Northern Illinois University

Huskie Commons

Faculty Peer-Reviewed Publications | Faculty Research, Artistry, & Scholarship

3-1-2012

Characterizing the Role of Strategic Disposition and Orientation to Risk for Route Selection Problems

Thomas J. Pingel

Follow this and additional works at: https://huskiecommons.lib.niu.edu/allfaculty-peerpub

Original Citation

Thomas J. Pingel "Characterizing the Role of Strategic Disposition and Orientation to Risk in Wayfinding" Transportation Research Part F: Traffic Psychology and Behaviour 15 (4) July 2012, 427-437

This Article is brought to you for free and open access by the Faculty Research, Artistry, & Scholarship at Huskie Commons. It has been accepted for inclusion in Faculty Peer-Reviewed Publications by an authorized administrator of Huskie Commons. For more information, please contact jschumacher@niu.edu.

Characterizing the Role of Strategic Disposition and Orientation to Risk in Wayfinding

Thomas J. Pingel*

University of California, Santa Barbara, Department of Geography, Santa Barbara, CA 93101, USA

Abstract

Although digital navigation systems are becoming ubiquitous, they generally only select routes based on relatively simple criteria (length and time) and fail to adequately consider the preferred strategy of the user. In order to account for these strategies, care must be taken to solicit not only simple preferences, but also deeper issues such as overall strategic disposition and attitudes toward risk. Hallmarks of true strategy include schematic, general, conditional and conscious consideration of the impact of important variables on the achievement of one's goals. Factor analysis of a forty-item questionnaire isolated five questions that well-account for the strategic disposition of individuals. Additionally, attitudes about risk were explored in pedestrian and driving contexts. This analysis suggests that within the individual, attitudes about risk are relatively fixed, yet the manifestation of risk-seeking behavior is dependent on the mode of travel.

Keywords: Wayfinding, strategy, navigation, heuristics, route selection, risk, spatial cognition

1. Introduction

Digital navigation systems are becoming quite ubiquitous. They are often purchased as stand-alone units for automobiles, and are increasingly integrated into cellular telephones. These single-purpose geographic information systems utilize a global positioning system (GPS) to establish the location of the user, while using highly detailed route information to provide turn-by-turn instructions for following (typically) least-distance or least-time routes for automobile drivers. While people overwhelmingly prefer fast routes (Golledge, 1995a,b) they often have secondary goals as well (Hochmair, 2004), including attractiveness, safety, and simplicity (Duckham & Kulik, 2003; Mark, 1986; Richter & Duckham, 2008).

While preferences are being increasingly incorporated into navigation systems, other aspects of navigation strategy are not. A first step in accounting for users' route selection strategies is a detailed examination of the concept of strategy itself. We offer two basic elements of strategy that we feel have been underexplored in the literature. First, we offer an exploration into the idea of a strategic disposition, or the degree to which individuals are willing and able to conditionally consider alternatives of behavior and how well these alternatives match their preferences and goals. Second, all strategic behavior occurs within the context of uncertainty, and as such the orientation toward risk of an individual will greatly affect his or her evaluation of possible outcomes. Orientation toward risk in this sense represents a kind of meta-strategy, in which the strategist either tends to take safe alternatives or tends to gamble.

2. Strategies, Strategists, and Risk-takers

In its most general sense, strategy is a deliberate and nonobligatory method or plan directed to achieve a goal (Naus & Ornstein, 1983; Siegler & Jenkins, 1989; Siegler, 1991). The scope of a strategy in wayfinding can vary considerably (Montello, 2005). In some cases, it indicates an explicit technique. The "look-back strategy," in which

*Tel: +1 805 893 3663; fax: +1 805 893 2578

Email address: pingel@geog.ucsb.edu (Thomas J. Pingel)

hikers traveling on unfamiliar trails are advised to stop and view the terrain as it would appear on the return trip is an example of such a technique (Cornell et al., 1992). Lawton (1994) distinguishes between "route" and "orientation" strategies, which largely correspond to a preference for local and egocentric reference systems (e.g., remembering routes via landmarks or remembering directions as a series of left and right turns) versus global orientation schemas (e.g., keeping track of one's heading as it relates to cardinal directions). Individuals and societies differ widely in the employment of navigational aids, and these decisions themselves could well be considered strategies (Hutchins, 1995; Ishikawa et al., 2008; Lobben, 2004).

Perhaps the concept with the clearest connection to strategy is that of the heuristic. Heuristics are a key way in which individuals reduce the complexity of difficult problems that cannot be efficiently calculated (Kahneman & Frederick, 2002). Heuristics are, in this sense, strategies for approximating a solution over a wide set of problems and they typically manifest as general rules or principles that people (consciously or unconsciously) follow when wayfinding. Heuristics in wayfinding have been studied extensively as a means to explain biases observed in simulated and actual travel. Bailenson and colleagues describe a preference for initially straight routes as a heuristic for calculating shortest-path routes (1998; 2000). Hochmair and colleagues describe the least-angle (LA) strategy (2000; 2005) in which individuals tend to choose roads that have the least angle to the believed bearing of a target. Wiener and Mallot (2003) describe the fine-to-coarse heuristic, in which individuals plan a route to the region containing the target, and only once inside that region determine the subsequent specific route.

In some cases preferences have been described as strategies (Golledge & Stimson, 1997). Christenfeld (1995) found behavior in map and walking-based navigation tasks that indicated a preference for simple routes, and individuals have in many cases self-reported the importance of this criterion (Golledge, 1995a; Hochmair, 2004). Hochmair found that thirty-five individual criteria presented in the literature could be well accounted for by four attributes of routes - fast, simple, safe, attractive - at least for the domain of bicycle travel.

Agents often choose locally optimal solutions to arrive at near optimal global solutions. This approach to solving routing problems is known variously as a greedy or nearest neighbor algorithms or locally minimizing-distance heuristics. Hayes-Roth & Hayes-Roth (1979) posited this heuristic as important to human route planning, while Gärling & Gärling (1988) reported empirical evidence of the use of this heuristic by pedestrians in shopping malls. Such locally based, distance-minimizing techniques typically work well for small problem sets, but may produce highly suboptimal (or, in very rare cases least optimal) solutions for large problem sets. A local (versus global) interpretation of the problem explains why individuals may exhibit a preference of making a turn later rather than sooner (Christenfeld, 1995). When decisions are made locally, then the cost at the first significant choice point is higher than to continue straight. Since decisions are sequential, a "procrastinator's strategy" is revealed which amounts to: "it is better to assume the same cost later rather than sooner."

In contrast to many of the descriptions of particular strategies discussed above, we might well ask whether and how individuals differ in their strategic orientation at a more general scale. We propose two particular constructs that are potentially important for capturing the role of strategy in wayfinding, as well as a provisional method of measurement for each. The first of these is the strategic disposition, or the degree to which an individual reasons strategically about wayfinding problems, without suggesting any particular strategy that the individual might use. It represents the amount and quality of cognitive effort that an individual is willing to devote to a wayfinding problem to make sure that his or her actions (via heuristics or particular strategies) are likely to accomplish his or her objectives. The second construct is an orientation toward risk, which measures the predisposition of an individual, when asked to choose between safe and risky options with equal mean payoffs, to choose the riskier alternative.

Strategies are often both conditional and schematic in character. While a strategy dictates an agent's behavior in response to contextual or environmental occurrences, it does not necessarily explicitly do so - the particular choices within the context of a game, problem, or other situation are typically derivative of the overarching strategy. This involves the distinction between strategy and tactics: both have similar characters, but the purpose of strategy is to determine the general plan, not the implied particulars. Taken further, it means that the individual considers the impacts of his or her own choice. For instance, when driving a vehicle, an individual may be presented with a choice that has benefits to his or her own outcome but negatively impacts the entire road system (e.g., moving the car into the middle of an intersection, thereby blocking it for others, but enabling the driver to move through a traffic light sooner). Consideration does not necessarily mean behaving so that others benefit. It merely means that, for good or ill, the repercussions of an individual's action are weighed inasmuch as they impact other people or things.

Strategic thinking also varies in its degree of latency. Latency in this context is the degree to which an agent creates or maintains the strategy in the conscious mind. In many cases, strategies are completely latent - the agent may not know what particular approach it has when solving a problem, and yet problems are solved in consistent ways. In other cases, strategies may be latent, but agents may be able to account for them when asked to do so. Finally, a strategy may be conceived and held in consciousness at all times. Since conscious strategies are more in line with both common usage and the concept origin, and since many researchers reserve the term strategies for those that are deliberate (e.g., Naus & Ornstein, 1983), it seems easiest to say that the more a problem-solving method has its origin and is maintained in the conscious mind (i.e., the less latent it is), the more strategic it is. Latency is related to, but distinguished from the capability of an individual to externalize his or her strategy. Highly latent strategies may not be externalizable by the agent at all. In these cases, the external manifestation of the strategy (i.e., the relevant behavior) may be the only indication of the agent's strategy. We might expect individuals with a strong strategic disposition to report a high degree of affinity or frequency of strategic thinking. For example, they may self report that they enjoy playing strategic games or puzzles, or that they play such games relatively often. While it is likely that an affinity for strategic thinking will result in more frequent strategic thinking this need not necessarily be the case.

Orientation to risk is a second kind of meta-strategy that is likely to be important in capturing the ways in which individuals solve problems across multiple wayfinding (and probably many other) domains. In a large body of work collectively known as Prospect Theory, Kahneman and Tversky (Kahneman & Tversky, 1979; Tversky & Kahneman, 1981) described several notable biases of individuals with respect to risk. In general, people were more risk-averse when options involved gain, and more risk-seeking when changes of fortune involved loss. Thus, the gambler is more likely to take an all-or-nothing bet to erase his losses, but less likely to take an all-or-nothing bet to double his gains. Propensity to risk was also described as a function of the amounts in question, where individuals were more risk-averse with larger gains than with small ones. Thus, the gambler may be willing to take a double-or-nothing bet for a small amount of money, but quite unwilling to do so for large amounts of money. Most hypothetical questions presented by Kahneman and Tversky involved hypothetical monetary gains and losses, though some featured gains and losses in other contexts as well. None featured gains and losses associated with wayfinding problems. The wayfinding domain involves interesting challenges to the methodology, given that they cannot be framed in all-or-nothing contexts - as is common for most prospect theory domains - since all travel involves some expense of time, distance, or effort.

Although Tversky and Kahneman's interest was to look at general patterns and biases in risk-taking and to explain psychological factors that account for them, we might well look at individual differences in risk-taking as well. We are confronted with many choices involving uncertainty in wayfinding contexts, and it seems reasonable to suppose that some individuals are more predisposed toward taking risks than others. We might therefore expect that that such individuals would exhibit quite different patterns of movement than others.

In the next section, we examine ways in which we might operationalize and measure strategic disposition and orientation to risk for wayfinding problems, and to investigate any possible connection between the two. For the sake of brevity, we will refer to those who exhibit a relatively higher degree of strategic disposition as strategists, and to those with a propensity to choose riskier options as risk-takers. It should be noted that "risk-takers" in these contexts are not daredevils, or those that engage in dangerous or threatening behavior, but merely those more inclined to choose risker options with respect to distance and time-related costs of travel.

3. Measuring Strategic Disposition and Orientation Toward Risk

One way to account for the strategic disposition of participants in wayfinding experiments is to administer a questionnaire in which participants externalize their attitude toward strategic thinking. In fact, self-report may be the best way to get at this information, given that strategic thinking is fundamentally an internal cognitive process. While the quality of a particular strategy can be measured by its impact on a variable related to performance, it tells us nothing about the internal state of the agent. Such an approach is still worthwhile, but only in as much as we can corroborate the story that the observed behavior seems to tell with information about what is going on in the agent's mind. While many cognitive processes may be unsuitable to self-report assessment techniques, strategic thinking is likely to be a good candidate because true strategic thinking is quite deliberate.

In contrast to strategic disposition, assessment of orientation to risk can be measured by presentation of hypothetical and real scenarios, as well as by self-report. Since hypothetical scenarios have been shown to strongly relate to real behavior for circumstances that are similar to those that an individual encounters in real-life (Kühberger et al., 2002;

Wiseman & Levin, 1996), and the questions posed here involved patterns of risk and payoff modeled after everyday circumstances, it seems reasonable to suppose that these questions probably capture the intended behavior well.

The goals of the research presented here were to determine the components of the strategic disposition as measured by self-report, to measure patterns orientation to risk in several wayfinding contexts, and to describe how these two high-level components of strategy are interrelated. We also investigate how these components related to overall environmental spatial ability as measured by the Santa Barbara Sense of Direction Scale (Hegarty et al., 2002), an instrument used widely in wayfinding research since its publication (e.g., Dillemuth, 2005; Hegarty et al., 2005; Ishikawa et al., 2008), and to a set of preferences derived from Hochmair (2004).

3.1. Materials

3.1.1. Strategic Disposition Index

The first portion of the questionnaire was designed to identify components of strategic disposition, and asked particpants to rate their level of agreement (on a seven-point scale) with statements related to their interest in and use of strategy in navigation-related and non-navigational situations. Other types of questions included willingness to take risks in navigational contexts (e.g., taking short-cuts), the degree to which they considered the effect of their navigation-related actions on other agents, and their general preferences for routes. Where possible, participants were asked questions on the same topic in both driving and pedestrian contexts. In all, the elements of strategy portion of the questionnaire consisted of forty statements. Of particular interest was an assessment of how well the theoretical division of the elements of strategy presented earlier represented the "strategic disposition" of the participants. The complete forty-item questionnaire is published elsewhere (Pingel, 2010).

Most items were original, though some of the items used in the questionnaire came from existing items in the literature, including questions that were part of the prototype 27-item SBSOD (Hegarty et al., 2002), Hochmair's (2004) complete list of route strategies and preferences used to develop his four factor model, Golledge and Stimson's (1997) list of path selection criteria, and Lawton's Way-Finding Strategy Scale (1994). Four of the top loading items for Lawton's orientation wayfinding strategy, and three of the top loading items for the route wayfinding strategy were included, and the mean response for each of these were used as an index of orientation and route strategy.

3.1.2. Attitudes Toward Risk in Walking and Driving Contexts

The second section of the questionnaire involved a series of hypothetical questions presented in binary choice format. The questions were modeled after those presented by Tversky & Kahneman (1981) in the context of Prospect Theory, but modified to involve prospects of costs, in terms of time or distance, between alternative routes. Route choice problems differ in important ways from the economic and medical problems typically presented by Tversky and Kahneman. In the case of these classic problems from Prospect Theory, questions often took the form of a choice between a sure thing and an all-or-nothing alternative involving some amount of risk. For instance, a researcher might ask a participant, "Which would you prefer, a sure one hundred dollars or a fifty-fifty chance of either nothing or two hundred dollars?" Real-life route choice problems can not easily follow this model because even the worst route will eventually pay off - it will just involve greater costs in terms of distance, time, or some other variable. Similarly, even the best route involves some expenditure.

Of primary interest was an understanding of how the mean time (or distance) affected the choice, and whether the modality of transport (walking or driving) affected the decision. Walking questions were phrased in terms of distance, with two mean distances, 120 and 480 yards, used. Distance was used instead of time, since traversing distance on foot typically incurs costs associated with physical effort, not just time. Driving questions were phrased in terms of time since physical effort is often minimal for casual travel, and issues of time are likely of paramount importance. Questions for driving used expected means of 15 and 60 minutes. Thus, in both walking and driving cases, the ratio of the higher mean to the lower mean was four to one.

Participants were asked to imagine that they were walking or driving and that they did not have a specific time at which they needed to reach their destination. They were then asked to choose between a route that provided a sure total time (or took a sure total distance) and a "risky" option where one had some probability (p) of a lesser time and a $(1 - p)$ probability of a greater time. Since an understanding of whether and how differences in dispersion manifest as costs was a secondary goal of the study, contributors to the variance were adjusted between questions as well. Probabilities used for the better alternative (i.e., the time or distance-saving option) of the risky option were

[.25 .5 .75]. Additionally the proportion of the payoff for the better alternative was varied. Payoff ratios for the better alternative were [.33 .5 .67] of the expected mean, and the amount of the payoff for the worse alternative was calculated to ensure that the expected mean for the risky option was equal to the time given as the "sure" option. Thus, one question was, "Choose between (a) a route that takes a sure 15 minutes or (b) a route with a 1 in 2 chance of taking 5 minutes and a 1 in 2 chance of taking 25 minutes." Each question was asked twice, once with the better alternative of the risky option listed first, once with the better alternative listed last.

In total there were four attributes per question: mean [1 4], probability [.25 .5 .75], payoff ratio [.33 .5 .67], and order of presentation [1 2]. In order to fully test each of these, a total of (2 x 3 x 3 x 2) thirty-six questions per mode (walking and driving) would have to be asked. Given the overall length of the questionnaire, the total number of questions was reduced to twenty (for walking) and nineteen (for driving), with only a sampling of attribute/level pairs related to the variance included. As such, the question sets are targeted at revealing risk orientation patterns for mode, mean, and question order and they are only suggestive for patterns of variance. Each question set asked the same combination of variance attributes, with the exception of the single, inadvertently omitted question on the driving section. Analyses based on this reduced set were based on only the remaining balanced sixteen questions.

The overall set of questions was then analyzed in several ways. First, a simple mean of the responses (coded 0 for the safe alternative, and 1 for the riskier alternative) provided a very rough metric of the respondent's attitude toward risk-taking. These simple metrics (calculated for walking and driving separately) were investigated as an explanatory factor for the outdoor search and route asymmetry studies.

A more in-depth analysis of these questions involved analyzing the effect of means and variances on risk-taking. According to Prospect Theory, as the stakes of games involving gain increase, players become increasingly risk-averse - that is, they are more likely to take the sure alternative. Games involving loss exhibit the opposite pattern, with higher stakes leading to great risk-taking. In this way, we can compare overall risk-taking behavior in driving and walking contexts to the monetary and medical contexts to see if the pattern is similar.

3.1.3. Expression of Preferences

The final portion of the questionnaire asked participants to explicitly rank five criteria for routes in driving and pedestrian contexts separately. Hochmair (2004) suggests that the many criteria on which people select routes can be compressed into four aggregates: whether the route is fast, safe, simple, and attractive. Although bicycle, pedestrian and automobile travel all share similarities, the network restrictions and relatively high cognitive demands associated with driving as compared with walking indicated that the "simple" factor be split into two separate factors. These were an "easy" category related to physical effort and "simple" category related to mental effort. Given how closely related these two words are out of context, they were parenthetically clarified on the questionnaire given to participants as "Easy (not physically demanding)" and "Simple (not complex)." Participants were asked to rank these five attributes [fast safe simple easy attractive] in order of importance for driving and walking contexts separately.

3.2. Procedure and Participants

A total of 101 people participated in the study. The questionnaire itself was developed as part of larger research program, and was administered after one of two wayfinding tasks (Pingel, 2010). The first wayfinding task was search-based, and asked individuals to locate points in space via audio cues. The second wayfinding task examined the route selection of individuals in a pedestrian environment. There was no significant statistical difference between these two groups in terms of how they responded to the questionnaire.

Of the 101 participants, 58 were women and 43 were men. The average age of participants was 19.5 years, and ranged between 17 and 38 years. Participants volunteered for the study in exchange for extra-credit in an introductory geography course.

3.3. Results

3.3.1. Strategic Disposition Index

The primary purpose in the administration of the forty-item questionnaire was to identify a smaller subset of questions that could be used to identify strategists in wayfinding contexts. In order to identify this subset, a central measure was selected that most directly and neatly expressed the desired factor. Item 31 ("I think about route planning in a way that I would characterize as strategic") was selected as this central measure. Correlations were then calculated

Factor	Item	Statement Text	Loading
I	2	I am good at finding the shortest or quickest route to a place.	.34
	5	When driving, I consciously try to find the best route for the circumstances.	.70
	7	When driving, I typically think about my route.	.74
	11	When walking, I typically think about my route.	.71
	14	When walking, I consciously try to find the best route for the circumstances.	.64
	20	I frequently keep track of the direction (N,E,S,W) in which I go when I travel.	.47
	25	I prefer to get directions where I am told the approximate distance to the next turn.	.36
	32	I try to remember the details of the landscape when traveling to a new area.	.40
	34	I frequently choose to try new routes when I travel.	.34
	35	I think it is important to find new routes in the environment.	.41
	39	When parallel parking on a street, I am careful to park so that as many vehicles as possible can fit in a given block of spaces.	.48
II	1	I enjoy playing games that involve a great deal of strategy.	.94
	6	I frequently play games involving a great deal of strategy.	.78
	29	I enjoy activities that involve strategic thinking.	.92
	30	I am good at explaining the strategies I use.	.40
	31	I think about route planning in a way I would characterize as "strategic."	.29
III	12	I generally do not worry much about whether my choices will impact other drivers.	.81
	16	When driving, I try to consider how my choices impact other drivers.	.75
IV	13	I prefer to find a detour rather than sitting in traffic, even if I'm not sure I can find a faster way.	.88
	15	I am willing to take a longer route, if it means not sitting in traffic.	.53
V	4	I enjoy playing games of chance.	.99
	26	I rarely feel anxious when leaving a place that I have not been to for the first time and deciding which way to turn to get to a destination.	.21

Table 1: Factor loadings for 22 Items correlated .1 or better with the central measure (Item 31). The mean score for items on Factor II formed the Strategic Disposition Index (SDI).

between this and each other item on the questionnaire, and only responses with a correlation of .1 or higher (an arbitrary value selected to eliminate only the least relevant items) were retained for further analysis. In total 22 items were retained based on this criterion. Many of the items that were eliminated were obfuscating questions that were not hypothesized to relate to strategic disposition, however some items related to generalized, schematic thinking were also eliminated by this criterion (e.g., Item 17: "I typically only keep a general notion of my route when I travel, and figure the rest out as I go.").

The remaining 22 items (Table 1) were then examined with a factor analysis using maximum likelihood estimation. Principal components analysis revealed that five factors adequately accounted for the variance, with these five factors accounting for 23%, 11%, 9.1%, 7.9%, and 6.9% of the variance, respectively (total 57.9%). Factor analysis using a promax rotation was then used to identify factor loadings. The central measure (Item 31) loaded most highly on the second factor, as did Item 1 ("I enjoy playing games that involve a great deal of strategy."), Item 6 ("I frequently play games involving a great deal of strategy."), Item 29 ("I enjoy activities that involve strategic thinking."), and Item 30 ("I am good at explaining the strategies I use.").

These five items constitute the Strategic Disposition Index (SDI) in the continued discussion. Cronbach's alpha for these five items was .81, indicating good internal reliability. Mean SDI across participants was 4.5 with a standard deviation of 1.2. A Lilliefors test on the distribution of SDI scores failed to reject the null hypothesis of normality, ($KS(99) = 0.075, p = 0.17$). Item-total correlations ranged from .60 to .86. Exploration of other factors was not a primary focus of this study, though it is interesting that items related to a general thoughtfulness about route planning tended to load on Factor I, but that such a thoughtfulness was distinct from an outright consideration of impacts that characterized Factor III, as well as from strategic disposition. SDI was related to mean Factor I score ($r(99) = .45$, $p < .001$), but unrelated to mean Factor III score ($r(99) = .06$, $p = .58$). The items loaded quite clearly on only one factor, with two exceptions. Item 30 loaded on the SDI (.40) but was also loaded somewhat on Factor I (.24). Item 31 had the lowest accepted loading on the SDI (.29) but also loaded weakly on Factor I (.23).

SDI was well-correlated with SBSOD score ($r(99) = .47$). The connection between SDI and SBSOD is explored in more detail via the issue of preferences in section 3.3.3. Like the SBSOD, which measures environmental spatial ability, and Lawton's "Way-finding Strategy Scale" that differentiated persons who typically followed "Orientation" versus "Route" strategies (1994), the SDI had a notable sex bias, with men tending to self-report a stronger strategic disposition ($M = 5.07$, $SD = 1.07$) than women ($M = 4.14$, $SD = 1.19$), a statistically significant difference ($T(99) = 4.03$, $p < .001$). SDI was correlated with the mean of the four questions representative of Lawton's Orientation strategy ($r(99) = .40$, $p < .001$), but not with the mean of the three questions representative of the Route strategy ($r(99) = -.002$, $p = .99$). SBSOD, a measure of performance as well as ability, was correlated with orientation strategy ($r(99) = .39$, $p < .001$) but not with route strategy ($r(99) = -.15$, $p = .14$).

Since choice of orientation or route strategy is related to sex (Lawton, 1994), we investigated the supplementary hypothesis that the relationship between strategic disposition and wayfinding strategy was influenced by sex. This turned out to be the case, as prediction was notably enhanced by a multiple regression model that included an interaction term between sex and SDI (Figure 1). For men, SDI was a good predictor of the use of a orientation wayfinding strategy ($r(99) = .48$, $p = .001$), but the same was not true for women ($r(99) = .19$, $p = .15$). In contrast, SDI was a better (but still weak) predictor of the use a route-based wayfinding strategy for women ($r(99) = .21$, $p = .11$), but not for men ($r(99) = .01$, $p = .93$).

3.3.2. Risk-taking in Walking and Driving Contexts

The hypothetical question sets for walking and driving contexts were evaluated to determine how propensity to risk varied according to mean and variance. The principal interest was in determining how an increased mean travel distance (or time) would affect the propensity to try the risky alternative. For the walking mode, participants were much more likely to choose the risky alternative when the expected mean was lower ($M = .52$, $SD = .25$) than when the expected mean was higher ($M = .35$, $SD = .26$), a difference which was significant according to a paired t-test, $t(100) = 7.4$, $p < .001$ (Figure 2).

The discrete variance for each alternative was calculated using the expressed probabilities and payoff ratios. The use of the payoff ratio rather than the payoff itself means that each variance is scaled to the mean. As a result, each discrete variance was presented four times (twice at each mean level, and twice at each order level), resulting in five different scaled variances present on the final questionnaire. The right-hand pane of Figure 2 illustrates the propensity to risk at different variances. Items with the same scaled variance were averaged together, and differences in means were tested using repeated measures ANOVA. While repeated measures ANOVA indicates significant differences between variance groups, $F(4, 400) = 3.64$, $p = .006$, it is somewhat questionable whether the average of four binary options (equivalent to five levels) shows enough variability to permit parametric testing. A second analysis using the non-parametric equivalent to repeated measures ANOVA, Friedman's test, also finds significant differences between groups, $\chi^2(4, 400) = 11.16$, $p = .025$. The complex pattern illustrated in Figure 2 suggests that though variance itself is likely not a concern, differences among groups may be attributable to either the probabilities or payoff ratios given in the problem. Due to time limitations on an already lengthy questionnaire set, the decision to focus on how means contributed to risk-taking precluded a more in-depth analysis of how the constituents of variance affect risk-taking.

In the driving presentation, as with walking, it was expected that as the mean outcome and variance increased people would be less likely to choose the risky alternative. In fact, participants were slightly more likely to choose the risky alternative when the expected mean was higher ($M = .41$, $SD = .23$) than when it was lower ($M = .37$, $SD = .22$), though the difference was not statistically significant $t(100) = -1.90$, $p = .061$. This relationship is shown in the left pane of Figure 3.

When factors of probability and payoff ratio are combined to calculate a variance scaled proportional to the mean, it becomes clear that increased variance is associated with a lower propensity to choose the risky option. The right-hand pane of Figure 3 illustrates the propensity to risk associated with increased variances. These results were calculated using all nineteen items. The missing item corresponds to a scaled variance of 0.33, and given the pattern of the data for the other items, it would likely have reduced the selection propensity by only two to five percent. The differences in means for all the groups was highly significant according to repeated measures ANOVA, $F(4, 400) = 25.5$, $p < .001$, as well as the non-parametric equivalent, the Friedman test, $\chi^2(4, 400) = 63.4$, $p < .001$.

The mean response for each mode was calculated to provide a risk-taking metric. The propensity to risk in the walking context overall ($M = .43, SD = .23$) was similar to the propensity to risk in the driving context ($M = .42, SD = .19$), $t(100) = .81$, $p = .42$. Risk taking in the walking context was correlated with risk-taking in the driving context, $r(99) = .46$. SDI was not correlated with risk-taking in either the walking ($r(99) = .08$) or driving contexts ($r(99) = -.02$). These results suggest risk-taking attitude, at least within wayfinding contexts, could be represented by a common factor, and that such a factor is distinct from strategic disposition. There was no significant difference between sexes for either walking ($t(99) = .36$, $p = .72$) or driving ($t(99) = .25$, $p = .80$) risk-taking mean.

3.3.3. Comparison of Walking and Driving Preferences

As is common in questions involving route preferences, the quality of being fast (an aggregate of shortest time and shortest distance preferences) was the most important factor in walking and driving contexts. Safety was the second most important factor, and attractiveness was consistently rated very low in importance. That routes were simple (not complex) was least important when walking, but was the third most important factor while driving. This is likely due to the much greater cognitive demands associated with the act of driving itself, and the relatively greater costs associated with correcting mistakes in that domain (Burns, 1998). Easy routes (i.e., those that were not physically demanding) were more important in walking contexts than driving, probably because driving is not typically a physically demanding task. Figure 4 illustrates these relationships.

Although a formal analysis of the role of sex on preferences is beyond the scope of this paper, it is worthwhile to note a difference in mean ranking for the criteria evident for men and women in both walking and driving contexts. For women, when walking, it is notable that safety is at least as important as distance/time, and that the attractiveness of a route is relatively more important for men than for women. Overall, the order of the criteria was unchanged between men and women in the driving context, though it is notable that for men, distance/time is the primary criterion, while for women, the difference in mean rank between this and other criteria is far smaller.

SDI was, in general, not related to stated preferences for either mode, and only two correlations reached significance: a higher SDI score was associated with a lower valuation of simple driving routes ($r(99) = .23$, $p = .02$) and with a higher valuation of attractive driving routes ($r(99) = -.21$, $p = .03$). Orientation to risk for walking (the mean response to walking-related hypothetical questions) was associated with reduced preference for easy walking routes ($r(99) = .31$, $p = .001$) and an increased preference for attractive walking routes ($r(99) = -.25$, $p = .01$) but with no other walking or driving preference rating. The mean response to driving-related hypothetical questions was not related to any walking or driving preference rating.

The preference data collected for each subject allows for a preliminary exploration of the connection between strategic disposition (measured by the SDI) and environmental spatial ability (measured by the SBSOD). Given the relatively high correlation ($r(99) = .47$) between these two indices, we might well wonder the degree to which they measure different things. In order to investigate this concern, we explored the differences between high-level strategists and persons with a high level of environmental spatial ability. Thirty-six participants had scores that were above the mean for both SDI and SBSOD. Among these, we classified as "strategists" those individuals who had a higher z-score on the SDI than on the SBSOD ($n = 20$). Similarly, we classified as "orienteers" those individuals who had a higher z-score on the SBSOD than on the SDI ($n = 16$).

There were interesting differences between these two groups for preference pattern in both walking and driving contexts (Figure 5). In the pedestrian context, orienteers exhibited a broader separation in the range of preferences, though no individual criterion exhibited a significant statistical difference in distribution. The driving context, however, exhibited a strikingly different pattern. Strategists in this context tended to have a broader range in the mean criteria ranks. In contrast, orienteers overwhelmingly preferred fast routes to the exclusion of all other criteria, which were rated nearly equivalently. Given the relatively small subsample, only the difference between strategists and orienteers on the "fast" criterion reached statistical significance according to a Mann-Whitney rank sum test ($Z = -2.01$, $p = .045$).

4. Discussion

We hypothesized that strategy is best characterized by deliberate, conditional, schematic, and externalizable thinking. We also expressed that strategic thinkers would relate a strong affinity for and frequency of participating in strategic activities. A questionnaire-based assessment showed that frequency, affinity, and externalizability for strategic thinking are strongly interrelated, and an expressed preference for strategy in wayfinding contexts shares a common factor with these. However, other elements of strategy appear divergent, including conditional and schematic thinking. Based on these results it would seem that the term "strategy" itself is a key concept with which some people ("strategists") identify, apart from a general thoughtfulness about route-planning or specific wayfinding techniques.

One provocative result is the connection between strategic disposition, wayfinding strategy, and sex. Lawton (1994) showed that the orientation strategy is preferentially used by men, while the route strategy is preferentially used by women. Our results show that this preference manifests particularly with strategists, for while male strategists are more likely than less strategically-minded men to use an orientation strategy, they are no more likely to use a route strategy. In contrast, female strategists are essentially drawn equally between the two options.

The strong relationship between strategic disposition and environmental spatial ability is notable, but not particularly surprising. There is certainly a naive assumption that good strategy yields good performance. The SBSOD instrument itself ostensibly measures environmental spatial ability, but was selected to predict performance. There again, though ability and performance should correlate quite well, we understand that ability is something akin to a potential to perform rather than a direct measurement of performance itself. Still, since the issue at stake is whether strategic disposition mediates wayfinding style better than a measurement of environmental spatial ability, we must address the question of whether or not SDI and SBSOD are measuring the same construct.

The analysis of strategists (relatively high SDI) and orienteers (relatively high SBSOD) and their connection to wayfinding preferences by mode indicates that these two groups think differently about wayfinding problems. Among individuals with both high SDI and SBSOD scores, those with relatively high SBSOD score focused on "fast" routes in both driving and walking contexts. Within the driving context, all other criteria were secondary and were barely distinguishable in terms of mean rank. Future work in which SDI, SBSOD, and preference sets are measured in the context of behavioral wayfinding will clarify the relationship between strategic disposition, strategy, and environmental spatial ability.

These relationships provide tentative evidence that the identification of strategic disposition is likely to be of use in predicting how people want to travel. Preferences, abilities, and strategies are all distinct but interrelated factors in determining overall performance on a wayfinding task. Strategic disposition is one link between these three, in that it represents the amount and quality of cognitive effort that an individual is willing to devote to a wayfinding problem to make sure that his or her actions (via heuristics or particular strategies) are likely to accomplish his or her objectives.

Attitude toward risk, or risk orientation, is another major element of strategic thinking, and correlation analysis suggests that it is quite distinct from strategic disposition. The strategic disposition fundamentally describes a willingness and affinity for strategic thinking without dictating its ultimate expression. In contrast, orientation to risk describes an overall willingness to choose the surer alternative to a riskier one, where the mean payoffs are equal. In this sense, orientation to risk is less about rationality than personality. The stability of measurements of orientation to risk in spite of differences in mode of transport indicates that it could be used in a variety of wayfinding contexts to predict preferences that may be otherwise difficult to quantify.

The differences in expression of risk-taking with respect to means and scaled variances is interesting given that there was a similar overall willingness to risk for both walking and driving modes. That the overall propensity-to-risk between the modes was the same indicates that the overall costs were probably viewed similarly. Drivers were apparently more sensitive to variability of the result than they were in differences in the mean result, while the reverse was true for walkers.

Although preferences for kinds of routes are in some sense a strategy, preference rankings were only very weakly related to either strategic disposition or orientation to risk. This result provides evidence that strategies in wayfinding are instrumental - that is, that the goals of wayfinding (preferences) are distinct from the strategies to achieve them.

One limitation of the study involves the use of college-aged participants. Wayfinding strategy, especially in driving contexts, could well change over time. These results provide a basis for how strategy and risk manifest in early adulthood, but future work with greater diversity in the age of participants could be very useful in showing how time impacts these kinds of individual differences.

Although we have shown relationships between strategic disposition and orientation to risk to wayfinding preferences, strategies, and a proxy measure of performance (SBSOD), we have not shown the relationship between these constructs and observed wayfinding behavior. Instead, we have emphasized the conceptual basis for strategy and outlined components of and metrics for strategic disposition and orientation to risk. Future work will apply these metrics to interpret observed wayfinding behavior in both traditional contexts (e.g., driving or walking to a known destination) as well as to search behavior.

The original inspiration for this work centered on the creation of useful metrics that could drive "strategic profiles" for digital navigation systems. Although most systems solicit wayfinding preferences, it is often difficult to relate the large number of potential preferences to each other in a robust way. The reduced set of five meta-preferences based on

Hochmair's (2004) set for bicycle travel is one way to compress this space; we believe that the solicitation of higher level elements of strategy - strategic disposition and orientation to risk - is likely to be important as well. These two dimensions provide a key link between preferences and their expression in travel, by highlighting the importance of the criteria set overall and by providing a mechanism to predict how the agent is likely to react to uncertainty estimates.

Acknowledgments

The author wishes to acknowledge the generous funding of the University of California Transportation Center in the form of a dissertation fellowship as well as the IC Postdoctoral Fellowship Program (Grant #HMN1582-09-1-0013). Additionally, the author wishes to thank Keith Clarke, Daniel Montello, Mary Hegarty, Martin Raubal and Reg Golledge for their very helpful advice on many aspects of the work, as well as to two anonymous reviewers whose comments greatly improved the quality of the paper.

Bailenson, J. N., Shum, M. S., & Uttal, D. H. (1998). Road climbing: Principles governing asymmetric route choices on maps. *Journal of Environmental Psychology*, *18*, 251–264.

Bailenson, J. N., Shum, M. S., & Uttal, D. H. (2000). The initial segment strategy: A heuristic for route selection. *Memory & Cognition*, *28*, 306–318.

Burns, P. C. (1998). Wayfinding errors while driving. *Journal of Environmental Psychology*, *18*, 209–217.

Christenfeld, N. (1995). Choices from identical options. *Psychological Science*, *6*, 50–55.

Cornell, E. H., Heth, C. D., & Rowat, W. L. (1992). Wayfinding by children and adults: Response to instructions to use look-back and retrace strategies. *Developmental Psychology*, *28*, 328–336.

Dillemuth, J. (2005). Evaluating map generalization for mobile display. *Cartography and Geographic Information Science*, *32*, 285–301.

Duckham, M., & Kulik, L. (2003). Simplest paths: Automated route selection for navigation. In *Spatial Information Theory, Proceedings - Foundations of Geographic Information Science* (pp. 169–185). Berlin: Springer-Verlag volume 2825 of *Lecture Notes in Computer Science*.

Gärling, T., & Gärling, E. (1988). Distance minimization in downtown pedestrian shopping. *Environment and Planning A*, *20*, 547–554.

Golledge, R. G. (1995a). *Defining the Criteria Used in Path Selection*. Working Paper No. 278. The University of California Transportation Center. Berkeley, California.

Golledge, R. G. (1995b). *Path Selection and Route Preference in Human Navigation: A Progress Report*. Working Paper No. 277. The University of California Transportation Center. Berkeley, California.

Golledge, R. G., & Stimson, J. (1997). *Spatial behavior: a geographic perspective*. New York: Guilford Press.

Hayes-Roth, B., & Hayes-Roth, F. (1979). A cognitive model of planning. *Cognitive Science*, *3*, 275–310.

Hegarty, M., Montello, D. R., Richardson, A. E., Ishikawa, T., & Lovelace, K. L. (2005). Spatial abilities at different scales: Individual differences in aptitude-test performance and spatial-layout learning. *Intelligence*, *34*, 151–176.

Hegarty, M., Richardson, A. E., Montello, D. R., Lovelace, K., & Subbiah, I. (2002). Development of a self-report measure of environmental spatial ability. *Intelligence*, *30*, 425–447.

Hochmair, H. (2004). Towards a classification of route selection criteria for route planning tools. In P. Fisher (Ed.), *Developments in Spatial Data Handling* (pp. 481–492). Berlin: Springer.

Hochmair, H., & Frank, A. U. (2000). Influence of estimation errors on wayfinding-decisions in unknown street networks - analyzing the least-angle strategy. *Spatial Cognition and Computation*, *2*, 283–313.

Hochmair, H. H. (2005). Investigating the effectiveness of the least-angle strategy for wayfinding in unknown street networks. *Environment and Planning B, Planning and Design*, *32*, 673–691.

Hutchins, E. (1995). *Cognition in the wild*. Cambridge, Mass.: MIT Press.

Ishikawa, T., Fujiwara, H., Imai, O., & Okabe, A. (2008). Wayfinding with a GPS-based mobile navigation system: A comparison with maps and direct experience. *Journal of Environmental Psychology*, *28*, 74–82.

Kahneman, D., & Frederick, S. (2002). Representativeness revisited: Attribute substitution in intuitive judgment. (pp. 49–81). New York: Cambridge University Press.

Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decision under risk. *Econometrica*, *47*, 263–292.

Kühberger, A., Schulte-Mecklenbeck, M., & Perner, J. (2002). Framing decisions: Hypothetical and real. *Organizational Behavior and Human Decision Processes*, *89*, 1162–1175.

Lawton, C. A. (1994). Gender differences in way-finding strategies: Relationship to spatial ability and spatial anxiety. *Sex Roles*, *30*, 765–779.

Lobben, A. K. (2004). Tasks, strategies, and cognitive processes associated with navigational map reading: A review perspective. *The Professional Geographer*, *56*, 270–281.

Mark, D. M. (1986). Automated route selection for navigation. *IEEE Aerospace and Electronic Systems Magazine*, *1*, 2–5.

Montello, D. R. (2005). Navigation. In A. Miyake, & P. Shah (Eds.), *Cambridge handbook of visuospatial thinking* (pp. 257–294). Cambridge: Cambridge University Press.

Naus, M., & Ornstein, P. (1983). Development of memory strategies: Analysis, questions, and issues. In M. Chi (Ed.), *Trends in memory development research*. New York: Karger.

Pingel, T. J. (2010). *Strategic Elements of Route Choice*. Dissertation. University of California, Santa Barbara Santa Barbara.

Richter, K.-F., & Duckham, M. (2008). Simplest instructions: Finding easy-to-describe routes for navigation. In T. Cova, K. Beard, M. Goodchild, & A. Frank (Eds.), *Lecture Notes in Computer Science 5266 (GIScience 2008)* (pp. 274–289). Berlin: Springer.

Siegler, R. S. (1991). *Children's thinking*. (2nd ed.). Englewood Cliffs, N.J.: Prentice-Hall. Robert S. Siegler. ill. ; 23 cm.

Siegler, R. S., & Jenkins, E. A. (1989). *How children discover new strategies*. Hillsdale, N.J.: L. Erlbaum. Robert S. Siegler, Eric Jenkins. ill. ; 23 cm.

Tversky, A., & Kahneman, D. (1981). The framing of decisions and the psychology of choice. *Science*, *211*, 453–458.

Wiener, J. M., & Mallot, H. A. (2003). Fine-to-coarse route planning and navigation in regionalized environments. *Spatial Cognition and Computation*, *3*, 331–358.

Wiseman, D. B., & Levin, I. P. (1996). Comparing risky decisions making under conditions of real and hypothetical consequences. *Organizational Behavior and Human Decision Processes*, *66*, 241–150.

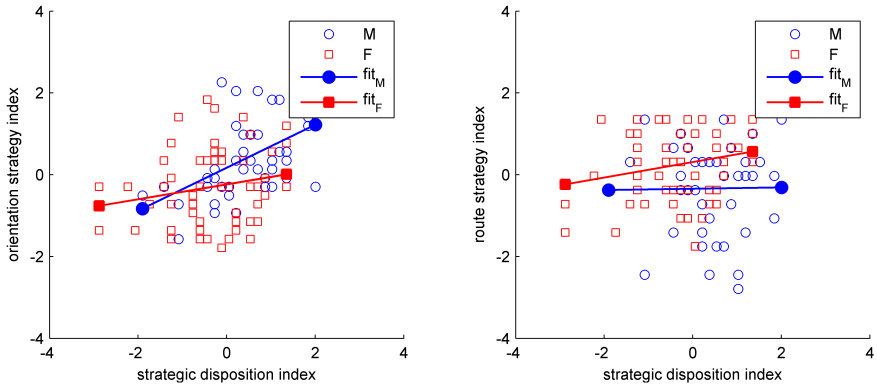

Figure 1: Z-score normalized strategic disposition index (SDI) against orientation (left) and route (right) wayfinding strategy indexes by sex. SDI was a good predictor of the use of orientation strategy and a poor predictor of route strategy for men, but was only modestly connected to either strategy for women.

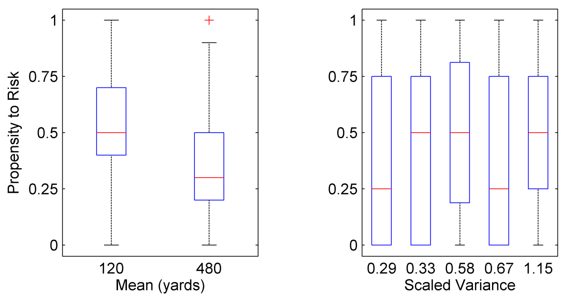

Figure 2: Propensity to choose the "risky" option (1) over the safe option (0) in the walking problem given changes in mean and variance. A higher mean increases the propensity to risk, while changes in variance produce no coherent effect.

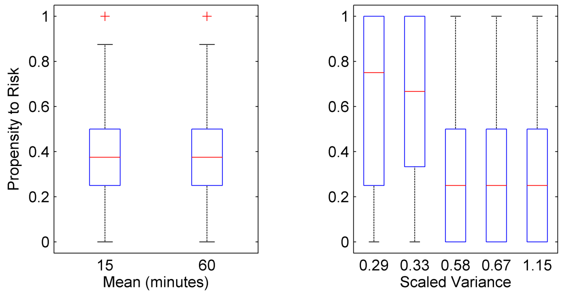

Figure 3: Propensity to choose the “risky” option in the driving problem given changes in mean and variance. Changes in mean did not affect propensity to risk, but increased variance decreased the propensity to risk.

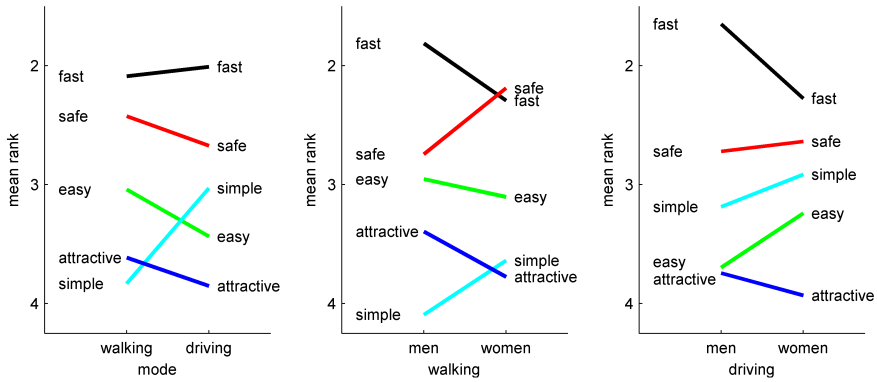

Figure 4: Comparison of mean rankings for route attributes by mode of travel. Route simplicity is an important attribute for driving, but not for walking. Men and women exhibit somewhat different preference patterns for each mode.

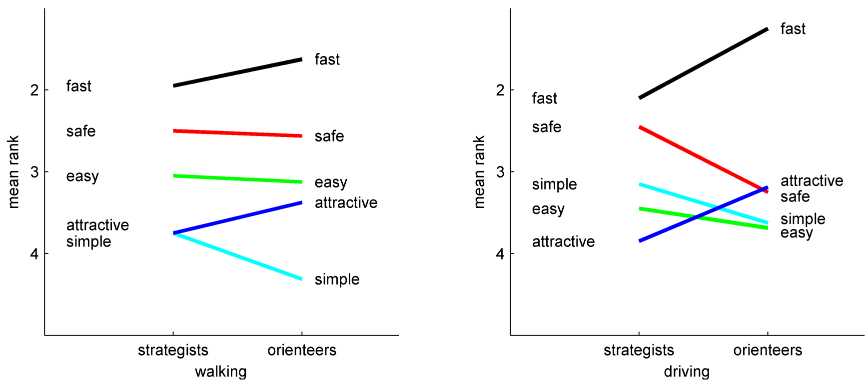

Figure 5: Comparison of mean rankings for strategists (i.e., those participants with high SDI and SBSOD scores, but relatively higher SDI) and orienteers (i.e., those participants with high SDI and SBSOD scores, but relatively higher SBSOD). Pedestrian patterns were similar, but driving patterns were strikingly different, with orienteers’ criteria dominated by a preference for fast routes.