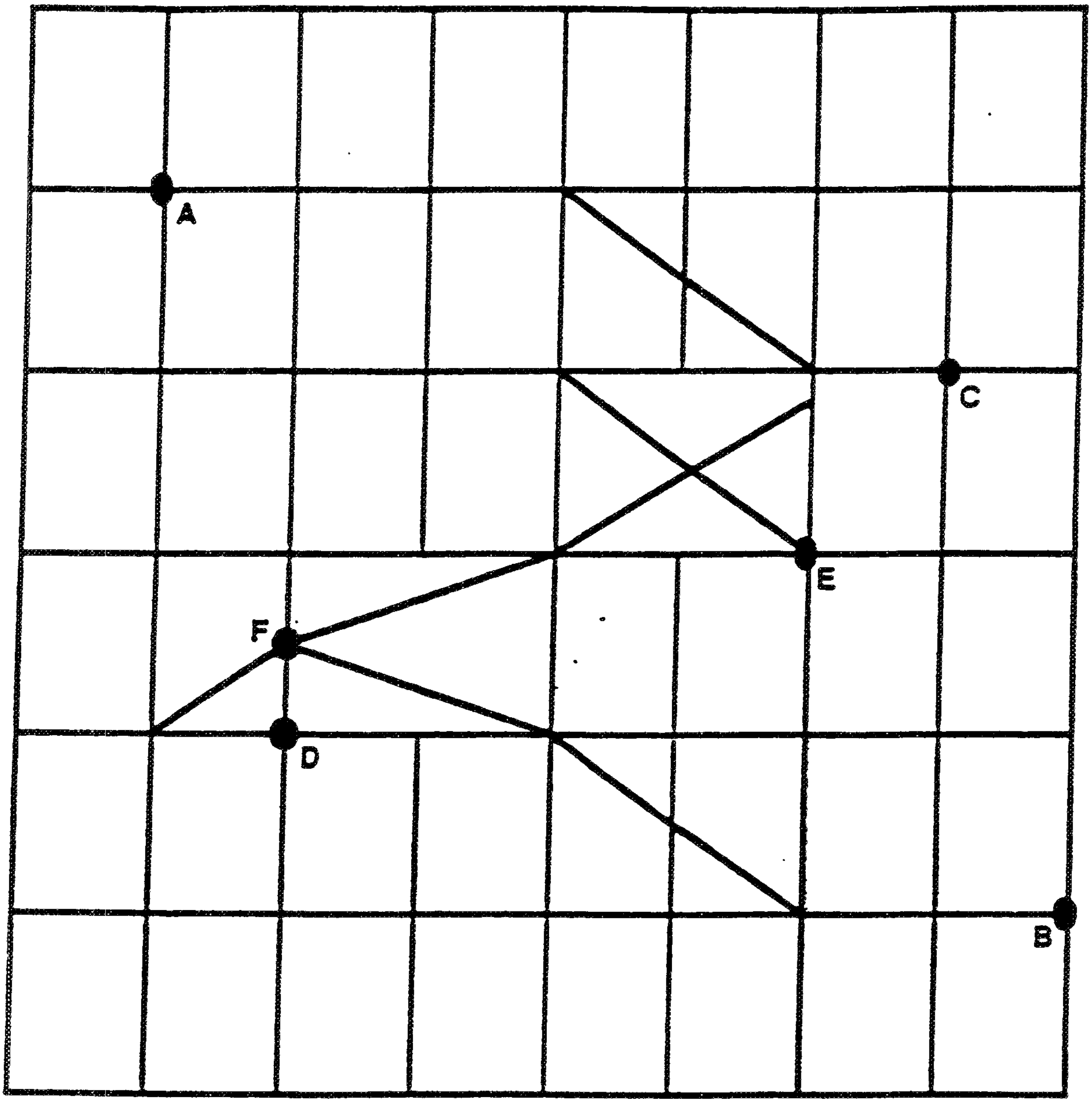
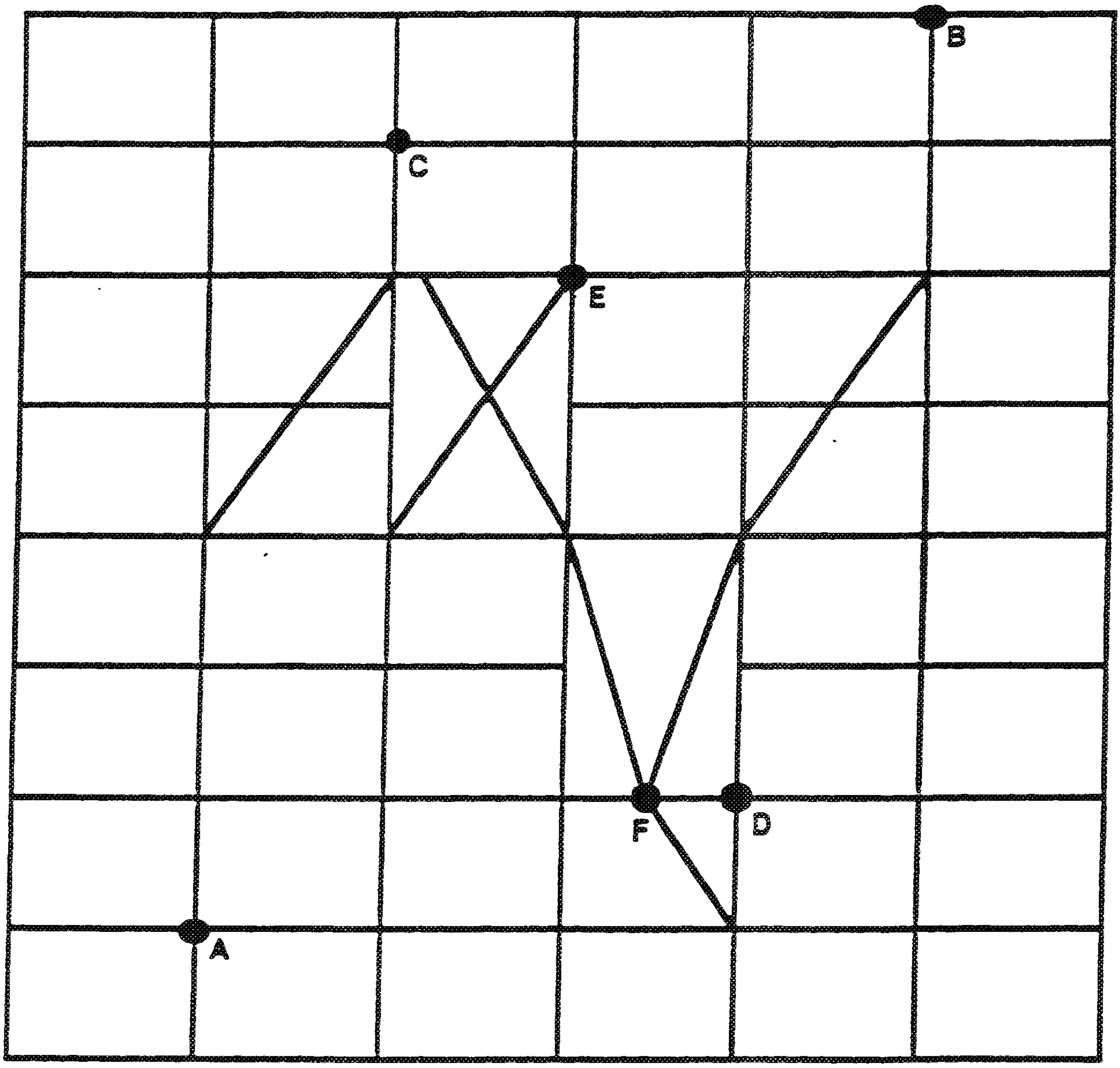


Figure 2(b)

Map Grid - A in S^{th} with Diagonals



In a third task, polygons representing either negative or positive externalities (e.g., waste dumps or parks) were interspersed throughout the maps (Figures 3a, b). Blockages were described on different trials as parks (a positive attractor) or waste dumps (a negative attractor). The same route choice task was repeated controlling directional components. The latter two tasks increased the number of places to be visited to examine if multiple segment routes with and without barriers were chosen using criteria that differ from simple barrier free path selection . Data was collected on route choice, including variables such as type of route chosen, number of segments in chosen route, number of left and right turns on chosen route, number of non-orthogonal intersections and turns on chosen route, frequency of positive or negative externality along route, number of curved segments, distance along chosen route, and perceived time of travel. Individual suggestions were solicited regarding what route choice criteria were being used and what criteria were thought to be normally used in daily path selection activities (Figure 4). Such variables were examined to isolate the type of reasoning or inference that underlies path selection.

7.0 Procedures

Individual data was first compiled on packets of maps in the following manner:

(a) Six stimulus groups were formed by crossing the three environments (grid, diagonal, and curved) with the two orientations ("A in the Nth" and "A in the Sth"). A in the Sth was a 90° rotation counter-clockwise from A in the Nth.

Figure 3(a)

Map Grid - A in N^th Aesthetics

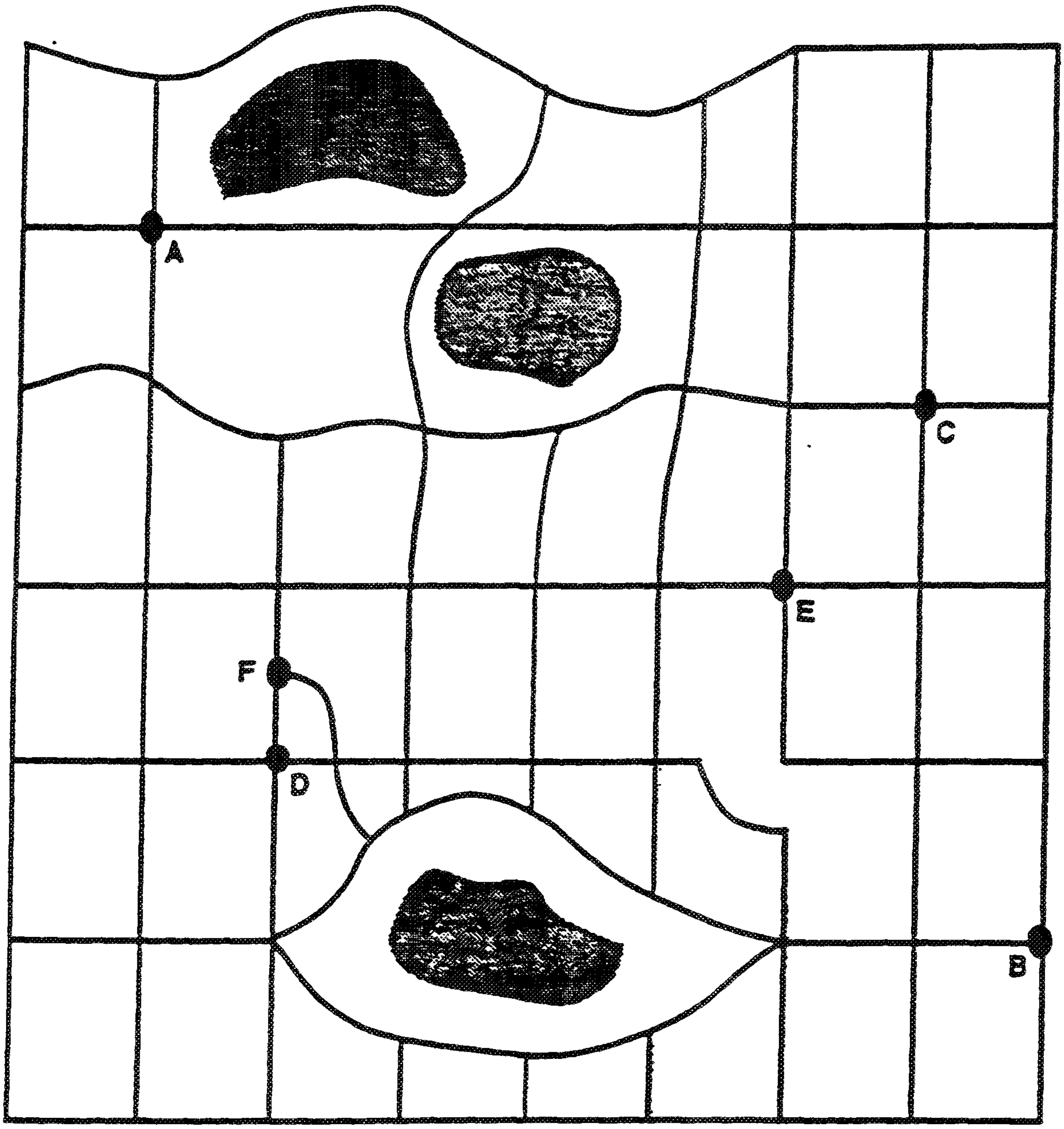


Figure 3(b)

Map Grid - A in S^th Aesthetics

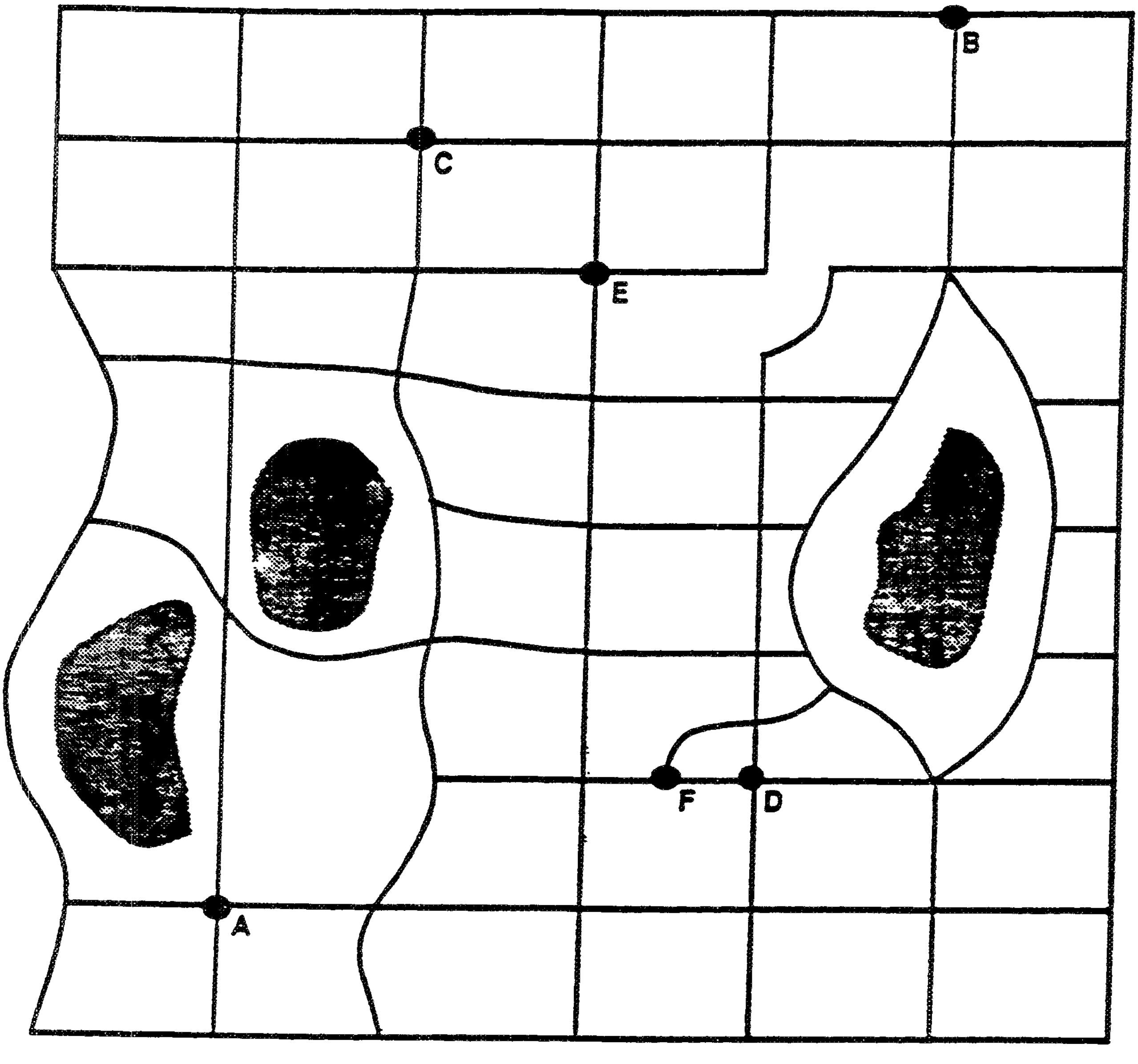


Figure 4

Criteria Used in Daily Path Selection Actitivties

Please think about the criteria you used to decide on the routes in the first task you completed (each task = a forward and a reverse trip).

Rate each of the following statements on how IMPORTANT each was to your choice of routes for each of the tasks (1 = quite unimportant; 2 = somewhat unimportant; 3 = important; 4 = quite important; 5 = extremely important).

TASK #1

The route:

was the shortest to travel	1	2	3	4	5
had the fewest turns (straightest)	1	2	3	4	5
had the longest leg of the route first	1	2	3	4	5
was the most aesthetically pleasing	1	2	3	4	5
had the shortest leg of the route first	1	2	3	4	5
had many curves	1	2	3	4	5
would take the least amount of time	1	2	3	4	5
was the first route I noticed	1	2	3	4	5
had the most turns	1	2	3	4	5
is the way I usually go	1	2	3	4	5
is an alternative to my usual route	1	2	3	4	5
always proceeds in the direction of the destination	1	2	3	4	5

Point A was accurately located in the Southwest in the former and Northwest in the latter orientation. A separate packet was used for each rotation.

(b) Within each stimulus group for each unique route drawn by subjects between each pair of points (i.e., on each page of the packet) a line of a different color was drawn on the compiled map. The number of subjects in the group who had drawn each of the unique routes was tallied at the bottom of each page.

(c) Routes were classified into cadres such as shortest distance, fewest turns, longest leg first, shortest leg first, most aesthetic, many curved roads, least time, first route noticed, most turns, and "different from a way I had already gone."

Results of matching these apriori route types with routes actually chosen by subjects (i.e., percentage time each route was chosen) were then tabulated.

A second set of field-oriented tasks were developed to help answer some of the above questions. Particular emphasis in these tasks was placed on orientation, route retrace, comparison of elapsed times for different route choices, and evaluation of perceived versus actual criteria. This second set of field tasks has yet to be evaluated.

8.0 Hypotheses

Questions investigated included the following:

- What criteria do people usually think they use when they are performing route selection tasks in the laboratory and in the field?
- What criteria do people feel they use most frequently when choosing routes in their normal everyday movements through geographic environments?

- Are spatial or temporal factors more important to route choice?
- How often do people retrace the same route when traversing between origins and destinations?
- How often is the same criteria chosen when traveling routes of different complexity?
- Do people try to retrace routes when the task involves using more than a single origin or destination?
- Are people consistent in their criteria for route selection (e.g., fewest turns, least time, shortest distance, longest leg first, etc.) regardless of whether the origin is distant from the body (i.e., journeys towards home) or is close to the body (the destination is distant)?
- How consistent are people in terms of their criteria for route selection as the environment changes (e.g., from simple grid to grid with curves or grid with diagonals)?

9.0 Results

Results appear to support other research that argues that people are not shortest path or least time decision makers (Gärling, Säisä, Böök, & Lindberg, 1986). Data from all six compiled packages was entered into an Excel spreadsheet and summarized for each of the offered hypotheses. Here we discuss only a selection of the results.

9.1 Perception of Criteria:

As part of the general information collected from our subjects we asked them to rate on a seven point scale (with values ranging from "unimportant" to "extremely important"), what criteria they thought they used when performing the route selection task. The response indicated that shortest distance was given the highest rating across the sample group (4.2) with shortest time close behind (4.1) (Table 1). Fewest turns was rated 3.6 and the most scenic or most aethetic route received 3.5. A noticable drop then occurred and the remaining criteria included: first noticed 2.5; longest leg first 2.3; many curves in the route 2.3; most turns 1.8; different from routes previously chosen 1.8; and shortest leg first 1.7.

Table 1

Mean Ratings of Criteria Used in Route Choice

	Rating of Criteria Used in Task	**Criterion "Usually Chosen"**
Shortest Distance	4.2	4.4
Least Time	4.1	2.6
Fewest Turns	3.6	3.5
Most Scenic/Aesthetic	3.5	1.9
First Noticed	2.5	4.3
Longest Leg First	2.3	2.3
Many Curves	2.3	1.6
Most Turns	1.8	2.7
Different from Previous	1.8	2.1
Shortest Leg First	1.7	3.4

Ratings were scored on a 7-point scale

Source: Golledge, Experimental Data

When asked what criteria they *usually chose* when selecting routes in their real world activity patterns shortest distance again received the highest rating (4.4) but the "first experienced" or noticed route was rated second (4.3). Routes with the fewest turns (3.5) and routes with the shortes leg first (3.4) followed in importance. Others included most turns (2.7), least time (2.6), longest leg first (2.3); and many curves (2.3), different from routes usually taken (2.1), most scenic or aesthetic (1.9), and routes with many curves (1.6). Obviously the map route selection task was perceived as being something different to what would normally be experienced in real world interaction patterns. What is interesting, however, is the lack of relative significance given to variables which are often said to be perceptually "popular" such as minimizing time (2.6) and scenic/aesthetic routes (1.9). The significance of the first route experienced or chosen between an origin or destination is quite noticeable and supports suggestions made by Golledge & Zannaras (1973) that when choosing routes people are likely to limit experimentation and develop a firm preference for a route to be followed on a regular basis after a small number of trials, regardless of its economic, temporal or spatial optimality.

Let us now turn to a detailed discussion of selected criteria and examine consistency of selection in different environments and from different perspectives.

9.2 Route Selection Criteria

Fewest Turns: For each environment the total people who chose a route with the fewest possible turns between each pair of points was first recorded. If there was more than one unique route on the compiled map that had the fewest turns possible, then this data represents the total number of people using all such routes. The actual number of turns that defines "the fewest" for each pair of points was also recorded. The proportion of people in the particular stimulus group who chose a route with the fewest turns was then calculated. The average is a summary score for the particular stimulus environment, across all pairs of points, for the use of the strategy "choose the route with the fewest turns" (Table 2). It is apparent that as the environment changes, so does the popularity of this criteria, dropping from a high of 67% in a simple regular grid environment to 25% in a curvilinear environment. Data is reported for each of three environments (Grid, Diagonal, Curves). A second table illustrates changes in criteria selection when perspective changes (Table 3).

Table 2

Fewest Turns: Criterion Selection in Each Environment

Environment	% Subjects Choosing This Criteria
Grid	67%
Curves	25%
Diagonal	57%

Source: Golledge, Experimental Data

Table 3

Fewest Turns: Perspective Change

Environment	A in N^th^	A in S^th^
Grid	7%	65%
Curves	56%	58%
Diagonals	32%	18%

Source: Golledge, Experimental Data

In the case where perspectives differ, there is a remarkable difference in choice of this strategy when the path to be travelled heads away from the body (65%) as opposed to heading toward the body (7%). A significant difference occurs in the diagonal environment also, but not in the curvilinear one.

Longest Leg First: Here, data represents the total number of people who chose a route in which the longest leg was the first segment. "Longest" was defined in terms of total distance travelled on each segment, not number of blocks, and related only to the actual route chosen. In the first experiment routes were given; in later tasks subjects chose their own routes and each route was judged as a unique unit. No attempt was made to define some form of optimal "longest leg first" route. If no one chose a route in which the longest leg occurred first then the count was zero. Summary strategies across the population and statistics stratified according to travel orientation are given below for the condition where a single pair of origins and destinations are used with no intervening points. In terms of criterion selection for each environment regardless of point of view, choice percentage varied from 47% in the simple regular grid environment to 27% in the diagonal case (Table 4). When perspective was considered, this criterion tended to be chosen somewhat equally when each perspective was considered (Table 5). In the curvilinear environment the "longest leg first" strategy was chosen approximately the same proportion of the time regardless of orientation, while in the diagonal environment, a somewhat higher proportion selected this strategy when travelling from a distant origin rather than a closer one.

Table 4

Single O-D Pair

Longest Leg First: Percent People Using This Criteria in Each Environment

Environment	% Subjects Choosing This Criteria
Grid	47%
Diagonal	27%
Curves	33%

Source: Golledge, Experimental Data

Table 5

Single O-D Pair

Criterion from Different Perspectives: Longest Leg First

Criteria	A in Nth Person %	A in Sth Person %
Grid	45	49
Diagonal	31	23
Curves	32	34

Source: Golledge, Experimental Data

Apparently in tasks involving a simple path between a single origin and destination, individuals emphasize different criteria depending on the nature of the environment represented on the map. Let us look now at what happens in a slightly more complex case.

9.3 O-D with Intervening Points

Turning now to a slightly more complicated situation in which an intervening point was included on the trip (i.e., from homebase A to intermediate point E to destination point C) we find substantial differences in path selection criteria in each type of environments. Focusing still on longest leg first criteria, for the simple orthogonal grid map where the origin was far from the body, *16.5%*used the longest leg first as a strategy on the outward trip but only *7%* used it on the return trip (Table 6). Except on the simple grid map, it usually didn't matter whether the origin was distant from or close to the body, similar results were obtained.

Table 6

O-D Plus Intervening Point: Longest Leg First

Population Summary by Environment and Perspective

Environment	**A in Nth**	**A in Sth**
Grid	16.5%	7%
Diagonal	9%	10%
Curves	17.5%	16.5%

Source: Golledge, Experimental Data

9.4 Route Retraces

Now let us consider situations where individuals were required to travel between A and B in each direction. Again we are concerned with the problem of whether the same route was retraced, and if so, what this did to the route selection criterion. Here we present results only for the longest leg first criterion.

First in the simple grid environment, route retrace was not usually followed. For example, 44% subjects chose longest leg first when travelling from A to B when A was distantly located. However, *61%* chose this strategy on the return route. This means the return route could *not* have been a retrace of the original! (Table 7). More confusion occurs when we change perspectives and pursue a path from a close A to a distant B. Here, only 29% used this criterion. In the reverse task, however, 64% chose the strategy!

Table 7

Simple O-D Pairs

Route Retrace: Longest Leg First Case

Criteria	Route	A in N^{th}	A in S^{th}
Grid	A-B	44%	29%
	B-A	61%	64%
Curves	A-B	35%	13%
	B-A	12%	0%
Diagonal	A-B	24%	7%
	B-A	24%	20%

Source: Golledge, Experimental Data

On the map with curves, 35% chose this strategy when travelling from a distant origin to a close destination, but only 12% chose the strategy on the retrace task. When the origin was close and the destination distant, 13% chose it on the outbound journey and zero chose it on the retrace. When diagonals were included, a similar outbound and retrace pattern occurred, but with a close origin, differences again fluctuated widely from 7% to 20%.

When considering a path through an intervening point, differences in criteria selection become marked depending on orientation. In a simple grid, 33% chose longest leg first when travelling from a distant origin towards a close destination. *Zero percent* did this on the return trip (Table 8). When travelling from a close origin to a distant destination, 14% chose the strategy, but zero percent chose it on the return trip.

On the map which included some diagonals and again required travelling through an intermediate point, when the origin was distant, *35%* used longest leg first, but on the return trip *zero percent* used that strategy. When the origin was close to the body, *33%* used longest leg first and again on the return trip *zero percent* used that criteria. In the curvilinear condition 15% to 20% respectively chose the strategy on the outbound trip, but zero selected it on the retrace. It might be suggested that in these cases, a pure retrace strategy may have been used, thus precluding any "largest leg first" strategies from being implemented. Visual examination of subjects' maps tends to confirm this explanation. The occurrence of zero percent choice on the return trip *does* indicate that route retracing *was* a possible option as a route selection strategy.

Table 8

Longest Leg First: O-D Plus Intervening Point

Route Retrace Data

Criteria	Route	A in N^th^	A in S^th^
Grid	A-E-C	33%	14%
	C-E-A	0%	0%
Curves	A-E-C	18%	20%
	C-E-A	0%	0%
Diagonal	A-E-C	35%	33%
	C-E-A	0%	0%

Source: Golledge, Experimental Data

9.5 Preference for Curved and Diagonal Routes

The question examined next was whether people have a *preference* for routes involving curves. For each pair of points the number of people who indicated routes including at least *one curved portion* were averaged (Table 9). Each unique route was recorded. Preference for curves was quite high (74% chose a route with curves in routes heading towards the body and 90% chose a route with curves in routes heading away from the body). There was quite a bit of variation between routes. However, this measure does not take into account how many curved routes were possible between each pair of points; data is only for routes actually chosen by subjects.

Table 9

Revealed Preferences for Path Types

	A in Nth	**A in Sth**
Revealed Preference for Routes with Curves	74%	90%
Revealed Preference for Diagonals	68%	91%

Source: Golledge, Experimental Data

Preference for diagonals proved to be similar to the preference for curves results (Table 9). Again, the ovrall preference for taking a diagonal was quite high (68% chose a route using at least one diagonal when traveling towards the body; 80% chose a route with at least one diagonal when moving away from the body).

10.0 Conclusions

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 which 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; Pequet 1984). It is essential both to understand what those concepts may be and how people are able to interpret or understand them, as well as to know if they are relevant to common sense decision making or are relevant only in the realm of the expert! For example, we need to be aware of and be able to describe spatial objects standing alone, in sequence (chain) or list form, connected, networked, or regionalized. The lack of a comprehensive theory of spatial relations to allow us to do this 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, to understand their various semantic interpretations, and to know how much people understand and can use them. The research reported in this paper is in this vein. 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; minimum distance; least time).
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; that paths consist of segments and turns and are either more or less direct connections between places).
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 neccesarily the ones typically used in common sense spatial problem solving, but are normative criteria useful for producing elegant mathematical solutions, but perhaps not relevant for human decision making. When relevant they apply most to certain environments, are directionally biased, and are used only by segments of a population.
6. There is a need for much research into the frequency of use of commonly used decision criteria and into the stability and validity of models that rely on such criteria - especially when used in policy and planning situations.
7. In free choice situations such as epitomized by the single O-D pair experiments, multiple criteria were used as route selection strategies and route retracing for the return trip was not a commonly observed strategy. However, in constrained environments, as when the route chosen must pass through an intermediate point, route retrace *was* a common strategy. However, considerable variation in strategy selected did occur.

In short, while our experiments are preliminary, we do provide evidence that conventional network route selection strategies found in most computer models may not reflect the decision making strategies of travellers. While we should not hasten to discard existing models, we should realize that they may be more normative than we usually assume. We also suggest that much needed research should be undertaken on path selection criteria to throw more light on this problem.

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