

ROAD CLIMBING: PRINCIPLES GOVERNING ASYMMETRIC ROUTE CHOICES ON MAPS

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Abstract

The focus of this paper was on how people plan routes when using maps. This issue is relevant not only to the design of maps, but also to the construction of new navigation systems built to help people plan routes. The research was concerned with the principles that people follow when selecting a route. Specifically, the authors investigated why people's route choices are often asymmetric—why a different route is chosen when traveling between two locations depending on which point is the origin and which is the destination. It is contended that this *path asymmetry* does not occur randomly; subjects' route selection is systematic and predictable. Often, subjects will employ a heuristic termed here as *road climbing*, which is similar to hill climbing strategies used in problem-solving. Road climbing is a preference for long and straight routes in the local area containing the origin. In Experiment 1, subjects chose paths predicted by a road climbing model even when the selected paths were 50 per cent longer than alternative paths. Moreover, this effect was exaggerated when subjects processed the maps on a region-by-region basis. In Experiment 2, the results were extended to include real maps that subjects may encounter in their day-to-day routines. These results are discussed in terms of their relevance to current problem-solving and spatial cognition research. Practical applications are also considered.

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Introduction

One of the most provocative findings in cognitive psychology is that people's judgments are not always optimal (Tversky & Kahneman, 1983; Newcombe *et al.*, 1996). One case in point is that judgments are often asymmetric. For instance, people may judge that Cuba is more similar to the Soviet Union than the Soviet Union is to Cuba (Tversky, 1977). Similarly, when people make judgments about spatial distance, their judgments often vary depending upon which location is viewed as the origin and which is viewed as the destination (Sadalla *et al.*, 1980; Holyoak & Mah, 1983; McNamara, 1991; Newcombe *et al.*, 1996; McNamara & Diwadkar, 1997). These asymmetries in judgments have often been taken as evidence that people's representations of information are inaccurate, or that their processing of information is fundamentally biased. However, it has also been argued that these 'shortcomings' are the products of heuristics that are often useful in that they allow us to make reasonably accurate judgments with

relatively little information or cognitive effort (Hogarth, 1981; Kleinmurtz & Kleinmurtz, 1981).

Our focus here is on a similar kind of asymmetry involving the selection and planning of routes from maps. The ability to select and plan routes is of critical importance to everyday navigation, be it walking, driving, or riding bicycles. Ostensibly, it would seem that people's judgments should be symmetric. For example, if people attempt to minimize time or distance (e.g. Senevante & Morrall, 1986), then they should select the same route when traveling from A to B than when traveling from B to A. However, this is not the case, as studies have shown that people's route selections are often asymmetric; they choose different routes when going from A to B than from B to A (Stern & Leiser, 1988; Christenfield, 1995). In this paper, we present an explanation of when and why these asymmetries occur. We view the occurrence of the asymmetries as stemming from a combination of limited cognitive processing capabilities and the use of heuristics when planning routes. We will argue that the asymmetries do not result from fundamental limits on

processing but rather arise from particular rules-of-thumb that may not be optimal in terms of minimizing distance or time, but are instead a compromise between the effort needed to choose the optimal route and the consequences of selecting less-than-optimal ones.

Previous research on asymmetry in route selection

Why do asymmetries in route planning occur? One previous explanation concerns individual variation in people's knowledge of available routes. For example, Stern and Leiser (1988) asked groups of professional and nonprofessional drivers to select from memory routes between two points (labeled A & B). Half the subjects were asked to choose a route from A to B and half were asked to choose a route from B to A. As a group, the choices of the non-professionals were highly inconsistent, despite years of experience driving in that city.

In explaining their results, Stern and Leiser suggested that

'the population must be considered as a collection of different individuals, each possessing its own incomplete cognitive opportunity sets of unidirectional routes' (p. 153).

Consequently, there will be substantial variability in the routes that people know and select when traveling in different directions. They argued that the large amount of variability resulted in 'a sizable irreducible random element' in the selection of routes and in the occurrence of asymmetries (p. 153). In sum, Stern and Leiser suggested that asymmetries occurred because their non-professional drivers as a group were more variant than their professional drivers, who appeared to agree as to which route was the most efficient.

In this paper, we argue for a different position: path asymmetries do not occur simply because of random chance or mere opportunity but because of some underlying mechanism inherent to the nature of problem-solving and the processing of maps. People do not select routes randomly; rather, specific strategies are used to decide between alternatives. Christenfeld (1995) described one such strategy that may be invoked in route choice. He asked subjects to choose from 'identical options' on a map. The route options were termed identical because they did not vary from each other in terms of distance, travel time, or number of turns. The only difference between the routes was when along

the route subjects had to make a turn. Some routes began with long, straight sections, whereas others required a turn near the origin. Christenfeld found that people usually preferred routes in which the need to turn was deferred for as long as possible. Thus, given the need to make a choice (i.e. what direction to turn), people preferred to wait and travel straight ahead for the greatest possible distance. This strategy can lead to asymmetries because the last possible path will necessarily be different when planning a route in one direction than when planning a route in the opposite direction.

Christenfeld attributed his findings to subjects' use of a general heuristic to minimize mental effort, in that subjects selected the path that deferred making a turn until the last possible moment. Our goal here is to extend this finding and to develop a more systematic and comprehensive model that can explain the subjects' choice of routes on maps. Particularly, we are interested in a model that can specifically predict the routes a subject will select when given a number of alternatives. Because alternatives are rarely identical in the real world, the model should be capable of handling decisions between choices that vary in factors such as appearance and distance. We begin by considering previous research on how people process distance information, including how this processing may influence people's selection of routes.

Processing of route distance

Much of the previous research on wayfinding has examined the factors that affect what particular route a person selects. Senevante and Morrall (1986) have proposed that these factors include minimization of time, distance, traffic, number of crossings and amount of crime along the route, and maximization of attractions and weather protection, among others. In addition, O'Neill (1992) has implicated familiarity and complexity as factors in wayfinding decisions. Clearly, the importance of each factor varies idiosyncratically, although the majority of route-choice research has shown that subjects are particularly concerned with minimizing length along a route (see Bovy & Stern, 1990 for review). Perceived length of a route, however, is not solely a function of the actual Euclidean length of the route. People's distance estimates are biased by a number of factors, two of which may be particularly important in determining which routes people select: clutter and regionalization.

Clutter. Research has established that a 'filled' distance appears longer than an 'empty' distance. This *clutter effect* has been shown with both simple perceptual stimuli (Oppel, 1855: in Thorndyke, 1981) and on complex maps (Byrne, 1979; Thorndyke, 1981). For example, Byrne (1979) found that routes in a crowded area of a city are estimated as longer than ones in a noncrowded area, despite being similar in actual distance. In addition to perceived distance, clutter influences choice of route (Senevante & Morrall, 1986). In the latter study, pedestrians attempted to minimize the number of crossings (intersections) encountered along a path when deciding on a route between two points. Interestingly, the clutter effect persists even when subjects are allowed to examine the map, rather than responding from memory (Thorndyke, 1981). Furthermore, the clutter effect has been shown in studies in which subjects actually navigated in the real world (Briggs, 1973; Canter, 1977).

Regions. A second factor that affects perceived distance of a route concerns the amount of information that can be processed at once. When we navigate through highly cluttered or complex areas, it may be necessary to 'break up' that area into a number of smaller, less-complex regions in order to reduce the required amount of working memory and to promote cognitive economy (Sadalla *et al.*, 1980; Downs *et al.*, 1988).

We believe that the way that an area is divided into regions is critical in determining decisions of what route to take. Rather than planning routes based on the entire path between two locations, people may instead make decisions on a region-by-region basis. The final route can be construed as the sum of a series of choices within regions. In other words, as they proceed from one segment to another, people may alter their path depending on the nature of the segment in focus.

In this paper, we suggest that the manner in which people make route choices on a region-by-region basis is analogous to a problem-solving strategy typically labeled *hill climbing* (Newell & Simon, 1972). Hill climbing is a localized strategy; people attempt initial steps which minimize the difference between the initial problem state and the goal state. A classic example concerns the traveler who needs to get from New York to San Francisco as quickly as possible. A person employing a pure hill-climbing strategy would leave her home and start walking west, even if there is an airport east of the home. While traveling east

(toward the airport) is in the opposite direction of the ultimate goal, it would facilitate a much quicker solution: flying to San Francisco.

Road climbing

We argue that when people navigate on maps they often depend on a strategy similar to hill climbing which we call *road climbing*. Instead of actually calculating the globally shortest route between origin and destination, people will resort to the strategy of attempting to leave the region containing the origin as quickly as possible using the longest and straightest road out. Subjects tend to prefer routes which take advantage of long and continuous roads because they are perceived to be shorter than winding roads (Downs & Stea, 1973). Research has shown that these preferred roads are particularly attractive at the beginning of a route. For example, Iida *et al.* (1989: cited in Bovy & Stern, 1990) studied drivers who were asked to use past experience with time estimation of familiar routes in order to make further wayfinding decisions. Their results demonstrated that a quick route at the beginning of a journey often produces an overestimation of the route average speed, compared to other parts of the route. In addition, Cornell *et al.* (1996) showed that lost children paid particular attention to the beginning of a route; they encoded the initial portions of a route more effectively than the other parts.

However, these initial straight roads may not be the most direct routes to the destination. A path which is locally optimal initially (i.e. based on perceived length) may not be part of the globally optimal route. In this paper we demonstrate two mechanisms that induce road climbing: forcing subjects to attend to the origin region (the region containing the origin), and increasing processing demands by lengthening the route to be traveled. We now present experiments which support a model predicting when navigators will resort to road climbing, and when path asymmetries will occur.

Overview of experiments. Our approach is to show that the number of path asymmetries elicited from subjects varies depending on map context, and to provide a model which predicts when and describes why these asymmetries occur. We demonstrate that subjects generally prefer routes which are initially long and straight, even if these routes are not the optimal routes in terms of Euclidean distance. Additionally, because people choose routes based on

how initially attractive they are, the same route will be differentially selected depending on whether the attractive segment of the route is closer to the origin or the destination. It is this differential selection that leads to path asymmetries. In Experiment 1, we induced road climbing by partitioning the map into regions. Subjects chose routes on maps that were arbitrarily segmented into regions by the

experimenters as well as on maps that were not divided into regions. There was evidence of road climbing for both types of maps, but the effect was greater for the maps with regions. In Experiment 2, we extended the results by using campus maps as stimuli and by demonstrating that more asymmetries occur for routes that cover greater distances and consequently contain more regions.

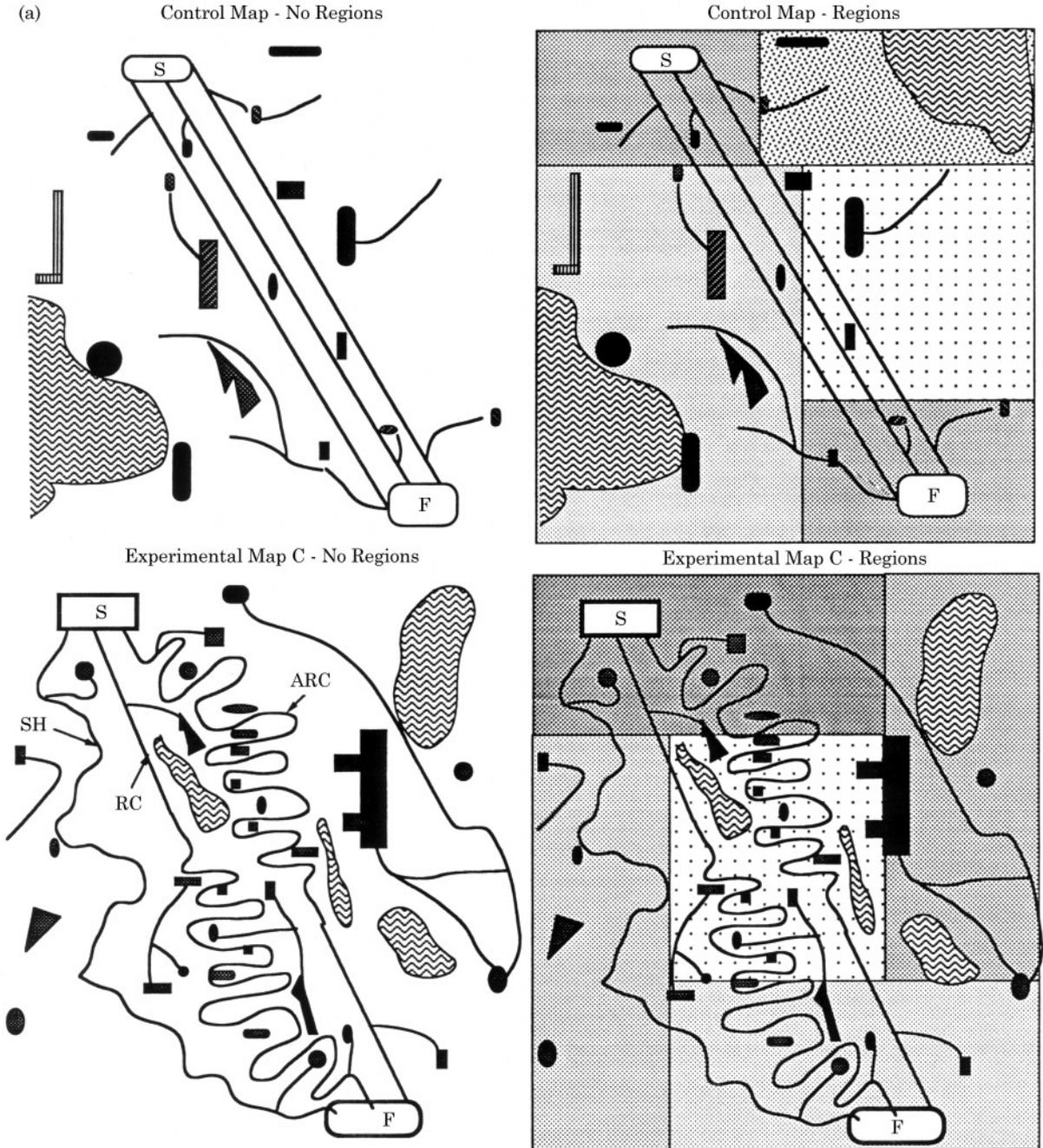


FIGURE 1A. The four map types used in Experiment 1. There are two versions of each map, one with regions and one without regions. This shows the Control maps. RC indicates the road climbing route, ARC indicates the anti-road climbing route, and SH indicates the shortest route.

Experiment 1

In Experiment 1, subjects had a choice of three paths to take from the origin to the destination. One path was attractive to subjects using road climbing strategies, in that it was initially long and straight. The second path minimized overall Euclidean distance but did not contain an attrac-

tive initial segment. The third path neither minimized overall distance nor offered an attractive initial segment. Half the maps were divided into regions in order to focus subjects' attention on the particular segments.

Our conceptual model of route selection and the occurrence of asymmetries leads to two general predictions. First, we predicted that subjects' route

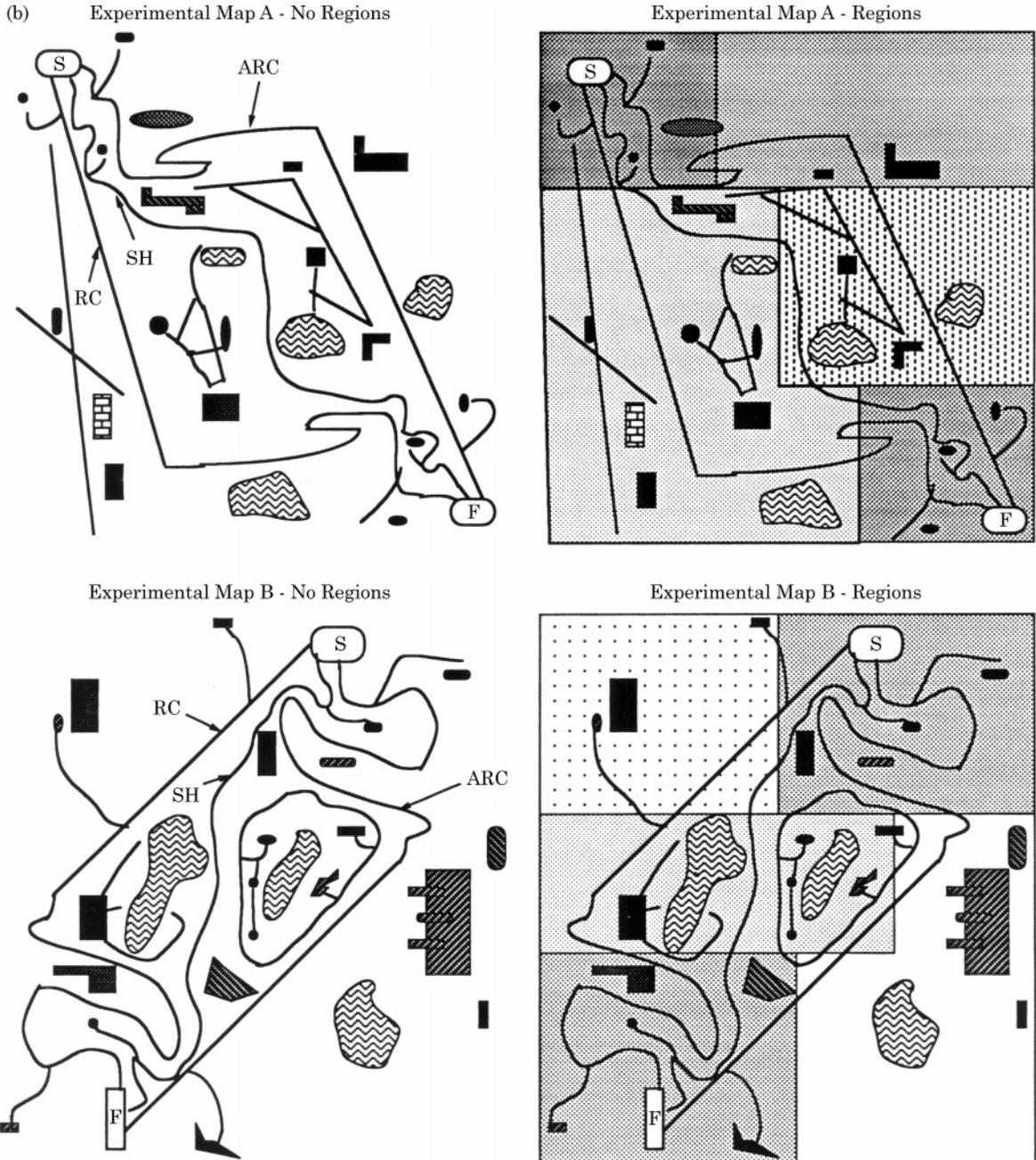


FIGURE 1B. The four map types used in Experiment 1. There are two versions of each map, one with regions and one without regions. This shows the Experimental maps. RC indicates the road climbing route, ARC indicates the anti-road climbing route, and SH indicates the shortest route.

selections would often be asymmetric, and that the asymmetries would stem from the use of road climbing strategies. In other words, we predicted that people would select routes with initially long and straight segments, even if these routes were not the shortest in terms of Euclidean distance between the origin and the destination. Second, we predicted that the use of the road-climbing strategy would be exaggerated when the maps were regionalized (i.e. divided into regions). Because subjects attend to the region containing the origin point first, the initial portions of the available routes may be particularly salient, and those routes which are initially attractive will be chosen more often.

Method

Subjects. Twenty-four Northwestern University students (18 females and 6 males) participated in order to receive experimental credit for an Introductory Psychology class.

Materials. The maps were designed to test the hypothesis that people would prefer paths that began with initially long, straight sections, even if these paths were longer than alternatives. In addition, the maps were designed to control for various factors, such as the positions of routes on the maps, that might conceivably affect people's preferences.

To this end, we constructed a total of 16 maps. [Figure 1](#) shows the four maps used in the experiment. On each map, one building was marked with an 'S' (start) and one was marked with an 'F' (finish). Each map showed three possible routes from the origin to the destination, and the three routes did not intersect. Consequently, once a person selected a particular route, he or she had to follow the same route until the destination was reached.

There were four maps, and we varied the characteristics of the three alternate routes across the four map types. Three of the four maps (Experimental Maps A, B & C) were designed to test the use of road-climbing strategies. For these three maps, we varied the overall length of the three routes and the characteristics of the initial segments (see [Figure 1](#)). Two of the three routes tested our road-climbing hypothesis: one route (the road-climbing route) always began with a long, straight initial segment and ended with an indirect curving portion. In constructing the anti-road-climbing route, we flipped the road-climbing route on the horizontal axis, and thereby placed the indirect curved segment at the beginning of the route and

the long, straight section near the end of the route. Therefore, the road-climbing route when traveling in one direction was actually the anti-road-climbing route when traveling in the opposite direction. Finally, the shortest route provided the shortest way from the origin to the destination (in terms of Euclidean distance). The three maps varied characteristics of the three routes, specifically the lengths of the road climbing, anti-road climbing, and shortest routes.¹

Additionally, we designed a fourth control map to test whether subjects were biased toward picking paths based on their positioning on the map (i.e. the leftmost route, the center route, or the rightmost route). All three routes were essentially identical and consisted of long straight paths connecting the origin and destination directly.

As shown in [Figure 1](#), each of the four maps was presented either with or without regions. In the regionalized version, we arbitrarily segmented each map into five different regions. The regions were separated by thin dark lines and each one featured a unique background pattern. Except for these regions, the maps with regions were identical to those without regions.

Design. There were two main variables of interest: map type and regions. Specifically we were interested in comparing the routes chosen on the three experimental maps. Additionally, we counter-balanced which of the two buildings on a map was designated the origin and which was designated the destination, such that the two buildings served both functions equally often. The crossing of these three variables (four maps, two regions, two building designation) resulted in 16 versions of the maps. Each subject saw four maps in one of the region's conditions and in one of the building designation conditions. Order of the four maps was randomized. No subject participated in both regions or building designation conditions.

Procedure. Subjects participated individually in sessions of five or less. They were instructed as follows:

In the following experiment, you will see a series of maps of a town. Each map is on a separate page. Thick dark lines on the map represent roads on which you can travel; you will also see buildings and lakes on the maps. Your task for each map is to find a route between two buildings. The letter 'S' appears on the building you must start from. Your destination is the building which is denoted with the letter 'F'. So your job is to find a path from 'S' to 'F'. While you travel, you must stay on the streets

(thick dark lines). Some of the maps you will be seeing have been broken up into different zoning areas of the town. Please begin on a street which emerges from the building indicated by 'S'. Please do not look back over maps that you have completed already.

After they completed the packet of four maps, subjects received a post-experiment questionnaire where they had to indicate their age, gender, and handedness.²

Results

The results provide strong evidence that subjects prefer routes with initial long segments, even when these routes are substantially longer overall than alternatives. This preference can lead directly to asymmetries in route selection. In addition, the results indicate that the presence of regions can lead to greater asymmetries in route selections.

The results were tabulated in terms of the routes that subjects preferred on each of the four map types. One subject's data was discarded because she did not follow instructions. Table 1 shows how often each route was selected on each map. The presence of regions substantially influenced people's route selections. Subjects chose the road-climbing more often when Experimental Maps A and B were regionalized (58%) than when they were not (20%). In contrast, on Experimental Map C, where the road-climbing route was twice as long as the shortest route, subjects preferred the shortest route whether or not regions were present (91%). This result suggests that there is an upper limit at

which subjects will switch their preference for the road-climbing to the shortest route. On the control map, subjects tended to choose the center route (83%) regardless of whether or not the map was regionalized. Given three near-identical choices, there is a tendency for subjects to prefer the center route. It is important to point out that this bias would work against our hypotheses, as on Experimental Maps A and B the road-climbing and anti-road-climbing routes were not the center path.

To ascertain the statistical significance of these effects, we analysed the data with a logistic regression model in which the dependent variable was the event of selecting the road-climbing route, and the explanatory factors were regions (regionalized vs nonregionalized), map type (the three experimental maps), and their interaction. The method of generalized estimating equations (GEE) was employed to analyse the model while adjusting for the repeated measures (e.g. Ten Have & Uttal, 1994). This analysis revealed that both factors were significant after showing that their interaction was not. Subjects were more likely to select the road-climbing route when maps were regionalized, $z = 1.96$, $p < 0.05$. In addition, subjects also chose the road-climbing route more often for Experimental Maps A and B than for Map C, $z = 2.31$, $p < 0.05$.

Discussion

The results from Experiment 1 demonstrate that peoples' route selection is often asymmetric. Recall that the road-climbing and anti-road-climbing routes were the same shape and length; the only

TABLE 1
Percentage that routes were selected by condition in Experiment 1

Map	Route selected %		
	Road climbing	Anti-road climbing	Shortest
Experimental A			
Regions	58	33	8
No regions	27	18	55
Experimental B			
Regions	58	0	42
No regions	18	27	55
Experimental C			
Regions	0	8	92
No regions	9	0	91
	Left	Center	Right
Control			
Regions	17	75	8
No regions	9	91	0

difference between them was which end was labeled the origin and which was labeled the destination. Subjects generally preferred the road-climbing over the anti-road-climbing route; this indicates that the path which subjects overwhelmingly choose when traveling in one direction may be largely neglected when they travel in the opposite direction.

On regionalized maps, subjects chose the road-climbing routes almost three times as often even though the routes were the exact same length. Moreover, they consistently preferred the road-climbing route over a route that was 50 per cent shorter. Furthermore, some of the subjects even preferred the road-climbing route when the maps were not regionalized.

We believe our arbitrary boundaries led subjects to process the maps on a region-by-region basis rather than as a whole. As stated in the Introduction, this type of incremental processing may lead subjects to adopt the road-climbing heuristic, selecting the route that will get them out of the origin region as quickly as possible, as long as this route is heading in the general direction of the destination. Subjects therefore are biased toward long, straight roads out of the origin region even if those routes are not, objectively speaking, the optimal ones. The results reveal that this bias is one of the causes of asymmetries.

Although the findings demonstrate clear and predictable asymmetries, they need to be qualified. For example, the maps were not particularly realistic. As a post-test we had subjects rate the maps on a realism scale ranging from 1 to 6, with 1 being 'not realistic at all' and 6 being 'extremely realistic'. The mean score was 3.01 (S.D = 1.31), suggesting that they felt our maps were only moderately realistic. In addition, subjects only had a choice of three routes on each map, and there were no intersections, so that once a path was selected there were no more decisions to make. Also, the way that we imposed regions on subjects may be unnatural, although it is often the case that real world maps are divided into countries, states, counties, etc. To this end, Experiment 2 was run with actual maps of university campuses, in order to see if our model generalizes to real world stimuli.

Experiment 2

In Experiment 2, we were interested in determining whether asymmetries would occur when subjects were asked to choose routes on actual maps of

the type that they might encounter in their daily routines. We tested for asymmetry by simply having half of the subjects choose a path from point A to point B on the maps, while the other half chose a path from point B to point A. Generally, we predict that any path asymmetries that result will involve those routes that would be predicted by use of road-climbing strategies. In addition, we varied the distance of the routes subjects were asked to select. On each map, subjects had to choose a route between two buildings that were far apart (Long Route) and between two that were closer together (Short Route). We felt that it was possible to induce processing of the maps on a region-by-region basis (and use of road-climbing) if the routes were long enough, as these appear to be more cluttered and contain more regions. Consequently, there should be more path asymmetries in the Long Route than the Short Route. Moreover, these asymmetries should involve those paths that would be predicted by a road-climbing model.

Method

Subjects. Seventy Northwestern University students (39 females and 31 males), participated in order to partially fulfill experimental requirements in an introductory psychology course.

Materials. The stimuli consisted of maps of the campuses of both Northwestern University (NU) and the University of Arizona (UA), photocopied from their respective course catalogs. Figure 2 contains simplified versions of the two maps used in the current experiment. The map of Northwestern University was assumed to be familiar to our subjects, while the map of the University of Arizona was assumed to be unfamiliar.

Conditions. For each map, we chose a long and short route, such that the Euclidean distance between origin and destination in the long route was at least 30% greater than the distance in the short route. On the NU map (see Figure 2), the long route was between the Lutheran Center and the Traffic Institute; the Euclidean distance between these two buildings on the page was 16.51 cm and the shortest route using the specified paths was 21.50 cm. The short route was between the Henry Crown Sports Pavillion and Searle Hall. For the short route, the Euclidean distance was 12.7 cm while the shortest route using specified paths was 14.61 cm. On the UA map (see Figure 2), the long route was between Buildings 432 and 420; the Euclidean dis-

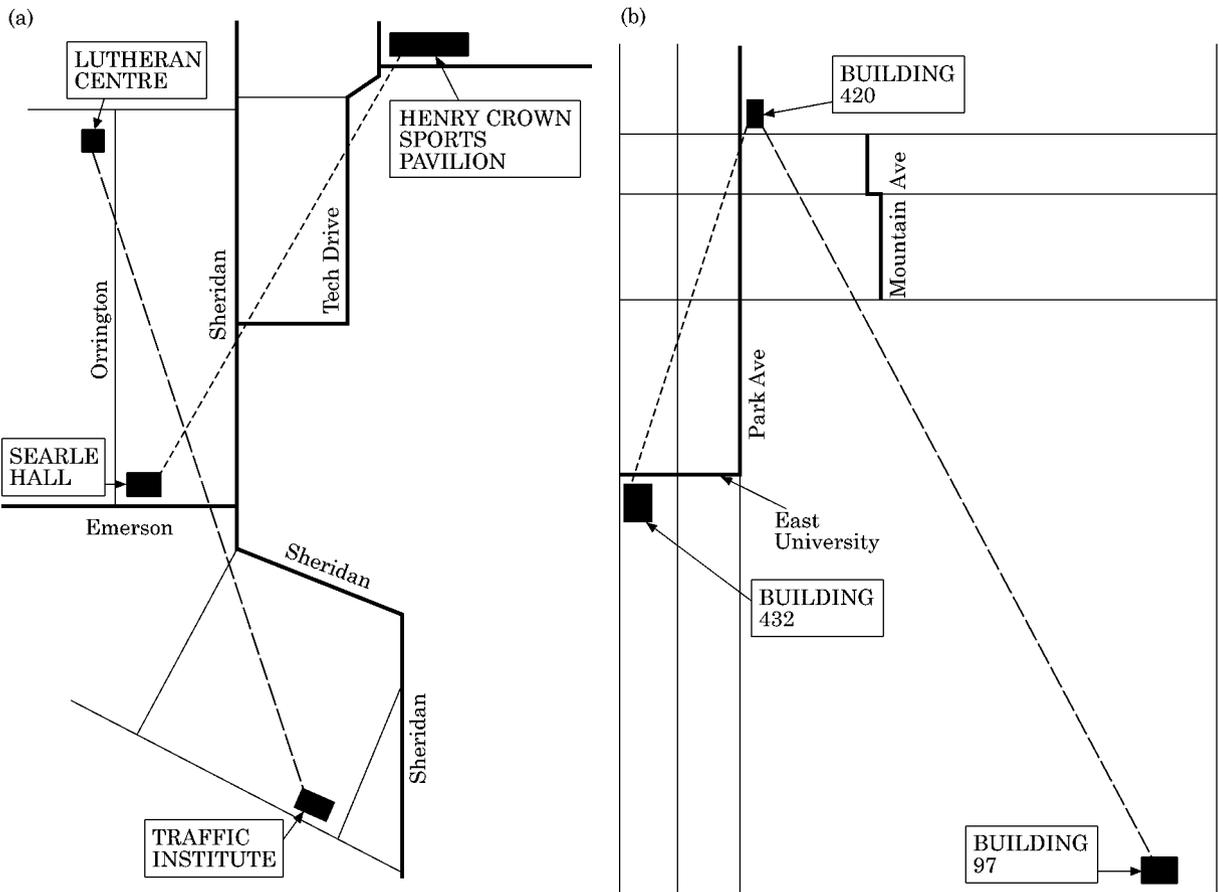


FIGURE 2. Schematized versions of the NU and UA maps used in Experiment 2. (a) shows the NU map and (b) shows the UA map. For each map, dashed lines connect the origin and destination for each route. Large dashes indicate the long route, while short dashes indicate the short route. Bold lines indicate roads which were chosen as consensus roads.

tance between these two buildings on the page was 16.50 cm and the shortest route using the specified paths was 31.24 cm. The short route was between Buildings 97 and 420 (Euclidean distance = 10.16 cm, specified path distance = 17.78 cm).

Procedure. In the main experiment, subjects were tested with either the NU ($n = 36$) or the UA ($n = 34$) maps; no subject saw both maps. Within each map, origin and destination points were indicated by different colors and were varied such that half the subjects received one location as the origin and the other half received the other corresponding location in the condition as the origin. Subjects were tested in both length conditions, and order of the conditions was counterbalanced so that half received the long route first and half the short route. Therefore, because there were three factors

with two levels apiece (length of route, origin point, and order of length) there were eight possible variants of the design for each map.

Subjects were tested individually in sessions ranging in size from 15 to 25 people. Each subject received a packet consisting of three pages: an instruction sheet, and the two maps corresponding to the particular condition to which the subject was assigned. The experimenter read the following instructions aloud:

In the following experiment, you will see two maps of Evanston's (or University of Arizona's) campus. Each map is on a separate page. You will see that two areas on each map are circled. One area is purple, and one area is yellow. Imagine that you are traveling on foot from the origin circled in yellow to the destination circled in purple. So you are going from the yellow area to the purple area. While you travel, you must stay on either the street or on a marked pathway. You cannot cut diagonally through blocks unless a distinct sidewalk is marked.

Please begin on the street which is next to the building circled in yellow.

Subjects were allowed to complete the experiment at their own pace. The entire procedure took approximately 5 min.

Results

The goal of the analysis was to discover whether or not asymmetry in routes existed between two points on a map when origin and destination were varied. To this end, we examined the paths chosen by subjects in two steps: first, we determined whether there was a common road or section of a road which was uniformly preferred by subjects going each way. In other words, we wanted to see if a majority of the subjects who chose a route from point A to B preferred a single path and whether or not subjects going the reverse way (from point B to A) also consistently preferred a single route. We then compared the two consensus routes to see if they were the same and, moreover, if they were the ones that would be predicted by the use of road-climbing strategies. More explicit descriptions of this analysis follow in the sections below. Data from subjects who violated the rules of the experiment (e.g. those that went off the roads in their paths) were not used.³ Data from each map were analysed separately.

NU map—short route. For short routes, there appeared to be a consensus path between Crown and Searle regardless of which point was the origin and which the destination. This path involved Emerson, Sheridan and Tech Drive (see Figure 2), and was taken by 15 out of 18 subjects going from Searle to Crown (83.33%), and 11 out of 16 participants going from Crown to Searle (68.75%). This difference was not significant, $\chi^2(1) = 1.01$. Although this null result does not provide conclusive evidence, it suggests there was not substantial difference between the two groups; moreover, this idea is supported by the finding that only two out of the 34 total paths were singular, that is, chosen by only one subject.

NU map—long route. Data from the long routes were more difficult to analyse as there was no clear consensus on a single entire route from start to finish. We decided to examine the general route selected by subjects, as determined by the 'main' road on which they chose to travel. This *consensus road* was calculated by finding for each subject the street upon which most of the distance between

the origin and destination was traversed. Analysing the results this way, we found that Sheridan Road (see Figure 2) was the consensus road used by 14 out of 18 subjects in the condition with the Traffic Institute as the origin; on the other hand, only three out of 17 subjects had Sheridan Road as their consensus road in the condition with the Traffic Institute as the destination. In this latter condition, subjects were more likely to use Orrington as the consensus road than Sheridan. This difference between groups is reliable, $\chi^2 = (1) = 10.30$, $p < 0.05$, and suggests that the routes chosen by subjects in the two conditions were clearly different from each other.

UA map—short route. For short routes, there was a clear consensus as to what path to take regardless of the origin building. This path is simple and involves just two streets: East University and Park (see Figure 2). Ten out of 14 participants chose this route when 432 was the origin, and 13 out of 14 chose this route when 420 was the origin; there was no significant difference, $\chi^2 = (1) = 2.19$. Even though the environment was unfamiliar, subjects were still consistent as to what route they selected.

UA map—long route. Again there was no clear agreement as to what specific path to take, so we employed the consensus road analysis described above. The consensus road used by subjects when Building 420 was the origin was Mountain Avenue (see Figure 2); seven out of 17 subjects had this as their consensus road. In contrast, none of the 13 subjects had Mountain Avenue as their consensus road when Building 420 was the destination. This difference was significant, $\chi^2 = (1) = 6.96$, $p < 0.05$ and suggests that subjects in the two groups were selecting qualitatively different routes.

Discussion

The results demonstrate that our model of road climbing and asymmetries extend to real world maps. We are able to predict which routes subjects would select, and when asymmetries would occur. Subjects were asymmetric on choices on Long Routes, but not on Short Routes. We believe this was due to Long Routes being more cluttered than Short Routes, which presumably led subjects to process the maps on a region-by-region basis and to use a road-climbing heuristic to select their routes.

It is important to note that the consensus routes used by subjects for the Long Routes in Experiment 2 were, generally speaking, also the routes that

would be predicted by a road-climbing model. As an example, on the Long Route on the NU Map, both Sheridan and Orrington provide long, straight paths between the Traffic Institute and the Lutheran Center. However, Sheridan is closer to the Traffic Institute than to the Lutheran Center, while Orrington is closer to the Lutheran Center than to the Traffic Institute. Note that subjects who had the Traffic Institute as the origin were more likely to select Sheridan Road than subjects who had the Traffic Institute as the destination. It seems to be the case that subjects preferred to exit the origin region as quickly as possible by selecting the longest, straightest path that was nearest to the origin.

Manipulation check. We have assumed to a certain extent that there will be more regions encompassing our Long than our Short Routes. So far, we have only used an intuitive notion of 'clutter' to describe this difference, but it would be better to ask subjects directly whether or not there were indeed more regions in our Long than Short Routes. To this end, we conducted a post-test manipulation check in which a group of 19 new subjects (10 male and 9 female) was asked to break up the maps used in Experiment 2 into regions based on the following instructions:

Your job is to look at each map and to partition it into separate regions. For example, a map can represent a city, and the city can be broken down into different neighborhoods. Or, sometimes boundaries such as lakes or highways break a map into separate regions. In this experiment, you will determine how many regions are in each map, and where the boundaries of those regions are. Use a pen to draw lines which surround your designated regions.

On the Long Routes, subjects drew an average of 2.89 regions, while on the Short Routes, subjects drew an average of 1.85 regions.⁴ This difference was significant, $t(18) = 2.94$, $p < 0.05$. This result indicates that there were more regions encompassing our Long than our Short Routes.

General discussion

Taken together, the results demonstrate that asymmetries in route-planning from maps occur frequently and across a variety of spatial layouts. We found numerous asymmetries, both when participants used real maps of college campuses (Experiment 2) and when they used maps that we created

to test specific hypotheses (Experiment 1). In addition, we reliably predicted both when asymmetries would occur and the general routes that participants would choose in planning routes in one direction and in the reverse (Experiments 1 and 2). The results extend those of previous work (e.g. Stern & Leiser, 1988; Christenfeld, 1995) by showing that the occurrence of asymmetries is not limited to situations in which the options are identical in terms of route length or distance.

Experiment 1 established that using the road-climbing strategy could lead to asymmetries in route choice. In that experiment, people reliably preferred routes with relatively long, straight initial segments. This was true even when the preferred routes were substantially longer in terms of Euclidean distance from an alternate route that did not begin with a relatively straight and long section. The results of this experiment therefore establish clearly that people may rely more on the initial segments of routes rather than on overall Euclidean distance. Similarly, in Experiment 2, the consensus roads that subjects selected coincided with those that would be predicted by a road climbing model. Participants' first choices in planning a route focused largely on selecting a route segment that exited the origin region quickly and went in the correct general direction, much like movement toward a solution in the hill-climbing strategy in solving a problem. The consistent preference for routes with relatively long and straight initial segments can lead directly to asymmetries in route choice; the preferred initial segment when traveling in one direction will often be different than the comparable segment when traveling in the opposite direction. In sum, it is the initial decision to select a straight route that proceeds in the right general direction that sets the stage for path asymmetry.

In demonstrating that asymmetries stem in part from heuristics or strategies that people use to plan routes, our results are thus similar to those of other studies which have found that the use of heuristics in problem-solving can lead to asymmetries or systematic biases. Although heuristics, such as the road-climbing strategy, can lead to inaccuracies or asymmetries, they can also be useful ways of reducing the amount of information that must be processed to make a decision (Christenfeld, 1995). The road-climbing strategy leads to predictable asymmetries that might be considered nonoptimal in terms of minimizing travel distance or time. However, road climbing will usually lead to reasonably short routes with much less cognitive effort than would be required to do an exhaustive search for

the optimal route. In short, road climbing is a reasonable compromise between the desire to select optimal routes and the cognitive effort needed to do so in cluttered regions.

Our results are consistent with recent claims that asymmetries in other spatial tasks, such as distance judgments, do not stem necessarily from the way in which information is represented mentally or from limitations in the way that people make distance judgments (Newcombe *et al.*, 1996; McNamara & Diwadkar, 1997). We view road-climbing as arising from a heuristic that reduces cognitive effort rather than from a more fundamental limitation on the processing or representation of spatial information. An important question in this regard is whether people's route choice could be more symmetric under different circumstances. For example, could people choose the shortest possible route, regardless of direction of travel, if the need to do so was extremely important? The answer to this question is probably yes, but the time that would be needed to plan the route may negate the advantage that would be gained in travel time. Road climbing may be the best compromise between time needed to plan an optimal route and the extra time required to travel a less-than-optimal route.

One question that could be explored in future research concerns the extent to which people rely on road-climbing. We claim that initial choices in the route-planning process often are based on road-climbing, but at some point in the process people almost certainly would change to another strategy that would ensure that they reached the goal. In other words, in the initial stages of route climbing, people seem concerned with picking long and straight routes that seem to move them toward the goal. As they near the goal, however, they rely on a more fine-tuned process that guarantees arrival at the destination (see Gallistel, 1990, for a similar discussion of route planning in some animal species). It would also be interesting to see if subjects' strategies would shift if they were given explicit instructions such as 'find the shortest route', for example.

An additional question for future research concerns the relevance of the findings for 'real world' navigation. Would the present findings and model generalize to the kinds of environments in which people typically navigate? On one level, the results seem directly generalizable: Experiment 2 demonstrated asymmetries in route planning across two different college campuses that had vastly different layouts. However, people may rely on different types

of strategies when they are actually traversing through an area as opposed to planning routes from maps. One possibility for future research is to test the road-climbing hypothesis with subjects who are actually traveling from origin to destination.

The results may have other important practical applications. When traveling in large, urban areas, people are often faced with choosing between several alternate routes, each of which is a viable option in terms of perceived distance, the likelihood of traffic congestion, etc. In these situations, people are likely to rely on heuristics, such as road climbing, that reduce the amount of cognitive effort that might be needed to select the ideal route. Our results therefore may help traffic engineers and city planners to predict with greater accuracy which routes people are likely to prefer. For example, our results lead to specific predictions regarding traffic flow patterns: given two alternate routes, people are likely to select routes with initially straight segments.

Our findings also may aid in the design of maps, particularly those that are intended to facilitate the choice of routes. For example, knowing the kinds of routes that people prefer when making selections on maps might allow cartographers to highlight those choices. Conversely, knowledge about which routes people are likely to select might also allow cartographers to highlight routes different from those predicted by our road-climbing model. It seems likely that the cognitively-preferred route will sometimes be a relatively poor choice in terms of distance, travel time, or traffic. Therefore, cartographers and traffic engineers must know when they should help people not to make the choices that seem appealing but that do not provide the optimal route.

It seems that our model and results would apply best to situations in which people must navigate through fairly cluttered areas, such as neighborhoods within a city. In this situation, the person planning a route is faced with numerous choices; people will resort to the road climbing. In other situations, however, the choice of routes may be greatly influenced by the existence of specific highways that constrain the number of choices that one can make and hence reduce the chance of asymmetries. By analogy, there may be relatively few ways to travel between major cities that are several hundred miles apart, and most maps show only a small subset of the total number of roads that one might encounter when traveling through the various regions. In this situation, the possible routes are highly constrained by the availability of highways

and the depiction of routes on maps. Hence many people are likely to choose the same route regardless of direction of travel. However, once one reaches the vicinity of the target city and exits the highway, the process of finding a specific location may involve numerous choices regarding which of many possible streets to follow at numerous junctions. It is these latter kinds of choices that are likely to be asymmetric.

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Notes

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(1) On Experimental Map A, the length of the road-climbing and anti-road-climbing routes was 36.83 cm and the length of the shortest route was 26.67 cm. The shortest route was always the center route, while the position of the road-climbing and anti-road-climbing routes varied depending on which buildings were designated as origin and destination. On Experimental Map B, the length of the road-climbing and anti-road-climbing routes was 36.12 cm and the length of the shortest route was 24.13 cm. Again, the shortest route was always the center route, while the position of the road-climbing and anti-road-climbing routes varied depending on which buildings were designated as origin and destination. Finally, on the Experimental Map C, the shortest route was much shorter (33.02 cm) than the road-climbing and anti-road-climbing (55.88 cm). We predicted that in this case, subjects would indeed choose the shortest route because it differed so dramatically from the other two. This map type therefore provides a control to demonstrate that people can select the shortest route when it is the most salient.

(2) Although amount of driving experience was not controlled for, we made the assumption that all our subjects were approximately equally experienced as drivers, considering that they were primarily freshmen.

(3) For the NU map we excluded 4 per cent of the maps; this resulted in 18, 16, 18, and 17 subjects in the Short (Searle to Crown), Short (Crown to Searle), Long (Traffic to Lutheran), and Long (Lutheran to Traffic) routes, respectively (note that each subject participated in two experimental conditions). For the UA map we excluded 14 per cent of the maps; there were 14, 14, 17, and 13 subjects in the Short (432 to 420), Short (420 to 432),

Long (420 to 97), and Long (97 to 420) routes, respectively.

(4) For a particular route, a number of regions along the route were calculated by drawing a region line directly from the origin to the destination, and counting the number of regions the line intersects.

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