ON GIVING AND RECEIVING DIRECTIONS: CARTOGRAPHIC AND COGNITIVE ISSUES

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ABSTRACT

Analysis of 20 sets of navigation directions, prepared to accompany invitations to events, is used to examine both cartographic and cognitive issues related to intra-urban navigation. First, maps are more commonly used (18 of 20 examples) than are verbal-procedural instructions (7 of 19 cases), even when a common trip-origin can be assumed. It appears that correct street orientation (and a north-arrow) are highly desireable features of a navigation aid, whereas neither an absolute scale nor even correct relative scale is important. Landmarks were present on 14 of the 18 maps; these included traffic lights (7 maps), fast-food outlets and gas stations (5 each), supermarkets (4), and schools, shopping centers, and convenience stores (3 each). Implications of these results, both for automated in-car navigation aids and for acquisition of spatial knowledge, are presented.

INTRODUCTION

When people give directions, they may draw maps, give verbal directions (printed or spoken), or use parts or copies of published maps (with or without annotation). The nature of direction-giving will differ, depending on whether the communication is in person or remote, one-way or two-way, written or aural, etc. This paper presents a general cognitive model for spatial learning, and the implications of that model for direction-giving and direction-following. Then, examples of directions (given on paper) intended to be used for navigation to novel destinations are analyzed. Finally, the work is placed in the context of designing computerized navigation aids for drivers, a topic of considerable interest to cartographers and the subject of sessions at recent Auto Carto meetings (Cooke, 1985; Streeter, 1985; White, 1985; Mark and McGranaghan, 1986).

CONCEPTUAL FRAMEWORK

The conceptual basis for this and related studies of direction-giving and way-finding lies in the new inter-discipline of **cognitive science.** Cognitive science is "a new and dynamic field that emerged from the unlikely marriage between cognitive psychology and computer science" (Couclelis, 1986, p. 2). In cognitive science, "cognitive functions such as problem-solving, pattern recognition, decision-making, learning, and natural language understanding are investigated by means of computer programs that purport to replicate the corresponding mental processes" (Couclelis, 1986, p. 2). Spatial learning has been a recurring theme in cognitive science (for example, Kuipers, 1978; Riesbeck, 1980; Thorndyke and Hayes-Roth, 1982). Recently, Mark and McGranaghan (1986) reviewed relevant literature in cognitive science, and proposed that this forms a useful approach to the problem of providing navigation assistance to drivers.

A Model for Spatial Knowledge Acquisition

Benjamin Kuipers has developed a powerful computational model for spatial knowledge. In particular, Kuipers' model is concerned with the processes by which one learns about large-scale (geographic) space. The model was introduced in Kuipers' 1978 paper in **Cognitive Science,** and was refined and expanded in a series of other papers. Mark and McGranaghan (1986) have proposed that Kuipers' model of spatial knowledge **acquisition** also forms an appropriate theoretical basis for studies of the **communication** of spatial information for navigation and other purposes.

Kuipers' model organizes spatial knowledge into three major categories. First, sensorimotor procedures consist of sets of actions, and their sequence, that are required to travel from one place to another (Kuipers, 1983b, p. 1). Second, topological relations represent "knowledge of non-metrical properties of the external environment, such as containment, connectivity, and order" (sequence) (Kuipers, 1983b, p. 1). Finally, metrical relations encode "knowledge of, and the ability to manipulate, magnitudes such as distance, direction, and relative position." (Kuipers, 1983b, p. 1). For convenience, Mark and McGranaghan (1986) referred to these as **procedural, topological,** and **metrical** knowledge, respectively.

Procedural knowledge is based on two types of objects, **views** and **actions.** A **view** is the set of sensory inputs available at a particular place and orientation; it is important that one can determine whether or not two views are the same. An **action** is a motor operation (such as a move or a turn) that changes the current view. As one travels through large-scale space, one "sees" a series of views; some of these views are associated with actions such as turns from one street to the other. **Routes** can be remembered as collections of "view-action" pairs. If a person remembers "(view-action)-view" triples, routes can be recreated in the mind, and described to others.

Kuipers' model proposes that many people are able to generalize from procedural knowledge of routes, and build **topological knowledge** of large-scale space. At this level, a **place** is identified as the cycle of views after repeated turns at a point; places may be common to more than one route. People with spatial knowledge at a topological level will usually know on which side of a major street (path) some known place lies, and will be able to plan new routes between places. However, the orientations of paths may be distorted, and places are not fitted into an overall coordinate system. Sketch maps produced by people with this level of knowledge may be distorted, but often will be useful and fully functional for spatial navigation. Also, regions at one level of abstraction may be equivalent to places at another level.

Kuipers' model proposes that some individuals integrate spatial knowledge acquired through navigation and produce spatial knowledge at the metrical level; at such a level, spatial knowledge is placed into the framework of a cartesian coordinate system. Mark and McGranaghan (1986) observed that access to graphic metrically-correct maps almost certainly plays a key role in the learning of spatial information at this level. Research by Thorndyke and Hayes-Roth (1982) appears to support this contention, although their experiments were conducted inside large buildings, rather than in an urban street network.

Kuipers' Model and Spatial Navigation

Mark and McGranaghan (1986) claimed that it is useful to classify various forms of spatial information for navigation according to the three categories of spatial knowledge proposed by Kuipers. Verbal directions for getting from one place to another, presented in words either spoken or printed, represent information at a procedural level. In a vehicle, procedural knowledge could also be provided to the driver in non-verbal form, by means of signals produced either by a human navigator (for example, pointing when it is appropriate to turn), by an on-board computer, or by electronic signposts. Sketch maps with distortions (deliberate or inadvertent) represent a topological level of spatial information. Road maps and other planimetrically-correct maps represent a metrical level of information.

Clearly, procedural (sensorimotor) knowledge **must** be available in the mind of the traveller so that order the traveller can make the decisions necessary to get from one place to another. If navigation information is provided at **any** level other than procedural (for example, in the form of a graphic map on paper or on a computer-graphics display device), then the traveller or navigator must do work to determine the relevant procedural instructions. This takes time and effort, may distract from other driving tasks, and may be subject to error.

Graphic Maps or Verbal Directions?

Graphic maps have been so much the dominant form for the representation of spatial information in support of navigation that the relative effectiveness of the map in this context has hardly been questioned. However, in addition to the cognitive theory presented above, there is empirical evidence that procedural directions may be useful and effective.

Astley (1969) reported the results of questionnaire surveys of 300 British road-users. Most of those surveyed used maps. However, "nearly half of the respondents used written route guides" or some kind; "the majority wrote their own from maps" (Astley, 1969, p. 130). One can infer that these travellers felt that written-procedural directions are easier and/or better to use during trips than are maps.

In perhaps the only experimental investigation of the relative effectiveness of navigation aids for drivers, Streeter and others (1985) found that drivers appear to navigate more effectively when given verbal (vocal) directions, rather than a graphic map. Streeter and others compared four methods for receiving navigation aid during automobile driving. These methods are: (1) standard road maps; (2) customized road maps (north at top); (3) verbal instructions from tape recorder; and (4) a combination of methods (2) and (3). Performance of test subjects was evaluated in terms of travel time, number of errors, and other measures. They found, not surprisingly, that method (1) (the "control" condition) produced the poorest performance. However, the best performance was observed when the subjects had only the tape recorder to guide them. (This method involved a customized tape recorder with two buttons: one to repeat the last instruction, and the other to play the next one.) Significantly, the "customized map" group (method 2) had the second-worst performance level. It also seems that providing the subjects with maps in addition to the tape recorders (method 4) detracted from performance given the tape recorder only. Perhaps the map constituted a distraction, reducing the ability of the subject to concentrate on the tape; alternatively, by providing a means to recover from errors, it may have reduced the perceived **need** to concentrate on the tape.

The main result of Streeter's experiment appears to confirm the implication that Mark and McGranaghan (1986) drew from Kuipers' model, namely that provision of navigation information at the procedural level should be easier to assimilate than would be graphic topological or metrical information. Mark (1985) presented a method for computer generation of routes which were simple to describe, at the possible expense of greater route length.

DATA

The directions (navigation-aid information) analyzed in this study were associated with invitations to parties and other events. These were "natural" directions actually prepared and distributed by event organizers. Preparers had time to think about the directions, to try again if the directions were not adequate, etc.; thus they might be expected to be different from directions produced more spontaneously. Only a few of the directions were prepared by cartographers. Some present only verbal directions, others include only maps. Still others are annotated maps (integrated graphic/verbal instructions), or include both maps and verbal directions, either of which could stand alone. Maps range from photocopies of printed road maps, to geometrically-correct maps showing only relevant information, to highly schematic diagrams which really illustrate only the topology of the route to be followed.

All 20 sets of directions analyzed were "mass-produced" and distributed along with the invitation and/or announcement of the event. Thus, the individuals preparing the directions could assume details regarding neither the recipient (knowledge of the area, navigation skills, etc.) nor the location of the trip origin. However, all directions were prepared in relation to a **single** event, and thus were intended for a particular **group** of people (the invitees). Thus more general characteristics and origins might have been known to the preparers of the directions.

The writer was a the recipient of 17 of the 20 sets of directions. As one might expect, many of the directions were prepared by cartographers (5 cases) and other geographers (9 cases); this introduces a potential for bias, since we might expect navigation aids produced by such people to be somewhat more "professional" than would be typical in our society. (However, readers who know cartographers and/or geographers will probably confirm the writer's impression that geographers and cartographers are outstanding in neither their navigation abilities nor their direction-giving abilities!) Results must be interpreted in light of this distribution.

RESULTS

All of the 20 sets of directions examined in this study were reproduced by photocopy, and consisted of black marks on paper; in only one case was any color added (the suggested route was drawn in red by hand on each map). Of the 20 examples, 18 included maps; verbal-procedural directions were included in 7 cases, accompanying maps in 5 of them. Thus 13 examples had maps as the only source of navigation information. The inclusion of verbal-procedural directions seems to be more frequent among non-geographers (see Table 1), but two of the "map + verbal" examples were prepared by the **same** non-geographer; without her second set of directions (prepared two years after the first set, in relation to a different destination), the association would

TABLE 1

Association Between Form of Directions and Background of Preparer

Preparer:	Cartographer	Geographer	Other
Map only	4	6	3
Map + verbal	1	1	3*
Verbal only	0	1	0

* includes two examples by same person

be weak, if present at all. Since maps were present in 18 cases, this section will concentrate on an analysis of the characteristics of these maps, under several sub-headings.

Orientation and scale. Text present on the paper clearly indicated an "up" orientation for each map. On all but two of the maps, north was in this "up" direction; in the other two, the orientation was "heading-up", that is, the goal was at the top of the map, and the typical trip origin was toward the bottom. Furthermore, north-arrows were drafted on 13 of the 18 maps (72 %). Two of the 5 maps without north-arrows were prepared by non-geographers, the other 3 by geographers who do not specialize in cartography. (Interestingly, neither of the two "south-up" maps had a north-arrow or any other explicit indication of cardinal directions!) In contrast, only 3 maps (17 %) included any explicit indication of scale; in two cases, a scale bar was drawn on the map, and in the other, two important road segments were labelled with their lengths in miles. Of the remaining 15 maps, only one other map explicitly stated: "scale variable"; users without local knowledge would have no way of knowing whether the other 14 maps were "to scale" or not, and what that scale might be.

Landmarks. Considerable evidence suggests that landmarks are very useful in navigation. Data from the current study supports this, since 14 of the 18 maps included either traffic lights, other landmarks, or both. In fact, general landmarks were included on 11 of the maps; between 1 and 7 landmarks other than traffic lights were present, with a mean of 3.1 instances per map using them. The landmarks are classified and tabulated in Table 2.

TABLE 2

Landmarks Used on Maps Studied

fast food outlet	5
service station	5
supermarket	4
school, campus	3
shopping center	3
convenience store	3

11 other landmark types appeared once each:

church, airport, funeral home, restaurant, doughnut shop, car dealer, bar, railroad, department store, hospital, hotel.

Traffic lights were included on 7 of the maps; four different symbols were used (see Figure 1), although only one of the maps included an explanation of the symbol used. Note that traffic lights are frequently used as landmarks in spontaneous, two-way direction giving.

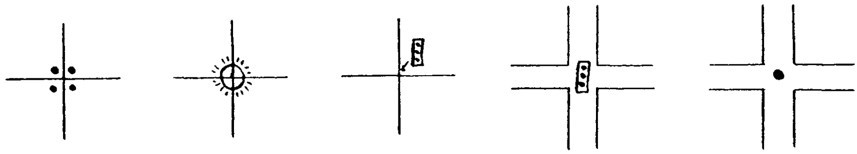

Figure 1: Traffic-light symbol A was used twice, and the others once each (C and D are the same symbol, used with single-line streets and "wide" streets).

Geometry. The geometry of each map was assessed qualitatively by the writer. Five of the maps were geometrically correct (having been photocopied or traced directly from roadmaps), and another 3 were hand drawn maps corresponding closely with the correct geometry. Nine of the remaining 10 maps contained substantial distortions of geometry (presumably inadvertant), but were topologically adequate. The tenth map used the technique of jagged breaks in wide roads to indicate scale variation produce by the omission of sections of roadway; this map attached lengths (in miles) of two road links.

In 7 of the 9 distorted maps and in the "interupted map", orientations of streets generally were correct, but distances showed large distortions. For 7 of the distorted maps, the distortions probably were not great enough to confuse a typical navigator. However, the geometry of the remaining 2 maps was highly distorted, and could easily have confused navigators who were not sufficiently familiar with the area to ignore these problems. Consider the example shown in Figure 2: Bailey Avenue actually is straight, and it appears straight on the ground; however the sketch map would lead one to expect major curves, and thus could produce cognitive dissonance in the mind of a navigator. In the other distorted map, angles were more-or-less correct, but relative distances were **greatly** distorted. Interestingly, correct geometry and inclusion of verbal-procedural directions showed a **positive** association (see Table 3). That is, of the 5 maps which

TABLE 3

Association Between "Correct" Geometry and Verbal-Procedural Directions

Verbal Directions?	Correct Geometry? Yes	No
Yes	4	1
No	4	9

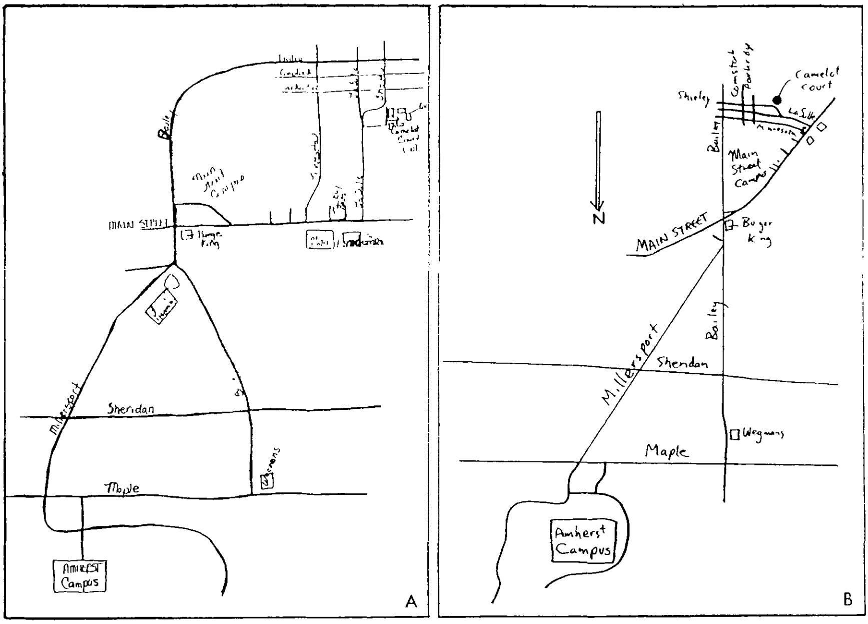

Figure 2: An example of a distorted sketch-map (A), and the same streets traced from a road map (B). South is at the top.

also included verbal-procedural directions, 4 had a "correct" geometry; of the 9 maps with substantially distorted geometries, only one included verbal directions.

Route Advice. As noted above, 5 of the 18 maps included verbal-procedural directions. In 3 examples, the verbal directions and the maps were equally prominent on the paper; for the other 2, the verbal directions were present as marginal information. In 3 sets of verbal directions presented with maps, as well as in the single example of verbal-only directions, a common origin for all trips was assumed; this was located at a recognizable point between most trip origins and the destination. In each case, it is the writer's opinion that almost all people invited would approach the destination from the assumed direction. In one of the two remaining cases, two different first steps were included to get travellers to a common point; in the other, two separate sets of directions were presented, one to be used by those approaching from the east, the other from the west.

Five of the 18 maps indicated a suggested route through the use of cartographic symbols; four included arrows indicating the suggested route, and the fifth drew the route in color on an otherwise monochrome map. Three of these maps were also accompanied by verbal directions, suggesting the same route using two different methods. Three of the maps with arrows placed them on all street links on the suggested route(s), whereas one placed arrows only at turns.

DISCUSSION

It would be a mistake to assume that methods used in informal cartography, primarily by untrained map-makers, provides a model of the ideal navigation-aid system. (This was pointed out by Judy Olson in comments during a presentation by the writer in East Lansing, Michigan, October 1986.) Clearly, a trained cartographer should be able to produce graphical navigation aids which are better and more effective than most of the ones analyzed here. Nevertheless, the results give some indications of characteristics which motorists find desireable in maps; at the very least, illustrate the sorts of "errors" or distortions which can be **tolerated** in a road map.

First, it is very clear that most people feel that **orientation** is essential in a graphic navigation aid. Even though street names and street patterns would provide orientation cues to navigators familiar with the area, and although all but two of the maps followed the cartographic tradition of a "north-up" orientation, fully 72 percent of the map-makers (13 of 18) added a north-arrow to the map. Conversely, **scale** seems unimportant, since only 3 of the 18 maps had any scale indication.

A purely topological spatial model (Kuipers, 1983b, p. 1) would contain neither orientation nor scale, whereas both would be present in a geometrical model of spatial knowledge. The present results suggest that an intermediate level of spatial knowledge is needed for intra-urban navigation: this intermediate level includes at least a generalized indication of orientation, but no precise indication of scale. The presence of an intermediate level is further supported by the fact that only 2 of the 16 maps analyzed included significant distortions in street orientations, whereas 7 included substantial errors of relative distances. This result also suggests that orientation information may be acquired before distance information during spatial learning; this would be an interesting area for further research.

Finally, the navigation aids analyzed in this study confirm the centrality of maps in this context. In a static medium (print on paper), verbal directions are inadequate for most situations for at least two reasons: (1) both the origin and the destination of the particular trip must be know (the map, on the other hand, allows the navigator to generate directions from **any** trip origin); and (2) printed verbal directions do not allow for straight-forward error recovery (whereas on a map, a new route can always be planned from the current location to the goal). It is important to note, however, that these weaknesses of verbal-procedural directions would not apply if the directions were produced in real time by an on-board computer with a street-network data-base and a location facility. The relative importance of procedural and graphic navigation output from computerized vehicle navigation aids appears to be an open question.

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