Let’s Go for a Run: Planning Routes to Remember

Holly A. Taylor (holly.taylor@tufts.edu)
Department of Psychology, Tufts University
490 Boston Ave., Medford, MA02155 USA

Thora Tenbrink (tenbrink@uni-bremen.de)
Department of Linguistics and Literary Sciences, Cartesium 1,059
Enrique-Schmidt-Straße 5 28359 Bremen GERMANY

Molly E. Sorrows (msorrows@gmail.com)
Department of Psychology, Tufts University
490 Boston Ave., Medford, MA 02155 USA

Abstract

Research shows that people handle the complexity of environments by cognitively simplifying them using spatial schemas and heuristics. Such simplification strategies can be seen in route planning situations, such as the Travelling Salesperson Problem (TSP) and tour planning. The present study extends this work by examining a situation where memory demands must be considered during route planning -- planning a running route through an unfamiliar area. Results of routes planned on maps in grid-like and non-grid-like environments suggest that the planned routes reflect aspects of cognitive simplification to meet memory demands. This was evident in both global and local features of the routes. Globally, route trajectories tended towards simple shapes in accord with the affordances of the environment. Locally, changes of direction were preferably chosen at landmarks. More demanding (non-grid) environments led to an increase in simplification strategy use, such as relying on major roads, and avoiding complex decision points.

Keywords: route planning, memory, spatial cognition.

Introduction

A *Cognitive Science Conference* attendee decides to hit the streets of Boston for an early morning run. Being unfamiliar with Boston, she checks an on-line map to plan a route. She knows she wants the route to begin and end at her hotel and be approximately 3 miles long. She also knows that while she could carry a concierge-provided map, she prefers to remember the route so as not to interrupt the flow of her run. Will her planned route through this unfamiliar environment reflect the cognitive demands of remembering it? The present experiment explores this question. Using running routes as a route-planning task provides an excellent naturalistic context for exploring how anticipated memory demands may influence the route planning process.

People commonly plan routes through unfamiliar cities with the aid of a map and then embark on their route without the map, sometimes successfully and other times not. Maps reflect the information rich nature of the environments in which we consistently engage. The information-richness, however, means we cannot remember everything about them. Instead, we extract what information we need (or think we need), sometimes schematizing it for later use (Freksa, 1999; Tenbrink & Winter, 2009; Tversky, 2001). The question in the current research is whether and in what ways people account for memory demands when planning routes. Furthermore, we address the extent to which route planning strategies are influenced by the structure of the environment.

One route-planning situation examined extensively is the Traveling Salesperson Problem (TSP). The TSP is an optimization problem wherein one devises an itinerary to visit a given number of cities, visiting each one once, while minimizing travel costs, and ending at the starting point. While hypothetical, the TSP is not unlike planning the best route to complete a set of errands. From a computational viewpoint the TSP is complex. Indeed, an efficient computational algorithm for the TSP has not been identified (Applegate et al., 2007). Yet, humans solve it relatively efficiently (e.g., MacGregor & Ormerod, 1996; Tenbrink & Wiener, 2009), most likely by employing some type of cognitive simplification or heuristic (Tversky & Kahneman, 1974) that focuses on the global spatial properties of the problem (Ormerod & Chronicle, 1999). Little work has applied findings based on the TSP to everyday navigation (Wiener & Tenbrink, 2009), apart from some studies on urban activity planning (e.g., Gärling et al., 1986).

Planning running routes to remember in unfamiliar cities differs from the TSP in interesting ways. First, the success of completing a running route in an unfamiliar area may depend on knowing the details. This is particularly true in areas without predictable structure (as in some areas in Boston). Predictable structure (e.g. roads forming a grid, symmetric city organization, etc.) affords more tolerance for divergence from the planned route. Second, running routes often have no particular sub-goals and instead focus on global goals of distance or time. In contrast to the TSP, route efficiency is not the primary emphasis. Planning a holiday or sightseeing tour bears similarity to running route planning in this way. Tenbrink and Seifert (2011) examined tour planning by having participants plan a 14-day island tour for a friend. They found that people approached this planning task by systematically simplifying its complexity (Freksa, 1999) in similar ways as in the TSP. For example, paths were coherent and circular rather than random (indicating planners' attention to trajectory shape), and the spatial organization was further managed by focusing on clusters of goal locations or sub-regions (e.g., eastern and western parts of an island). Both of these techniques are known from earlier research on human TSP solving (Ormerod & Chronicle, 1999; Graham et al., 2000). Thus, people deal with complexities of route planning using basic cognitive simplification strategies that are flexibly adaptable across tasks. Third, running routes differ because they are ideally committed to memory, whereas the TSP and tour plans are not (but see Wiener, Ehbauer, & Mallot, 2009). Memory demands should further promote use of heuristics and simplification strategies. However, to our knowledge, no previous work has explored how known memory demands influence the route planning process in a task involving no sub-goals.

Route selection, as opposed to planning, research suggests possible simplification strategies. More decision points increase memory load, thus people should select routes that decrease decision points. Any decision point, such as an intersection, requires a decision about reorientation. Bailenson, Shum, and Uttal (2000) support this contention, showing that people tend to choose routes that are initially long and straight (see also Hochmair & Karlsson, 2005). Similarly, Christenfeld (1995) showed that people choose the last possible turn to a destination, even holding distance constant. Deviating from the destination increases orientation demands, thus people should select routes that show either minimal or systematic deviations. Bailenson, Shum, and Uttal (1998) support this prediction showing a preference for routes that do not deviate globally from a destination (Hochmair & Karlsson, 2005).

Another likely strategy is to rely on perceptually available patterns in the street network when looking at the map. When thinking about and navigating in space, humans rely heavily on whatever structure the environment provides (Golledge, 1999; Tversky, 2003). Davies & Pederson (2001) demonstrate the effects of urban grid patterns on orientation, memory, and features of sketch maps drawn by participants. Clear gridlike structures in the environment, then, can be expected to affect route planning particularly in the case of memory demands.

Route planners are also likely to use the salience of landmarks in their routes (Klippel & Winter, 2005; Sorrows & Hirtle, 1999). Landmarks serve an organizing role in memory for environments (Gollege, 1999), not unlike that of spatial categories (Maddox, Rapp, Brion, & Taylor, 2008; McNamara, Hardy, & Hirtle, 1989).

In the present study, participants planned a 2 to 3 mile running route using one of two maps, knowing they would have to remember the route. The maps depicted areas that intuitively should differ in memorability, due to the extent to which spatial schemas could be applied to them (Moar & Bower, 1983). One map represented a region with streets arranged roughly in a grid while the other showed a region without the structure provided by a grid. We expected evidence of memory-based planning to be evident in two ways. First, the routes should, in general, exhibit characteristics of simplification in relation to baseline characteristics of the environment. For one example, routes would use landmarks at decision points at a rate exceeding the general availability of landmarks in the environment. Second, a grid pattern should support simple trajectory shapes, such as squares or rectangles, which are not available with a non-grid pattern. In contrast, the routes in the non-grid environment should show increased evidence of simplification heuristics due to the environment's increased complexity. In this case, the increased complexity comes about because a regularized pattern that a grid imposes is unavailable.

Experiment

Methods

Participants. Thirty-four participants, who had responded to advertisements seeking joggers and runners, completed the study. Prior to coming to the experiment, each participant completed a running experience questionnaire asking about gender, running frequency (times per week), and average distance per run. Using this information, we assigned participants to one of the two route map areas, thus equating participants planning in these areas for gender, running frequency, and running distance. Data from one participant (assigned to Map 1) was eliminated from analyses due to computer recording error. In this study, participants were asked to plan a running route as if they would run it, but they were not actually asked to run.

Materials. We used a commercially available web-site (www.mapmyrun.com). We selected three map areas such that participants would not be highly familiar with the area, but it was within driving proximity of Tufts University. One area served as a training map. The two experimental areas differed such that one had streets forming primarily a regular grid pattern and the other was perceptually ungrid-like, i.e., showed a less clearly structured pattern. Although differing in adherence to a grid structure, the two areas did not differ substantively in complexity. We determined complexity by coding environment characteristics of two overlapping circular regions (0.75 mile diameter and 1.5 mile diameter) centered on the designated starting point for route planning. The diameters of the regions represented the most likely area used for route planning of a 2 to 3 mile run if participants planned a loop course (0.75 mile) and if they planned an out-and-back course (1.5 mile).

Characteristics coded included road segments (road between intersections), distinguishing between major and minor roads, intersections, distinguishing number of branches and prototypicality, and landmarks. Landmarks consisted of park boundaries, main road intersections, and atypical road properties (e.g., traffic circles; cf. Lynch, 1960). See Table 1 for characteristics of these environments, and Figures 1 (grid) and 2 (nongrid) for screenshots with example routes.

Table 1: Baseline map area characteristics

Map (diameter)	Minor Road Segments	Proto-typical DP	2 to 4-way DP	Land-marks
Grid (0.75)	83%	82%	98%	48
Non-grid (0.75)	81%	77%	99%	40
Grid (1.5)	93%	81%	98%	214
Non-grid (1.5)	88%	75%	99%	219

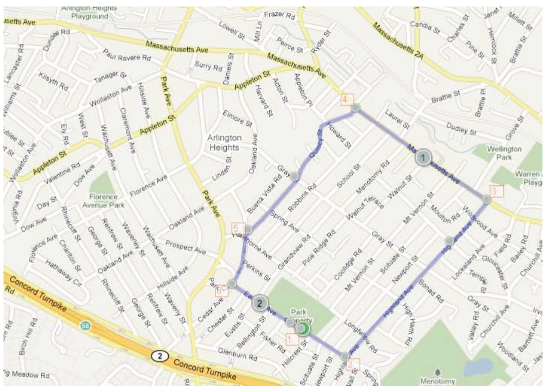

Figure 1: Grid environment with example route. The green dot (south) marks the designated start- and endpoint.

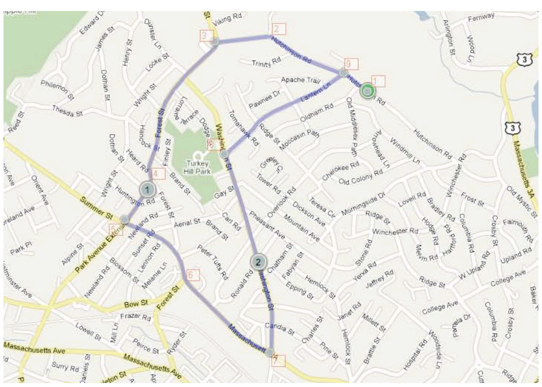

Figure 2: Non-grid environment with example route. The green dot (north) marks the designated start- and endpoint.

Procedures. Participants first planned a route on www.mapmyrun.com in the practice area to familiarize themselves with technical aspects of marking a route on the map. They started at the designated starting point, marked with a green circle. The experimenter pointed out how to undo parts of the route if the participant changed their mind and how to complete the route at the end. After completing the practice route, the participant saw a different browser window with the assigned mapping area and starting point visible. The experimenter informed participants that they should plan a 2 to 3 mile running route that they would be able to later recall. Participants then planned their route by marking it on the map with the web-site tools. After the participant had completed their route, the experimenter saved the route via a screen capture.

Results

Data Coding and Analyses. Coding of the planned routes involved two approaches, a local and a global approach. For the local approach, initial coding involved the first author marking segments on each planned route. A segment started at a decision point (e.g., beginning of route, intersection) and included the path until the next decision point. A decision point was defined by whether the segment changed direction (as defined by Klippel et al., 2004) and whether an alternative direction existed. In some cases direction change at a decision point involved a change in street name. If the street name did not change, a new decision point was defined only in the case of a minor road, and only if a sharp corner existed at an intersection. Major and minor roads differed on the map by color. The second author reviewed all coding and disagreements were resolved through discussion. Number of segments served as one of the dependent measures of route complexity.

A trained research assistant coded each segment of the planned routes for characteristics of the decision point and of the path. Characteristics of the decision point included number of direction options, prototypicality, direction of turn (sharp, prototypical, or veer, cf. Klippel et al., 2004), and available landmarks (e.g., parks, complex intersections, major roads encountered along the way; cf. Lynch, 1960). Characteristics of the paths included street name, major or minor road, whether path was retraced during the route or a decision point was crossed for the second time, and the number and type of intersections (potential other decision points) along the path. One final variable coded how path name interacted with direction choices at a decision point, i.e., whether one could have gone more than one direction on the same road at the decision point.

The global approach involved visual inspection of the routes and coding of features related to shape and extent of the routes.

Analyses consisted of two types of t-tests, those comparing route characteristics to the baseline occurrence of these characteristics in the environment (see Table 1) and those comparing characteristics of the planned routes as a function of the different map areas (grid vs. non-grid).

General Characteristics of Planned Routes. The planned routes had on average 9.82 segments. Planned routes had more of a loop than an out-and-back pattern. This fact was confirmed initially by visual inspection of the routes. Of the 33 maps analyzed, only one (grid environment) followed an out-and-back path. Two others (one from each environment) followed an out-and-back with a loop at the turn around, sometimes called a lollipop course by runners. The looped structure was confirmed statistically by examining the proportion of route segments not overlapping with any other part of the route (95%), ($t(32) = 27.7$, $p < .001$). Not a single route involved a crossing of the trajectory, which would mean using an intersection twice without retracing any associated segment of the route. In other words, no routes resembled the shape of an 8, or the like.

Analysis of turn direction also confirmed the tendency to plan routes that made a loop. Routes involved turns in a single direction more often than would be predicted by chance ($M = 73\%$; $t(32) = 11.49$, $p < .001$). The proportion of turns of a particular direction (e.g., right turns) did not differ statistically from chance ($p > .05$), but showed a slight preference for left turns (58%).

Other segment-based features of the routes showed that as a whole, the planned routes utilized major and minor roads in proportions similar to those in the environments, as indicated by the baseline environment coding ($p > .95$). Further, planned routes made heavy use of landmarks (63% of time) at decision points. This landmark use exceeds the baseline proportion (30%) of landmarks to decision points ($t(32) = 10.706$, $p < .001$).

Characteristics Differing by Environment. The planned routes did not differ between map areas in terms of the total number of segments ($p > .80$), with an average of 9.75 segments for the grid area and 9.88 segments for the non-grid area. Similarly, use of landmarks at decision points did not differ as a function of map area ($p > .65$).

Analyses focusing on characteristics of the decision points themselves showed differences as a function of map area. The number of direction choices at a decision point differed by map area ($t(31) = 3.047$, $p < .01$), with routes in the grid environment ($M = 3.56$ choices) having somewhat more complex directional choices than those in the non-grid environment ($M = 3.34$ choices). The greater complexity of directional choice at decision points could also be seen in use of decision points where one could turn in more than one direction on the same road ($t(31) = 3.46$, $p < .005$. Use of these types of decision points occurred more in the grid environment (70% of decision points) than in the non-grid environment (49% of decision points). Participants also differed in the types of turns they would use as a function of environment. Although the two environments did not differ overall in the proportion of prototypical (close to 90-degree) intersections (see Table 1), participants included more turns classified as "veer" in the non-grid environment (41%) compared to the grid environment (17%) and to baseline occurrence in the environment ($t(31) = -4.392$, $p < .001$). Use of turns classified as "sharp" also occurred more in the non-grid (12%) than in the grid environment (2%), $t(31) = -4.694$, $p < .001$, but less than predicted by occurrence within the environment.

Characteristics of path segments also differed as a function of map area. Although overall the routes used major and minor roads proportionally similar to their presence in the environments, within this proportional range the use of major roads differed by map area. Routes in the grid environment (12% of segments) utilized major roads to a lesser extent than those in the non-grid environment (27% of segments). Routes in grid environments stayed on the same path longer (passing an average of 4.04 possible decision points) than those in non-grid environments (passing an average of 2.76 possible decision points; $t(31) = 2.395$, $p < .05$).

Discussion

When planning a running route in an unfamiliar city, one generally has in mind some desirable properties of that run. Regardless of any other properties, a key one is being able to return to the start, whether it be to one's car or hotel. To do so effectively requires remembering the planned route. Although the role of memory in this context is clear, does one incorporate this role in planning the running route? The present study explored whether and in what ways people account for memory demands when planning running routes. We manipulated memory demands through characteristics of the environments, using one grid-like environment and one non-grid environment. While cultural experiences and expectations about urban areas guide use of environment grids (Davies & Pederson, 2001), regardless of this experience a grid does provide a predictable structure that then allows some cognitive off-loading.

The overall structure of the planned routes provides some evidence of simplification. Considering the full range of route structures, the range would seem to be the least complex out-and-back option to an intermediately complex loop course to the most complex random or unstructured course. The vast majority of participants (30 of 33) planned a loop course. While evident through visual inspection, this overall structure was confirmed by the absence of trajectory crossings, the low proportion of segment overlap, and the high proportion of turns in a single direction occurring within a route. Thus, generally route trajectories corresponded to shapes also known to be preferred in human solutions to the Traveling Salesperson Problem (Ormerod & Chronicle, 1999) and tour planning involving a set of goals (Tenbrink & Seifert, 2011). In the TSP, avoiding line crossings is clearly a useful strategy in order to find the shortest route (Van Rooij et al., 2003). Apparently, however, this goal is not the only driving force for such a strategy, since this same type of route efficiency is not a primary emphasis in running route planning. The complete avoidance of line crossings found in our study may thus seem surprising, also in light of the fact that the holiday tour plans reported by Tenbrink and Seifert (2011) did involve a number of path crossings. However, a simple general trajectory certainly supports the memory demands involved in our study but not in tour planning and as such may reflect efficiency in this context.

Only a few participants (a total of three) adopted strategies to wholesale minimize memory demands. Only one participant took an out-and-back course. An out-and-back course minimizes the different road names traversed and allows a strategy for remembering directions at decision points, namely “reverse the direction used on the way out.” This participant also noted specifically planning an out-and-back course to minimize memory load. Two other participants planned lollipop routes, characterized by out-and-back courses with a loop at the turn around. The small number of these “memory saving” strategies suggests that while memory may be important in route planning, other factors also play a role. Some of these reasons, although not explored in the current study, might be more aesthetically, emotionally, or motivationally based.

While memory or cognitive demands may not account for all aspects of running route planning, we argue that our results, without having given participants explicit instructions about memory, point to cognitive influences in route planning. Running route planners appeared to support their memory by relying on landmarks to a much greater extent than would be expected in the environment. Participants used decision points with landmarks at rates more than doubling the baseline occurrence. This finding reflects the vast earlier literature highlighting the importance of landmarks in spatial representations (Sorrows & Hirtle, 199) and wayfinding (e.g., Lynch, 1960; Evans et al., 1984). Our finding also extends more typical definitions of landmarks. Unlike typical definitions of landmarks, including buildings, statues, parks, etc., the landmark information available to participants included those evident on a typical map. While maps do note parks and some buildings, the more common map landmarks emerge from the street network’s structural elements. This is consistent with Claramunt and Winter’s (2007) finding that people do engage the street network’s structural elements as landmarks. Our finding also extends work showing landmark salience in memory for environments, as seen in maps and descriptions (Klippel & Winter, 2005; Taylor & Tversky, 1992), to route planning situations. To our knowledge there is no evidence so far for the role of landmarks in a scenario involving a general trajectory resembling that of a TSP task. Our results thus provide first evidence for a compatibility of an orientation to landmarks with a loop-based route plan.

Evidence of simplification can also be seen when comparing route characteristics between the grid and non-grid environments. As predicted, routes in the non-grid environment showed greater evidence of simplification strategies. Routes through the non-grid environment used major roads to a greater extent, and used less complex decision points. Additionally, routes through non-grid environments reduced the need to remember the direction of turns. These routes tended to use decision points where a road name corresponded to a single possible travel direction. However, routes in grid environments stayed on the same path longer, similar to known simplification heuristics in path selection tasks (Bailenson et al., 2000; Christenfeld, 1995).

One suggestion to explain the difference in evidence of simplification strategies as a function of environment structure (grid versus non-grid) lies in the affordances of the environment. Participants clearly planned routes that followed a loop, starting and ending at the same point but having little to no overlap, and no crossings. The shape of the loop, however, appeared to differ. In the non-grid environment, the planned routes made much more use of turns that changed direction (veer). This might reflect an (often rather unsuccessful) attempt to form a *circular path*, similar to the *aesthetically pleasing* TSP solutions found by Vickers et al. (2001). Such an attempt would make little sense in a grid pattern environment, which suggests itself much more to a *square* or rectangular pattern. Aiming to achieve a square-like structure would lead to the observed effect of passing more decision points: the traveller would tend to continue straight ahead until the next corner of the square, rather than veer to one side to achieve a curved trajectory.

While the behavioral data in this study alone do not capture all aspects of participants' actual underlying aims, our results are consistent with the assumption that participants chose trajectories that utilized the environment's spatial characteristics as optimally as possible for their running route. Simple geometric figures such as circles and squares may provide substantial cognitive support in this regard. Additionally, the strength of the current study’s findings lie in its direct applicability to real-world behavior. Our paradigm closely matches an activity in which people commonly engage, planning the route they themselves might run in an unfamiliar city. The observed parallels of our findings to those of TSP and other related studies suggest shared cognitive processes of route planning across situation contexts. Simplification appears to be decisive in each case, adapted to the task with its specific requirements as well as to the features of the environment involved.

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