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North is Up(hill): Route Planning Heuristics in Real-World Environments

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Abstract

Navigators use both external cues and internal heuristics to help them plan efficient routes through environments. In six experiments we discover and seek the origin of a novel heuristic that causes participants to preferentially choose southern rather than northern routes during map-based route planning. Experiment 1 demonstrates that participants who are tasked to choose between two equal-length routes, one going generally north and one south, show reliable decision preferences towards the southern option. Experiment 2 demonstrates that participants produce a southern preference only when instructed to adopt egocentric rather than allocentric perspectives during route planning. Experiments 3-5 examine participants' judgments of route characteristics and find that judgments of route length and preferences for upper relative to lower path options do not contribute to the southern route preference. Rather, the southern route preference appears to be a result of misperceptions of increased elevation to the north (i.e., north is "up"). Experiment 6 further supports this finding by demonstrating that participants provide greater time estimates for north- relative to equivalent south-going routes when planning travel between U.S. cities. Results are discussed with regard to predicting wayfinding behavior, the mental simulation of action, and theories of spatial cognition and navigation.

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North is Up(hill): Route Planning Heuristics in Real-World Environments

I always like going south.
Somehow it feels like going downhill.

- Treebeard, Lord of the Rings

Wayfinding, or moving purposefully from origin to destination, is a highly complex yet exceedingly common human task. Sometimes we move unaided, retrieving and applying mental representations of environments to guide us from place to place; other times we move aided by external representations of environments, such as road maps and global positioning systems (GPS). In the absence of digital support, travelers must develop a route plan that details the path segments and turn angles that guide effective movement through an environment (Golledge, 1999; Montello, 2005). Six experiments provide the first evidence of a heuristic that biases the route planning process and produces a *southern route preference* wherein travelers disproportionately select southern rather than equivalent distance northern routes during planning.

Route Planning Asymmetries

In most cases the ostensible goal of wayfinding is to move from one place to another as quickly and effortlessly as possible. This process is accomplished by reviewing the spatial relationship between an origin and destination, identifying and comparing route options, and selecting the most viable path (Benshoof, 1970; Bovy & Stearn, 1990; Gärling, Lindberg, & Mantyla, 1983; Golledge, 1995; Jacoby, 1917; Seneviante & Morrall, 1986). When interviewed, most agree that they can identify the shortest and most efficient route quickly and without much effort, particularly when using a road map (Gärling & Gärling, 1988; Ueberschaer, 1971). People are not generally aware, however, that their route selections are affected by several implicit strategies for deciding which route to choose when there is no objectively ‘correct’ decision (Bailenson, Shun, & Uttal, 1998; Christenfeld, 1995; Conroy Dalton, 2003; Gärling & Gärling, 1988; Golledge, 1995; Hochmair & Karlsson, 2005; Holscher, Meilinger, Vrachliotis, Brosamle, & Knauff, 2006; Janzen, Herrmann, Katz, & Schweizer, 2000; Seneviante & Morrall, 1986; Wiener, Lafon, & Berthoz, 2008; Wiener & Mallot, 2003; Wiener, Schnee, & Mallot, 2004).

Some early work in this area (Christenfeld, 1995) found that when no objectively ‘correct’ decision exists during wayfinding, people use implicit strategies to minimize the mental and physical effort involved in moving through the environment. Indeed some work suggests that people will simplify route plans in an attempt to reduce the costs associated with planning and executing wayfinding sequences (i.e., Freska, 1999; Levine, 1982). Further work demonstrates that travelers use *least-angle strategies*, choosing routes that deviate minimally from the global direction of a designated goal destination (Conroy Dalton, 2003; Hochmair & Frank, 2002, Hochmair & Karlsson, 2005), *initial segment strategies*, choosing routes based on their initial straightness as they depart from an origin (Bailenson et al., 1998, 2000), and also choose routes containing the fewest number of landmarks and turns (Sadalla & Staplin, 1980; Senevirante & Morrall, 1986). Interestingly, these strategies are sometimes relied upon even when they result in selecting a relatively inefficient route. As such, predicting wayfinding behavior is best accomplished by knowing not only which route is shortest or most efficient, but also by considering several heuristics or implicit strategies that guide decision making, but seem to be outside of participants' awareness (Bailenson et al., 1998, 2000; Christenfeld, 1995). Identifying the full range of wayfinding heuristics is critical for the prediction of wayfinding behavior in applied contexts (i.e., in the lost, Heth & Cornell, 1998; or for environmental engineering, Gärling & Gärling, 1988; Raubal, 2002; Weisman, 1981), and the theoretical and computational modeling of human spatial behavior (Golledge, 1999; Kuipers, 2000; Montello, 1998; Yoshino, 1991).

Experiment 1: Southern Route Preference

In a recent study examining the influence of non-spatial variables on wayfinding performance (e.g., time, mode of locomotion, load carriage), we found evidence that participants were selecting southern rather than northern routes at a rate exceeding that predicted by chance. Given that this earlier research was not specifically designed to test wayfinding preferences, we conducted a series of experiments to directly examine this apparent southern route selection bias. Our first two experiments had participants plan routes between origin-destination pairs using modified maps of Pittsburgh, PA and Chicago, IL. The design of the maps and wayfinding pairs created either a north/south dilemma, an east/west dilemma, or no dilemma. Dilemma trials presented equal-length alternative routes between wayfinding pairs that went either to the south or north, or to the east or west. Filler (no dilemma) trials did not have competing route possibilities, i.e. one of the possible routes was perceptibly shorter. On dilemma trials we measured the extent to which participants chose north versus south and east versus west route options, to examine whether route planning deviates from chance behavior (50/50). We expected that if participants show a southern route preference, their selection of southern versus northern routes would depart from chance.

Given work demonstrating that the application of wayfinding heuristics might vary as a function of the perspectives adopted by participants (Janzen et al., 2000), we also examined the perspectives spontaneously adopted by participants during route planning, and how they might modulate any southern preference. In general, when describing a route one can adopt an egocentric, allocentric, or mixed perspective on an environment (Levelt, 1982; Taylor & Tversky, 1992a, 1992b). An egocentric ("first-person") perspective describes an environment from the ground level, referencing movements and turns to the dynamic position of an entity within the environment (e.g., *go forward, turn left, turn right, go back*). An allocentric perspective, in contrast, describes an environment from a "bird's-eye" view, referencing movement and turns to a fixed position outside of the environment, typically using cardinal terms (e.g., *north, south, east, west*). Maps typically depict the world in an allocentric perspective, maintaining a bird's-eye view on an environment. As such, adopting an egocentric perspective to describe movement through a map-based environment involves complex mental imagery and rotation in order to actively imagine oneself moving through the environment (i.e., Brunyé, Rapp, & Taylor, 2008; Brunyé & Taylor, 2008a, 2008b; Fincher-Kiefer, 2001; Tversky, 2009). Both perspectives are commonly used, and often mixed, when describing movement through an environment (Taylor & Tversky, 1992b).

Adopting different perspectives on an environment can affect the information people seek, gather, memorize, and can subsequently apply (Brunyé & Taylor, 2009; Magliano, Cohen, Allen, & Rodrigue, 1995; Taylor, Naylor, & Chechile, 1999; Tversky, 2009; van Asselen, Fritschy, & Postma, 2006). It might be the case that increased first-person immersion during route planning may exacerbate route planning preferences by activating the same heuristics that are used during actual, real-world wayfinding. This hypothesis is based on work demonstrating that taking alternate perspectives can differentially guide the mental simulation of actions, promote immersed (or "grounded") understanding, and activate mental representations that are common to those activated during action execution (Barsalou, 2008; Brunyé, Ditman, Mahoney, Augustyn, & Taylor, 2009; Ditman, Brunyé, Mahoney, & Taylor, in press; Fischer & Zwaan, 2008; Glenberg, 2007; Glenberg & Kaschak, 2002; Richardson, Spivey, McRae, & Barsalou, 2003; Ruby & Decety, 2001).

Method

Participants & Design

Sixty-four Tufts University undergraduate students (45 female; age *M* = 19.9) participated for monetary compensation. We used a repeated-measures design with three trial types: north/south dilemma, east/west dilemma, or no dilemma. We measured which route option participants chose in the two dilemma conditions (north/south and east/west). We also recorded whether participants used egocentric, allocentric or mixed terms to describe their chosen routes.

Materials

Maps. Two real-world environments were chosen from suburban Pittsburgh, PA and Chicago, IL, using the Google™ Maps utility at a zoom level of 1" = 290 linear feet. Each map measured 1200x793 pixels and contained a compass rose and thirteen landmarks: a park, chapel, dance club, bike shop, hotel, café, information booth, theater, café, grocery store, restaurant, and 3 metro stations. Each landmark was depicted with a representative icon and defined in a legend (see Figure 1). Two versions of the maps were created, one in the original orientation and one rotated 180° (maintaining a north-up compass rose orientation, and properly-oriented street name text); these two versions were used across-participants to control for effects of differential route complexity (e.g., number of turns; Seneviante & Morrall, 1986) in dilemma pair options (i.e., northern routes became southern routes in the second map version, and vice-versa; the same applies to east/west dilemma pairs).

Routes. A total of 20 routes were developed for each of the two maps. Routes and landmark locations were modified such that each map contained 10 dilemma and 10 non-dilemma (filler) origin-destination pairs. Of the 10 dilemma pairs, 5 had origin-destination pairs positioned north-south of one another with routes running to the east or to the west between them (east/west dilemma) and 5 had origin-destination pairs positioned east-west of one another with routes running to the north or to the south between them (north/south dilemma). Dilemma trials contained two equal-length route options between two landmarks; in an east/west dilemma the two route options went east and west, and in a north/south dilemma the two route options went north and south. Across all 20 routes within a map, each landmark was referenced at least once (and no more than three times) as an origin or destination, and the distances between origin-destination pairs varied widely within a single map (Pittsburgh $M = 6.13$, $SD = 2.33$; Chicago $M = 7$, $SD = 1.63$). Two versions of the routes were created by swapping origins and destinations (i.e., *Park to Information Booth* became *Information Booth to Park*);

these two versions were used across-participants to control for effects of route complexity immediately surrounding an origin (i.e., Bailenson et al., 1998, 2000), and also control for the possibility that participants would prefer routes that allowed right turns (i.e., right-on-red affordances; Scharine & McBeath, 2002).

Procedure

Following informed consent, participants sat at a 19” monitor connected to a Macintosh computer running SuperLab 4.0. Participants completed two study-test blocks, one for each of the two maps (Pittsburgh, Chicago), in counterbalanced order across participants. During study, participants familiarized themselves with the map, presented on the computer monitor for 2 minutes. The experimenter then probed for landmark knowledge by asking the participant to verbally confirm whether they knew each landmark location as it was read aloud. Once the participant affirmed landmark location knowledge, they received 20 route planning trials, one at a time in random order. Each trial was read aloud by the experimenter, and included an origin and destination, and the instructions: *What is the best route from the [origin] to the [destination]?* Participants were told that the “best” route was one that was shorter and/or faster. Participants verbally reported a route and the experimenter digitally recorded their response; no formal response time limit was established, and most participants began reporting a route within 5-10 seconds of being probed. This procedure was then repeated for the second map and its corresponding trials, for a total of 10 north/south and 10 east/west dilemma trials.

Results

Scoring & Analysis. For each trial, we recorded the chosen route and the perspective used to describe the route. On dilemma trials, the chosen route was either north or south, or east or west. On non-dilemma filler trials, the route was not associated with directional conflict, and thus not further analyzed. Perspectives were recorded as either egocentric (used terms *forward*, *left*, *right*), allocentric (used terms *north*, *south*, *east*, *west*), or mixed (any combination of egocentric and allocentric). We performed our analyses separately for the two dilemma types, and based them on the adopted perspective (3: egocentric, allocentric, mixed) and the proportion of chosen routes in a dilemma trial (2: north or south, east or west). Results did not differ as a function of map (Pittsburgh versus Chicago) or map version (original, rotated 180°), and all analyses thus collapse across these two factors. Effect size is reported using Cohen's d.

Route Choice. Our first set of analyses focused on the extent to which north/south or east/west dilemma trials are associated with decisions that depart from chance (50%). Overall, on north/south dilemma trials, participants chose the southern route on 62.8% of trials, and the northern route on only 37.2% of trials (*SDs* = .15; see Figure 2). We performed a one-sample t-test on the sample proportion choosing south (62.8%) versus the chance expected value (50%), and found a significant effect, $t(63) = 6.97$, $p < .01$, $d = .81$. Overall, 44 participants showed a southern route preference, 14 showed no preference, and 6 showed a northern route preference. On east/west dilemma trials, however, participants chose at chance level between the eastern route (50.2%) and the western route (49.8%; $SD = .19$), $t(63) = .07$, $p > .05$, $d = .01$.

Route Choice by Perspective. Our second set of analyses focused on the extent to which participants' spontaneously produced perspectives predicted their choices on dilemma trials. To examine this question we categorized individual trials by the perspective(s) used while describing the route, and then examined participants' route selection on both types of dilemma trials. This process resulted in three perspective categories: egocentric, allocentric, mixed. To analyze these data, we compared the sample proportion choosing south (to examine north/south dilemma trials) or east (to examine east/west dilemma trials) in each of the three term categories versus the chance expected value (50%). On north/south dilemma trials, participants showed a southern preference exceeding that of chance when they used egocentric terms (64%), $t(44) = 2.38$, $p < .05$, $d = .45$, or mixed terms (69%), $t(14) = 4.21$, $p < .01$, $d = 1.11$. This effect was marginal when they used allocentric terms (56%), $t(17) = 1.93$, $p = .07$, $d = .79$. On east/west dilemma trials, participants did not show route selection preferences in any of the three perspective categories (all t's < 1, p's > .10).

Experiment 1 Discussion

Experiment 1 results demonstrated a distinct route selection preference as participants disproportionately selected southern versus northern routes during route planning tasks. Critically, the northern and southern routes were the same length, and across-participants we controlled for initial segment length and number of turns. Indeed the only difference between the two route options was their direction in the canonical world. Participants generally chose southern routes on approximately 2/3 of trials, only choosing the corresponding northern route on 1/3 of trials. To our knowledge, this is the first evidence of such an effect in human route planning.

There was also evidence that southern route preferences are only evident when individuals spontaneously use an egocentric perspective to describe routes (i.e., when participants actively imagine movement through the environment from an embedded perspective). In contrast, we found minimal evidence for a southern route preference when the described route used a perspective external to the environment. However, this conclusion is tentative given that the overall number of individuals who spontaneously produced allocentric or mixed perspectives was quite low, as evidenced above by relatively low degrees of freedom in our analyses by perspective; that is, we may have insufficient power to identify a southern route preference when participants adopt allocentric perspectives. Experiment 2 addresses this possibility.

Experiment 2: Forced Perspectives

Our second experiment was designed to further examine the effects of spatial perspectives on route selection. This experiment used the same paradigm as our first experiment, but added an induced perspective manipulation. In Experiment 1, participants spontaneously produced various perspectives to describe routes, and in the present experiment we asked participants to use only one of two perspectives: egocentric or allocentric. This manipulation reliably leads individuals to adopt alternate perspectives on an environment, altering both visual attention during map study and subsequent spatial memory (i.e., Brunyé & Taylor, 2009; Magliano et al., 1995; Taylor et al., 1999; van Asselen et al., 2006). We used this manipulation to examine whether encouraging participants to take either an egocentric or allocentric perspective would differentially lead to southern route preferences during route planning. Given Experiment 1 results, we expect that the former and not the latter perspective will produce the southern route preference.

Method

Participants & Design

Ninety-six Tufts University undergraduate students (57 female; age $M = 20.3$) participated for monetary compensation. We used a mixed design with Perspective varied between (2: egocentric, allocentric) and Dilemma Type (2: north/south, east/west) varied within participants. We measured the extent to which participants chose each conflicting route option in the two Dilemma Type conditions as a function of Perspective group.

Materials

The same maps and routes were used as in Experiment 1.

Procedure

All procedures were identical to Experiment 1 with the exception of the Perspective manipulation. Prior to each of the two route planning blocks, participants were instructed to use either an egocentric or allocentric perspective to describe their movement. In the egocentric group, participants were told to only use the spatial terms "forward, right, left" to describe movement through the environment; they were told that their instructions should refer to the changing position of a person within the environment, such as "go forward, turn right, turn left." In this group, participants were encouraged to take an embedded perspective, providing route instructions from the perspective of an imagined character moving through the environment. In the allocentric group, participants were told to only use the spatial terms “north, south, east, west” to describe movement through the environment; they were told that their instructions should be relative to an outside “bird’s eye” view of the environment, such as “go north, or continue west.” In this group, participants were encouraged to take an external perspective, providing route instructions from a fixed perspective outside of the environment.

During pilot testing of this procedure we noticed that some participants had difficulty adopting a particular perspective, and that this typically occurred only during the first trial of route planning. To avoid data contamination we used a pseudo-randomization scheme whereby all route planning trials were presented in random order (as in Experiment 1), but with the exception of always using a non-dilemma trial as the first trial of each block.

Results

Scoring & Analysis. We recorded the chosen route and the perspective used to describe the route. Analyses first examined overall route choice collapsed across Perspective group, then whether the selection of routes would interact with Perspective group, and finally separately for each of the two Perspective groups, analyzing the directions chosen in the two dilemma types. As in Experiment 1, all analyses collapse across map (Pittsburgh versus Chicago) and map version (original, rotated 180°). Effect size is reported using Cohen’s d.

Conformity to Perspective Instructions. When participants showed difficulty adopting the intended perspective, the experimenter reiterated the instructions; subsequent to the first trial, all participants conformed to their perspective instructions.

Route Choice. Our first set of analyses focused on the extent to which north/south or east/west dilemma trials are associated with decisions that depart from chance (50%). When collapsed across both Perspective groups, on north/south dilemma trials, participants chose the southern route on 57.2% of trials, and the northern route on 42.8% of trials (*SDs* = .20). We performed a one-sample t-test on the sample proportion choosing south (57.2%) versus the chance expected value (50%), and found a significant effect, t(95) = 3.51, $p < .01$, $d = .46$. On east/west dilemma trials, however, participants were close to chance performance, choosing the eastern route on 49% of trials and the western route on 51% of trials, t(95) = .52, $p > .05$, $d = .06$.

Route Choice by Perspective. To test for effects of perspective, we compared the sample proportion choosing south (to examine north/south dilemma trials) or east (to examine east/west dilemma trials) in each of the two Perspective groups versus the chance expected value (50%). In the egocentric group, participants showed a southern preference exceeding that of chance (63%), $t(47) = 4.30$, $p < .01$, $d = .83$; they did not show any preference on the east (49%) versus west (51%) trials, $t(47) = .613$, $p > .05$, $d = .09$ (see Figure 3). In the egocentric group, 34 participants showed a southern route preference, 11 showed a northern route preference, and 3 showed no preference. In the allocentric group, participants did not show a southern preference; the proportion of southern route choice was 51.4% ($t(47) = .55$, $p > .05$, $d = .09$). Further, these participants did not show any preference in the east (49%) versus west (51%) trials, $t(47) = .17$, $p > .05$, $d = .03$. In the allocentric group, 21 participants showed a southern route preference, 16 showed a northern route preference, and 11 showed no preference. Finally, we conducted an independent samples t-test which demonstrated that the proportion choosing southern routes was significantly higher in the egocentric (63%) versus allocentric (51.4%) group, $t(94) = 2.96$, $p < .01$, $d = .60$.

Discussion

Our second experiment examined whether induced spatial perspectives could affect the extent to which participants show a southern route selection preference. Supporting Experiment 1, an induced egocentric perspective led to a southern preference; these participants generally chose southern routes on approximately 2/3 of trials, only choosing the corresponding northern route on 1/3 of trials. In contrast, an induced allocentric perspective produced no particular preference.

It seems to be the case that participants reliably choose southern versus northern routes when they take an embedded perspective during planning. Indeed this is the case when participants spontaneously adopt, and when they are instructed to adopt, a particular perspective. That is, whether participants are inherently predisposed to thinking about and communicating using egocentric terms (i.e., Pazzaglia & De Beni, 2001), or instructed to adopt such a perspective regardless of any predisposition (i.e., Brunyé & Taylor, 2009), they show similar southern route preferences. Participants appear to use heuristics that may be specifically activated when they take an embedded perspective on an environment. Indeed embedded perspectives have been shown to activate similar mental imagery and brain areas as when people perform real-world actions (i.e., Brunyé et al., 2009; Ruby & Decety, 2001). As such, southern route preferences elicited during route planning might be expected to reflect wayfinding behaviors in natural environments.

Why might a southern preference exist during route planning? In general, considering future actions is thought to activate motor simulations that allow an individual to imagine actions and their consequences on the world and themselves, and plan accordingly (i.e., Jeannerod, 2001; Knoblich & Flach, 2001). Informal debriefings from both experiments reveal that a handful of participants misperceived northern routes as more “difficult” or “demanding,” suggesting that this may have led to avoidance of those routes during planning. That is, north may be associated with moving “uphill,” as suggested by the introductory quote of the Treebeard character in the *Lord of the Rings*. An initial segment strategy (i.e., Bailenson et al., 2000) that minimizes perceived effort may lead to the disproportionate selection of southern-going routes. In fact, a number of studies have revealed that action planning and perception consider current and predicted body states (e.g., Fajen, 2005; Knoblich & Flach, 2001; Proffitt, 2006; Witt, Proffitt, & Epstein, 2004); if participants misperceive north as uphill, this more physically demanding route would thus be avoided. Two alternative possibilities exist, however; first, participants may misperceive northern routes as physically lengthier than southern routes, and second participants may simply have a preference to select options towards the bottom of the computer monitor; Experiments 3 and 4 ruled out these two alternative explanations.

Experiment 3: Perceptions of Route Length

Our third experiment was designed to test the possibility that participants misperceive northern routes as physically lengthier than southern routes. Length perception can be modulated by proximal spatial attention biases (i.e., preferentially attending to close versus far information) and/or the distance of judged lengths from participants' bodies (i.e., judging more distal information as lengthier than proximal information; see Kwon, Lee, Ji, Jeong, Kim, Heilman, & Na, 2004). Given our experimental configuration (all routes equally distal from participant given vertical computer monitor alignment), we did not expect these factors to affect route length judgments. In the present study, participants completed a forced-choice task involving the selection of one of two highlighted routes that either went north/south, east/west, or in non-opposing directions.

Method

Participants & Design

Twenty-four Tufts University undergraduates (14 female; age *M* = 20.7) participated for monetary compensation. We used a within-participants design with Dilemma Type as the single independent variable. Our critical dependent measure was the extent to which participants chose north versus south options on tasks involving the forced-choice of shorter or longer routes.

Materials

The same maps and routes were used as in preceding experiments. A total of 160 images were created, each depicting two routes, one highlighted in red and one in blue. Images were made for each of the two Pittsburgh and Chicago map versions, with 10 dilemma and 10 non-dilemma trials per map (plus versions rotated 180 degrees, for a total of 80 images). Eighty additional images reversed which routes were depicted in red or blue. As in preceding experiments, dilemma trials were either north/south or east/west dilemmas. Non-dilemma trials depicted two routes, one of which was perceptibly longer than the other (minimum route length difference of 25%), and did not fall evenly upon north/south or east/west axes.

Procedure

Participants were instructed to select either the shorter (n = 12) or longer (n = 12) routes on each of 80 randomly-presented trials. Using a forced-choice procedure each participant chose either the route highlighted in red or blue by pressing color-matched keys (C and M, respectively).

Results

Scoring & Analysis. We recorded the chosen route and assessed whether route choice departed from chance (50%) on north/south and east/west trials. For non-dilemma trials we evaluated route choice accuracy. No differences were found when comparing choices of participants instructed to make shorter versus longer route decisions ($p > .05$), or whether the northern versus southern (or eastern versus western) routes were depicted in blue or red (*p's* < .05), so data were collapsed across these groups (longer-route group data were reverse-scored). Further, no differences were found when comparing choices with the two maps (Pittsburgh versus Chicago) or map versions (original, rotated 180°; *p's* < .05). Effect size is reported using Cohen's d.

Route Choice. One-sample t-tests on the proportion choosing south (49.5%) versus the chance expected value (50%) did not reveal a significant effect, $t(23) = 0.2$, $p > .10$, $d = .04$. Similar results were found when examining the proportion choosing eastern routes (54.7%), $t(23) = 1.29$, $p > .10$, $d = .26$. On non-dilemma trials, participants generally selected the appropriate route (M = 95%, SE = .02), demonstrating that they understood and were performing the task.

Experiment 3 Discussion

There was no evidence that participants misperceived northern versus southern (or eastern versus western) routes as different in length. In conjunction with Experiment 1 and 2 results demonstrating that adopted perspectives modulate route selection, the present results provide converging evidence that southern route selection preferences are not driven by a misperception of route length. Experiment 4 examines a second factor that may drive a southern route preference: the possibility that participants may prefer information towards the lower versus upper regions of the computer monitor.

Experiment 4: Spatial Preferences by Monitor Region

Our fourth experiment examines the possibility that southern route preferences may be driven by participants' preference to select options that appear in lower regions of the computer monitor (we thank an anonymous reviewer for pointing out this possibility). To test this, we presented participants with the same routes as used in Experiment 3, but modified the stimuli to be devoid of geographical space cues (i.e., terrain, buildings, streets, compass); these stimuli presented origins and destinations as black dots and alternate ‘routes’ as blue versus red colored dots that provided competing options for connecting the two black dots. In this task, participants connected presented origin and destination dots, responding in a single color to select either upper (north) or lower (south) options on north/south dilemmas, and right (east) or left (west) options on east/west dilemmas. If participants preferentially select information from lower regions of the computer monitor, then they should show lower (versus upper) ‘route’ selection probabilities exceeding that of chance (50%).

Method

Participants & Design

Twenty-four Tufts University undergraduates (16 female; age *M* = 20.1) participated for monetary compensation. We used a within-participants design with Dilemma Type as the single independent variable. Our critical dependent measure was the extent to which participants chose lower versus upper options (and left versus right options) when connecting dots between origin and destination pairs.

Materials

We used the same 160 images as in Experiment 3, modified in several ways. For each image, origin and destination buildings were replaced with single black dots. Each route option on those images was depicted by placing a colored dot at each turn along a possible route (one route depicted with red and the other with blue dots). All information other than the dots was then removed from the images (i.e., terrain, buildings, streets, compass rose, legend). In this way, the stimuli resembled a 'connect the dots' puzzle involving the selection of either the blue or red dots to connect the two black dots together in space. The overall structure of the images, however, remained identical to that of Experiment 3: dilemma trials were either north/south (now upper/lower) or east/west (now right/left) dilemmas, and non-dilemma trials depicted two routes, one of which was perceptibly longer than the other (minimum route length difference of 25%), and did not fall evenly upon north/south or east/west axes. Route options were rotated through the two colors (red, blue) and rotated 180 deg across participants.

Procedure

Participants were instructed to select either the red or blue series of dots to connect the two black dots together. Using a forced-choice procedure each participant chose either the red or blue series of dots by pressing colored keys (C and M, respectively).

Results

Scoring & Analysis. We recorded the chosen route and assessed whether route choice departed from chance (50%) on upper/lower and right/left trials. For non-dilemma trials we evaluated route choice accuracy. Results did not vary as a function of, and analyses collapsed across, route color (blue, red), map (Pittsburgh versus Chicago), and map version (original, rotated 180°; *p's* > .05). Effect size is reported using Cohen's d.

Route Choice. One-sample t-tests on the proportion choosing lower routes (48.9%) versus the chance expected value (50%) did not reveal a significant effect, $t(23) = .33$, $p > .10$, $d = .07$. Similar results were found when examining the proportion choosing right-side routes (50.6%), $t(23) = .30$, $p > .10$, $d = .04$. On non-dilemma trials, participants generally selected the route with fewer connecting dots (i.e., the shorter route; $M = 79\%$, $SE = .02$).

Experiment 4 Discussion

There was no evidence that participants preferentially select lower versus upper route options in a context devoid of geographic spatial cues. In conjunction with Experiment 3, we provide evidence that the southern route preference cannot be accounted for by misperceptions of route length or preferences to select information towards the lower region of the computer monitor. Experiment 5 examines the possibility that southern route preferences may in fact be driven by misperceptions of physical demand (i.e., north is ‘up’).

Experiment 5: Perceptions of Physical Demand

Our fifth experiment was designed to test whether participants deem northern routes as more elevated (i.e., “uphill”) or physically demanding than southern routes. Participants rated depicted routes on four dimensions. One of the dimensions was directly related to assumed elevation (scenic potential), two were related to physical exertion (calorie expenditure, fuel consumption), and one was an unrelated filler dimension (traffic potential). We expect that if participants consider northern routes as moving generally ‘up’ then they should also rate those routes as potentially more scenic (i.e., providing a vista given their relatively high elevation). They may also transfer this bias to ratings of calorie expenditure (relatively near transfer) and fuel consumption (relatively far transfer). We do not expect northern and southern route options to be differently rated in terms of traffic potential, or any ratings to vary as a function of east- or west-going route options.

Method

Participants & Design

Sixty-four Tufts University undergraduate students (33 female; age M = 20.3) participated for monetary compensation. We used a within-participants design with route direction (north, south, east, west, non-directional) as the single independent variable. Our dependent measure was average ratings on four dimensions: calorie consumption, fuel consumption, scenic potential, and traffic potential.

Materials

The same maps and routes were used as in Experiment 3, except that each depicted a single route highlighted in red. Routes went either north, south, east or west in direction, or in no single canonical direction (going somewhat diagonally across the map). Below the map was a rating scale that ranged from 1 to 9 with anchors corresponding to one of the four dimensions (e.g., *Fewest Calories* to *Most Calories*).

Procedure

Participants were instructed to use all possible information to rate each route. For calorie consumption, participants were instructed to rate each route based upon how many calories a person might consume while walking the highlighted route. For fuel consumption, participants were instructed to rate each route based upon how much fuel a person might burn while driving the highlighted route. For scenic potential, participants were instructed to rate each route based upon how scenic the route might be in terms of scenic views and number of landmarks passed along the way (this latter characteristic is equated across routes). Finally, for traffic potential, participants were instructed to rate each route based upon how much traffic they think someone might experience while traveling the route. Note that each of these instructions promotes a ground-level perspective. Participants used the number keypad to respond to each route trial. Trials were presented in random order within eight randomly-presented blocks corresponding to rating type (i.e., Scenery, Calories, Fuel, Traffic) and map (i.e., Pittsburgh, Chicago). As in preceding experiments, maps were rotated 180deg across participants.

Results

Scoring & Analysis. We evaluated average ratings (on a scale from 1-9) for each of the four rating types as a function of whether the route went north, south, east or west.

Route Ratings. For scenery ratings, paired t-tests revealed that scenery ratings were higher on northern relative to southern routes, $t(63) = 3.68$, $p < .01$, $d = .46$, and showed no difference on eastern relative to western routes, $t(63) = .85$, $p > .10$, $d = .11$ (see Table 1). For calorie ratings, paired t-tests revealed that calorie ratings were marginally higher on northern relative to southern routes, $t(63) = 1.89$, $p = .06$, $d = .24$, and showed no difference on eastern relative to western routes, $t(63) = 1.1$, $p > .10$, $d = .14$. For fuel ratings, paired t-tests revealed that fuel ratings were not different for northern relative to southern routes, $t(63) = .15$, $p > .10$, $d = .02$, or eastern relative to western routes, $t(63) = .27$, $p > .10$, $d = .03$. Finally, for traffic ratings, paired t-tests revealed that traffic ratings were not different for northern relative to southern routes, $t(63) = .29$, $p > .10$, $d = .04$, or eastern relative to western routes, $t(63) = 1.03$, $p > .10$, $d = .13$.

Experiment 5 Discussion

Our fifth experiment demonstrated that participants rate northern-going routes as having higher potential for scenery and as associated with higher calorie consumption relative to southern-going routes. In terms of scenery, it seems to be the case that participants deem northern routes as generally travelling uphill relative to southern ones, providing more opportunities for scenic vistas at elevation. We find no other reasonable explanation for higher scenery ratings, given that all physical visual factors were equated across north and south route conditions (e.g., number of landmarks, number of intersections). Converging evidence suggesting that northern routes are misperceived as generally uphill emerges from the fact that participants rated northern-going routes as associated with somewhat higher calorie consumption. This second effect suggests that the uphill journey associated with the northern routes would be more physically demanding for a traveler; note, however that this effect only reached marginal significance. To further examine perceptions of relative difficulty, and to extend the present results to a larger-scale environment, Experiment 6 tested whether participants would estimate north-going routes as more time consuming to travel relative to south-going routes, using a US road atlas.

Experiment 6: Travel Time in Large-Scale Environments

Our final experiment was designed to test the notion that northern-going routes are misperceived as more ‘demanding’ routes than southern-going comparisons. To do so, we asked participants to judge the amount of time it would take to travel routes between U.S. cities; in general, travel time estimates are sensitive to predicted changes in travel speed due to such variables as weather, topography, and traffic (Fuller, Gormley, Stradling, Broughton, Kinnear, O'Dolan, & Hannigan, 2009; Selten, Chmura, Pitz, Kube, & Schreckenberg, 2007; Svenson, 2008). In the present study, participants provided estimates for routes running east to west, west to east, north to south, south to north, and diagonal (filler trials) across the map. Origins and destinations were reversed across blocks and we examined the extent to which participants predicted longer travel times as a function of route travel direction. We expect that if participants consider north-going routes as moving generally 'uphill' then they should also estimate longer travel times relative to when the same route moves north to south. Given the results of Experiment 5, we do not expect that travel time estimates will vary as a function of whether routes are east- or west-going.

Method

Participants & Design

Twenty-four Tufts University undergraduate students (13 female; age *M* = 19.6) participated for monetary compensation. We used a within-participants design with route travel direction (north-going versus south-going, east-going versus west-going) as the single independent variable. Our dependent measure was average time estimates (in hours).

Materials

Using the Google Maps™ utility at a zoom level of 200 miles per linear inch, we plotted 30 routes, 10 of which ran along the longitudinal (north-south) axis, 10 along the latitudinal (east-west) axis, and 10 fillers that had no single canonical travel direction (fillers, typically diagonally-oriented). Route length varied widely, from 183 to 2065 miles, with a mean length of 798 miles. Within each set of 10 routes, origin and destination cities (e.g., San Francisco, CA to Portland, OR) were similar in elevation; this was confirmed in three t-tests comparing origin and destination elevations, which revealed no significant difference in the north-south set, $t(9) = .07$, $p > .05$, $d = .02$, the east-west set, $t(9) = .36$, $p > .05$, $d = .11$, or the filler set, $t(9) = .67$, $p > .05$, $d = .21$. The 30 route images were each 1200 × 700 pixels in resolution.

Procedure

Participants were instructed to use all possible information to estimate how much time it would take to travel from a presented origin to a destination, such as topography, weather patterns, traffic, and travel speed. Participants were given a text description of a route (e.g., San Francisco, CA to Portland, OR) in the center of the screen; the description was then removed and the corresponding route image was depicted on the screen. For each description-image pair, participants were instructed to enter (using a number keypad) a predicted travel time for the route (in hours). Participants were presented with two blocks, each containing the same 30 route images; in the first block, half of the north-south routes traveled from north to south and half from south to north (east-west routes and fillers were structured in an identical manner). Across blocks, the travel direction of each route was reversed to allow us to compare time estimates of the same routes, but in the opposite travel direction. To ensure that participants were attending to which city was the origin and which the destination, they were tested on their memory for the pairs immediately following the first block of 30 description-image pairs.

Results

Scoring & Analysis. We evaluated average time estimates (in hours) for north- versus south-going routes, and east- versus west-going routes. To do so, we conducted two paired t-tests, one comparing mean time estimates for north- versus south-going routes, and one comparing estimates for east- versus west-going routes.

Results: Travel Time Estimation. Time estimates given to north-going routes (M = 17.43, SE = 1.28) were greater than those given to paired south-going routes (M = 15.78, SE = 1.16), $t(23) = 2.92$, $p < .01$, $d = .60$. This effect was not found when comparing east-going (M = 15.66, SE = 1.35) to paired west-going routes (M = 16.23, SE = 1.35), $t(23) = .64$, $p > .05$, $d = .13$.

Experiment 6 Discussion

Our final experiment demonstrated that participants provide greater travel time estimates for north-going relative to south-going routes; in contrast, participants did not provide different travel time estimates as a function of whether the route was east- or west-going. Interestingly, these travel time differences persisted despite the origins and destinations being equated in actual elevation, the travel tasks taking place in a highly familiar environment, and the opposing-direction routes being identical in both length and origins and destinations. In conjunction with Experiment 5, we provide converging evidence that traveling north is misperceived as more effortful or difficult (i.e., north is 'uphill') relative to traveling south, even when making judgments in a large-scale and relatively familiar environment.

General Discussion

In our first two experiments we demonstrate a reliable bias wherein route planners choose southern over equivalently long northern route options when assuming an egocentric perspective. Indeed participants tend to choose a northern route option on only about 1/3 of north/south dilemma trials, indicating a strong preference towards southern route options. Despite its strength and reliability, during debriefing sessions many participants were not aware of their bias, and only a handful suggested that northern routes were somehow more difficult or demanding options. When probed further, these latter participants seemed aware that their suggestions were unfounded and many were even surprised and puzzled by their own behavior.

We were also able to delineate some of the possible sources for the southern route selection bias. First, participants modulate their route selection behaviors as a function of spatial perspective. Participants produced rather symmetric decisions, choosing northern and southern routes on approximately half of trials, when they spontaneously used, or were instructed to use, an allocentric perspective. This perspective involves taking an outside bird's-eye perspective and referencing movement through an environment to a canonical coordinate system. In contrast, participants produced asymmetric decisions, preferentially selecting southern route options approximately 2/3 of the time when they spontaneously used, or were instructed to use, an egocentric perspective. This perspective links navigation movements to the body axes of an imagined individual moving through the environment, and thus takes an embedded or immersed perspective on described movement. The egocentric perspective was not only the most commonly used when participants were provided with the flexibility to choose their own perspectives, but it also produced the highest rate of southern route selection. Interestingly, egocentric perspectives have been shown to activate similar mental imagery and brain areas as when people perform real-world actions, suggesting that the behavior patterns associated with this perspective might be a result of the integration of real-world perceptual and motor experiences into everyday decision making (Barsalou, 2008; Brunyé et al., 2009; Ditman et al., in press; Glenberg, 2007; Ruby & Decety, 2001). Indeed some work shows that people perform motor simulations of intended actions, and these motor simulations are responsible for distorted spatial judgments during distance and perceived slant estimations (Witt & Proffitt, in press; Seeley & Waughtel, 2008). We suggest that motor simulations of navigation influence path selection and guide whether the southern route heuristic is incorporated into the decision making process.

Related, participants appear to misperceive northern routes as traveling uphill relative to southern routes, as revealed when participants rated routes on a variety of dimensions and estimated travel times for routes between U.S. cities. First, participants rated northern routes as having higher potential for scenic views, suggesting that they misattributed higher elevations to northern routes. More evidence came from the fact that participants rated northern routes as somewhat higher in terms of predicted calorie expenditure. That is, participants predicted that travelers would burn more calories walking northern rather than southern routes. The misperception that northern routes move uphill is somewhat puzzling given that, under this rationale, uphill path segments would be offset by later downhill path segments. Specifically, most north/south dilemma trials had 3 path segments, one moving generally north from an origin, one moving somewhat horizontally across the map (due east or west) and then the final path segment moving south towards the destination. We suggest that this effect might be due to the misperception that northern routes move uphill, but that participants' decisions are further guided by a focus on the initial path segment, as suggested by earlier work (i.e., Bailenson et al., 1998, 2000; Conroy Dalton, 2003; Hochmair & Frank, 2002). That is, participants may be most dependent upon the initial path segment for making route selections, and if this initial path segment is deemed as traveling uphill (due to its northward orientation) then this dependence may lead to a northern route aversion. Another possibility is that participants integrate knowledge of physical momentum and consider that traveling downhill on an initial path segment (i.e., south) will ultimately lead to less energy expenditure on the uphill path segment; this possibility meshes nicely with the notion that route planners strive to minimize cognitive and physical effort (Christenfeld, 1995; Freska, 1999). This latter possibility, however, cannot explain the increased time estimates for long-distance routes between U.S. cities found in Experiment 6. Participants apply the north-up heuristic to travel planning in large-scale and familiar environments, when there are no potential advantages of physical momentum with one route relative to another.

Many heuristics can be reliably evoked in experimental laboratory tasks, and some evidence suggests that they also manifest themselves in natural environments. Indeed most studies examining route planning have used maps of realistic environments, such as college campuses, towns and/or cities (e.g., Bailenson et al., 1998, 2000; Christenfeld, 1995). Further, some work has reliably replicated route planning heuristics in natural environments, such as by observing students navigating a college campus or shopping center (Christenfeld, 1995; Gärling & Gärling, 1988; Shum, Bailenson, Hwang, Piland, & Uttal, 1998). One assumption of the present work is that the spatial processes involved during route planning, and their behavioral results, are similar whether someone is verbally reporting or memorizing and eventually traveling a proposed route; to our knowledge, however, no work has directly tested this hypothesis. A possibility for future research, therefore, is to examine whether the present results replicate with alternate response mechanism, such as whether a participant verbally reports versus draws a route on a map; indeed the latter may more accurately reflect the process of naturalistic route planning (we thank an anonymous reviewer for pointing out this possibility). However, given the realism of our small-scale and larger-scale maps, and the past evidence suggesting that spatial heuristics manifest themselves both in laboratory and real-world settings, we expect the current effects would replicate in real-world environments; future work in our laboratory will test this hypothesis in pedestrian and driving contexts using virtual reality.

Our results further suggest that the southern route preference does not necessarily reflect inherent perceptual biases (such as length/distance perception) but rather higher-level conceptual heuristics that shape the representation of space. A remaining question is the source of such a heuristic. One possibility is that the geographic region of the present university sample is characterized by higher elevations to the north (i.e., White Mountains in New Hampshire, Green Mountains in Vermont) and lower elevations to the south (i.e., large sea level regions in Rhode Island and Connecticut). In Experiments 1, 2, and 4, it could be the case that participants transferred their knowledge of large-scale regional space to decisions made on relatively small-scale and unfamiliar environments. This possibility is limited, however, in that the majority of the Tufts undergraduate population (76%) is from states other than Massachusetts, with only approximately 30% being from the New England region. Further, these students made biased time estimates when the environment (the USA) was both familiar and remote. Future work, however, should examine whether the effects found in Experiments 1 and 2 can be replicated in geographic regions characterized by opposite elevation patterns, such as Pittsburgh, PA (which has the Appalachian Mountains to the south), or in participant groups who have lived primarily in such areas.

Another possibility is that participants transfer their knowledge of gravity (moving upward is more difficult than moving downward) to decisions made using maps viewed perpendicular to the ground. That is, the computer monitor orientation perhaps makes upward movement (i.e., north) deemed as more difficult than downward movement (i.e., south). This possibility does not seem particularly likely given that even though the computer monitor orientation was held constant the southern route selection bias diminished with the use of the allocentric perspective. An additional remaining question is the extent to which a southern route selection preference will exist when northern route options become perceptibly shorter in length. Indeed some work suggests that spatial heuristics are strong enough to bias route selection even when shorter routes exists (Bailenson et al., 1998, 2000), and this is an exciting possibility for future research.

Selecting and planning routes through an environment is a critical part of everyday navigation whether in car, on foot or on bicycle. Predicting these behaviors is an exceedingly complex task given that route planners consider not only which route is seemingly shorter or more efficient, but also several heuristics that guide and constrain their selections. Indeed accurate prediction of wayfinding behavior can only be performed by considering, at least, that participants tend to deviate minimally from the global direction of a goal destination, select routes based upon the straightness of an initial path segment, choose routes containing the fewest number of turns and landmarks, tend to delay route decisions until late in travel when several equivalent options exist, and in the present case tend to prefer southern rather than northern routes when adopting an egocentric perspective during route planning (Bailenson et al., 1998, 2000; Christenfeld, 1995; Conroy Dalton, 2003; Hochmair & Frank, 2002; Sadalla & Staplin, 1980; Senevirante & Morrall, 1986). In most cases, spatial heuristics are thought to minimize cognitive effort while maintaining somewhat satisfactory choices; but in other cases, we know that heuristics can negatively affect people's judgments and impair task performance (Tversky, 1977; Tversky & Kahneman, 1983; Newcombe, Huttenlocher, Sandberg, & Lie, 1996). Defining heuristics and quantifying their effects on human route planning is critical to understanding, modeling and predicting human navigation.

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Author Note

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Table 1. *Experiment 5 mean ratings and standard error for north and south routes (derived from north/south dilemma trials) and east and west routes (derived from east/west dilemma trials), as a function of rating type (scenery, calories, fuel, traffic).*

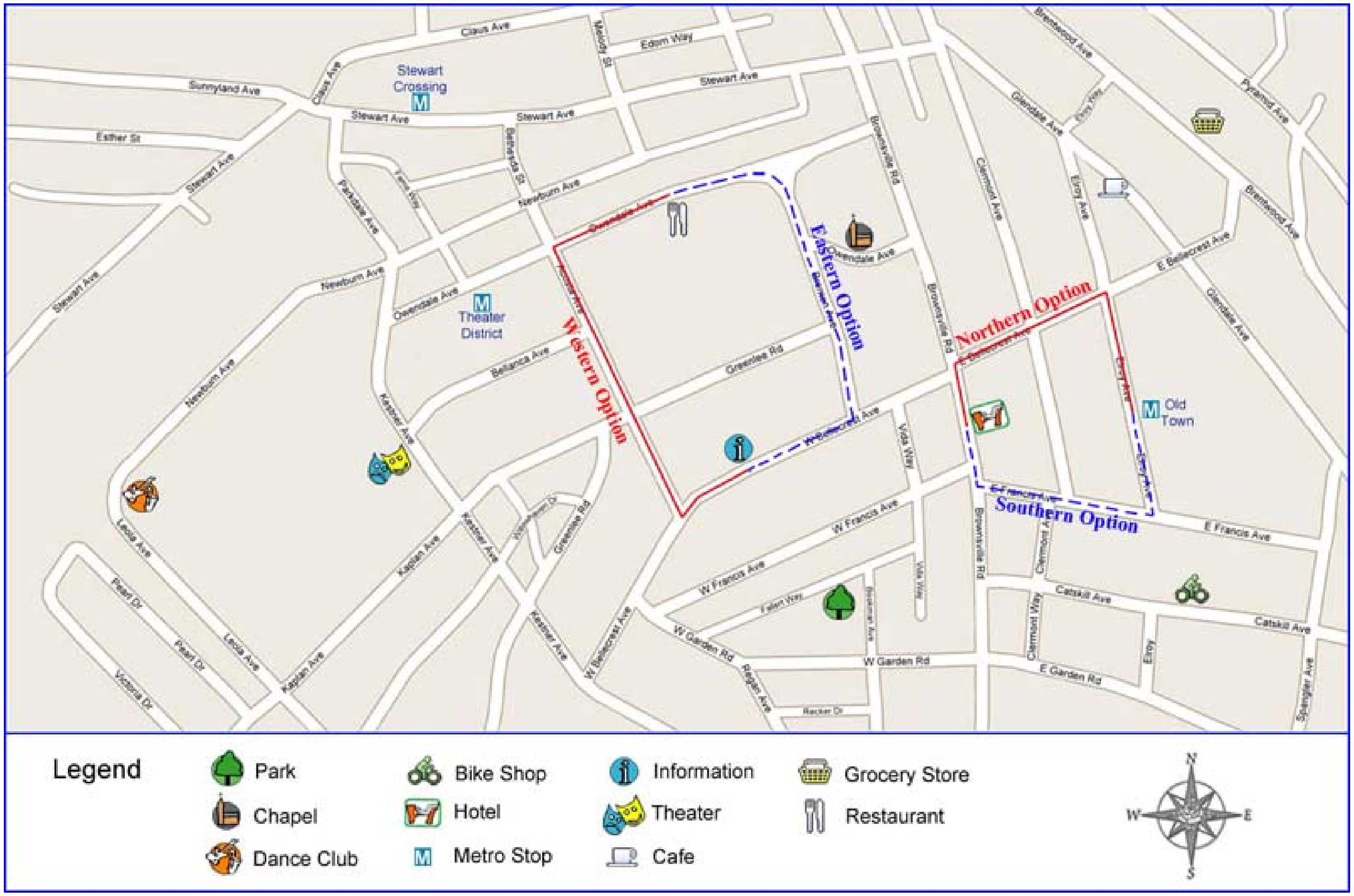
	Route Type							
	North		South		East		West	
Rating Type	M	SE	M	SE	M	SE	M	SE
Scenery	4.62	.13	4.12	.10	4.48	.11	4.54	.10
Calories	4.32	.13	4.17	.10	4.35	.10	4.41	.09
Fuel	3.91	.09	3.92	.09	4.11	.10	4.09	.09
Traffic	4.16	.09	4.14	.10	4.45	.10	4.50	.10

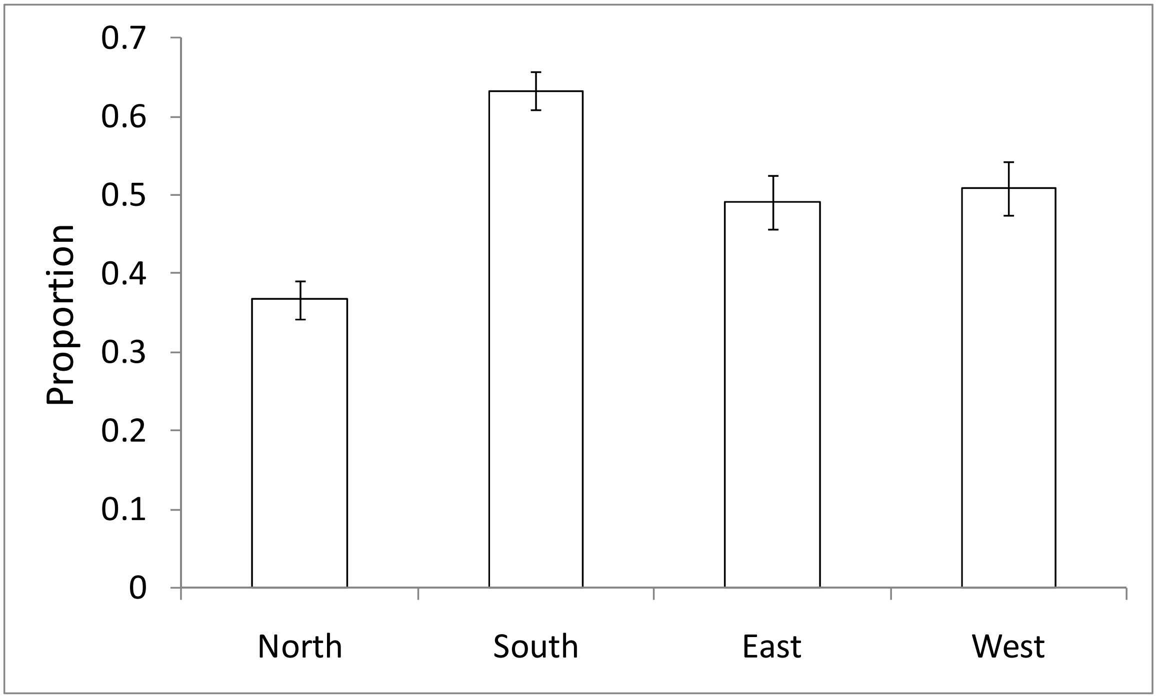
Figure Captions

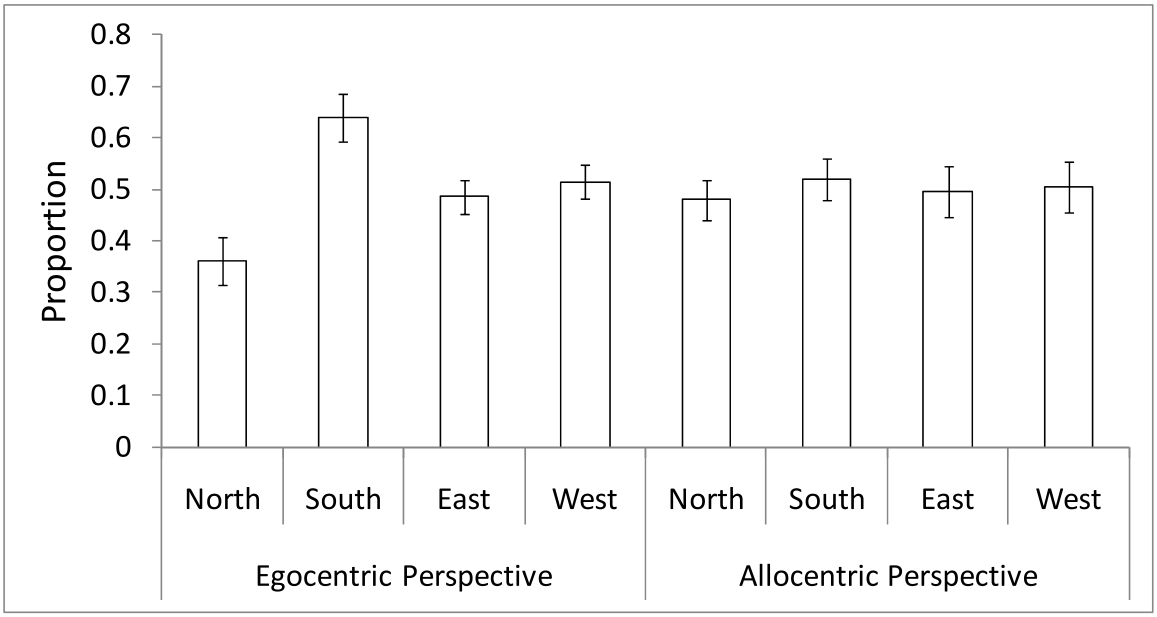
Figure 1. A sample map of the Pittsburgh, PA neighborhood (in original orientation) with two example dilemma trials: north/south (Hotel to Old Town Metro Stop) and east/west (Restaurant to Information Booth).

Figure 2. Experiment 1 mean proportion and standard error route selection for north and south routes (on north/south dilemma trials) and east and west routes (on east/west dilemma trials).

Figure 3. Experiment 2 mean proportion and standard error route selection for north and south routes (on north/south dilemma trials) and east and west routes (on east/west dilemma trials), as a function of perspective group.


Western Option
Eastern Option
Northern Option
Southern Option
Stewart Crossing
Theater District
Old Town
Sunnyland Ave
Esther St
Stewart Ave
Claus Ave
Edom Way
Newburn Ave
Owendale Ave
Bellanca Ave
Greenlee Rd
W Bellecrest Ave
E Bellecrest Ave
W Francis Ave
E Francis Ave
Catskill Ave
W Garden Rd
E Garden Rd
Brownsville Rd
Clermont Ave
Glendale Ave
Brentwood Ave
Kaplan Ave
Leola Ave
Pearl Dr
Victoria Dr
Kestner Ave
Legend
Park
Chapel
Dance Club
Bike Shop
Hotel
Metro Stop
Information
Theater
Cafe
Grocery Store
Restaurant
N
S
E
W


0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Proportion
North
South
East
West


Proportion
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
North
South
East
West
North
South
East
West
Egocentric Perspective
Allocentric Perspective