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Up North and Down South: Implicit Associations Between Topography and Cardinal Direction

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Abstract

Route planners show a reliable tendency to select south- relative to north-going routes between two horizontally (east/west) aligned landmarks, suggesting the application of a north-is-up heuristic [Memory & Cognition 38: 700-712, *2010*]. The source of this north-is-up bias remains unknown, and there is no strong evidence to suggest that it is due to explicit strategy use. In four experiments we attempt to further elucidate the source of this effect by testing whether it can be attributed to implicit associations between cardinal direction (north/south) and topography (mountainous/level terrain). Experiments 1 and 2 used an adapted Implicit Association Test and demonstrate automatically activated judgments that associate north with mountainous and south with relatively level terrain. Experiment 3 rules out the possibility that this effect is due to the local topography of New England by replicating in participants from the topographically dissimilar Midwestern United States. Finally, Experiment 4 tests the relative contribution of implicit versus explicit associations between cardinal direction and topography in predicting route planning asymmetries; we show that implicit associations are a stronger predictor of southern route biases than explicit processes. Overall, results demonstrate that the conceptualization of space can be driven by physically unfounded implicit associations between cardinal directions and topographical features, and these associations are at least partially responsible for southern route preferences.

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Up North and Down South: Implicit Associations Between Topography and Cardinal Direction

We think about and act within space in a variety of ways; we can think about where we are, where other things are, and how to get there. Underlying this diversity of spatial behavior are mental representations of space that have proven vulnerable to a number of factors. For instance, navigational decisions are often guided by functional (e.g., building purpose; Hirtle & Jonides, 1985), semantic (Hirtle & Mascolo, 1986), and demographic (e.g., race; Maddox, Rapp, Brion & Taylor, 2008) information associated with spatial locations. Additionally, people use heuristics or rules of thumb to aid in decisions within unfamiliar environments; for instance, selecting routes based on straightness (Bailenson, Shum & Uttal, 1998, 2000), number of landmarks and turns (Sadalla & Staplin, 1980), and angular deviation from the overall direction of a destination (Hochmair & Frank, 2002). We recently discovered another heuristic that biases spatial decision making, the *north-is-up* heuristic, which causes participants generally to select south- rather than north-going routes through unfamiliar environments, and to estimate longer travel times when traveling northward relative to southward (Brunyé, Mahoney, Gardony, & Taylor, 2010). In other words, participants appear to associate a canonical axis (*north/south*) with a vertical axis (*up/down*). It is unclear, however, whether these effects are due to conscious, explicitly-guided judgments of space or implicitly-guided judgments occurring outside a participant's awareness. The present experiments thus seek to better define the mechanisms that might underlie biased spatial decision making.

One ostensible goal of spatial thinking is to support action within an environment, such as describing where you are with respect to someone else or navigating between landmarks. In many cases the spatial thinking responsible for accomplishing these tasks might include reviewing spatial relationships, identifying routes, and selecting a viable path (Benshoof, 1970; Bovy & Stern, 1990; Gärling, Lindberg, & Mantyla, 1983; Golledge, 1999; Jacoby, 1917; Seneviante & Morrall, 1986). In these situations, people typically do not realize that their selections can be biased by a number of common strategies, or rules-of-thumb. For instance, the *least-angle strategy* predicts that participants will select routes with minimum angular deviation from a goal destination, even when that route may in fact be less than optimal (Conroy Dalton, 2003; Hochmair & Frank, 2002, Hochmair & Karlsson, 2005). Other research shows an *initial segment strategy* that biases participants to select routes based on their initial straightness and length as they depart an origin, even when curving routes may ultimately be shorter (Bailenson et al., 1998, 2000). People also select routes in a manner that minimizes the number of turns and landmarks experienced along the way (Sadalla & Staplin, 1980; Senevirante & Morrall, 1986), and the amount of information they will need to maintain in working memory (Christenfeld, 1995). Finally, there is also evidence of a *regionalization strategy* that causes navigators to select routes that cross fewer regional boundaries and provide fast access to a goal region, independent of where the goal lies within that region (Hochmair, Büchner, & Holscher, 2008; Wiener & Mallot, 2003). The fact that the application of these strategies can lead to inefficient spatial decisions highlights their powerful influence on spatial thinking.

Recent research in our laboratory has revealed that people also use a north-is-up heuristic when planning routes and estimating travel times. In a series of six experiments, we demonstrated that when participants are presented with two equal-length alternate routes connecting horizontally (east/west) aligned landmarks, they tend to select the southward route on 63% of trials (Brunyé et al., 2010); no such bias exists when choosing between east- versus west-going routes. In physical space, of course, there is no valid reason to believe that northern regions should be avoided more than southern regions; moreover, the vast majority of participants were completely unaware of their bias. Yet participants' route selection (as well as their estimates of time, calorie expenditure, and scenic potential) suggests that they represent northern regions as being higher in elevation – a representation that is, in general, unfounded. For example, at a large scale, dividing the USA into northern versus southern areas at 39.5° latitude produces similar mean elevations (in meters of elevation per km^2 of area; $p = .40$). However, participants in our original studies were sampled from a region (Southern New England) characterized by higher elevations to the north, and as a result, our results could reflect the transfer of local geographic knowledge (higher elevations to the north) to unfamiliar environments. To rule out this possibility, we have since replicated our findings with route selection in topographically dissimilar regions, including the University of Twente, Netherlands (Dr. Matthijs Noordzij), the University of Padua, Italy (Dr. Francesca Pazzaglia), and the New Bulgarian University, Sofia, Bulgaria (Dr. Elena Andonova). Most compelling, participants showed a reliable southern route preference (62.1%) in Sofia, Bulgaria, which is topographically characterized by large mountains to the south and relatively level areas to the north (Brunyé, Andonova, Meneghetti, Noordzij, Pazzaglia, Wienemann, Mahoney, & Taylor, in review), which is strongly contrasted with the topographical layout of the New England, U.S.A. region.

The mis-association of north with high elevation may be due to simple correlational learning (Hebb, 1949) wherein participants are accustomed to viewing north in a physically upward orientation (on maps, atlases, and even GPS devices), causing them to associate north with the upward direction. The upward direction relative to the vertical body axis is associated with greater physical exertion; consider ascending relative to descending a mountain, or tossing a ball up relative to dropping it. In both cases, the upward movement leads to greater perceived and actual physical exertion and energy expenditure (Staab, Agnew, & Siconolfi, 1992). A number of studies have demonstrated that action planning and perception involve assessments of current and predicted body states and affordances (Fajen, 2005; Knoblich & Flach, 2001; Proffitt, 2006; Witt, Proffitt, & Epstein, 2004). Thus, if participants misperceive northward areas as higher elevation (or 'uphill') then it logically follows that they might adopt heuristics that minimize traveling through areas associated with higher physical demands. Indeed our earlier work (Brunyé et al., 2010) demonstrated that participants tend to rate north-going routes as requiring more caloric expenditure to travel relative to south-going routes.

Although there is ample evidence for the existence of a north-is-up heuristic, the source of this association is not entirely clear. With the present studies, we ask whether the north-is-up heuristic can be accounted for by strategy selection that occurs within (explicitly) or outside (implicitly) of a participant's awareness. The majority of studies evaluating spatial heuristics suggest that spatial heuristics are implicit, although they have not used methodologies that effectively test for implicit processes (Christenfeld, 1995; Bailenson et al., 1998, 2000; Sadalla & Staplin, 1980). For instance, Christenfeld (1995) demonstrated that people prefer the last of several turn options towards a destination, and though the experiments did not directly examine the source of this bias, Christenfeld notes that it is likely to occur outside of participants' conscious awareness. In contrast, there is very limited evidence suggesting that in certain cases, participants may be explicitly applying these spatial strategies. For instance, Hochmair and Karlsson (2005) noted that a small number of participants verbally report an explicit preference for shorter initial path segments as a form of risk aversion (to minimize potential backtracking if a route turns out to be incorrect); most participants, however, were unaware of their inclination and could not explain their performance. In our own studies, very few participants reported an explicit judgment that north-going routes were more "difficult" or "demanding" and therefore selected the southern option to minimize physical effort (Brunyé et al., 2010). Thus, there is limited evidence that, when directly asked, some participants are aware of using spatial heuristics to guide decision making.

In general, three pieces of evidence demonstrate that north and south are only weakly explicitly associated with up and down, respectively. First, near-neighbors latent semantic analysis (LSA; Landauer & Dumais, 1997) suggests that north and up, and south and down, are weak associates. Thus, it appears that these words are rarely contextually bound in large text segments, and do not share strong meaning similarities or substitutability. Second, free association norms (Nelson, McEvoy, & Schreiber, 1998) demonstrate that fewer than 3% of participants produce the word “up” in response to a North cue, and fewer than 2% produce “down” in response to a South cue. Thus, north and up, and south and down, do not appear to hold strong associations at a level of explicit awareness. Third, pilot data from our laboratory involving responses to a free-association task using a New England college student sample (n=40) confirm that spatial terms describing the vertical dimension are rarely produced in response to a North cue (e.g., "*up"* is < 3% of all responses), or South cue (e.g., *down* is < 3% of all responses). Taken together, there is very weak evidence for explicit associations between terms describing the vertical axis (up/down) and those describing canonical axes (north/south).

Determining the origin of spatial heuristics is critical for fully understanding the mechanisms underlying variation in human spatial cognition and ultimately modeling and predicting spatial behavior in complex environments (Gärling & Gärling, 1988; Golledge, 1999; Kuipers, 2000; Montello, 1998; Raubal, 2002; Yoshino, 1991). Given only limited evidence that the north-is-up heuristic could be driven by explicit associations, we sought to examine the potential contribution of implicit processes to the north-is-up heuristic. To do so, our first three experiments adapted the Implicit Association Test (IAT; Greenwald, McGhee & Schwartz, 1998) to spatial stimuli. The IAT assesses the relative fluidity of making congruent versus incongruent associations by measuring speeded responses during a category discrimination task. Traditionally, this task has been used in experimental social and personality psychology to identify associations between, for instance, racial target categories (black/white) and pleasantness attribute categories (good/bad). If the target categories (black/white) are differentially associated with the attribute categories (good/bad), the participant will show faster response times when the associated concepts are congruent with their natural inclination (e.g., white/good) versus incongruent (e.g., white/bad). In this manner, the IAT is thought to measure automatic and implicitly activated judgments that are outside of the participant's awareness, and is also considered invulnerable to explicit strategies (Greenwald et al., 1998). Our first three experiments thus examined whether the IAT would provide evidence of the implicit nature of the north-is-up heuristic. Our final experiment directly examined whether implicit versus explicit associations between topography and cardinal direction would predict route planning asymmetries.

Experiment 1

Our first study adapted the IAT to measure the implicit association between cardinal direction target categories (northern/southern) and topographical attributes (mountainous/level terrain). If the north-is-up heuristic is at least partially driven by implicit associations between cardinal direction and topography, then participants will be faster to categorize north with mountains and south with level terrain than they are to categorize north with level terrain and south with mountains. This first experiment tests this hypothesis in a sample of New England area participants.

Method

Participants & Design. 40 Tufts University (Medford, MA) undergraduate students (age M=19.4, SD=1.5; 23 female) participated for monetary compensation ($10). In a within-participants design, each participant performed both congruent and incongruent associations.

Materials. All materials and procedures were developed using standard criteria reported by Greenwald, Nosek and Banaji (2003). We developed a total of 16 target images (550 x 413 pixels), each depicting an urban satellite image background, gathered from suburban Canada: Winnipeg, MB, Calgary, AL, and Toronto, ON, using the Google^{TM} Maps utility at a zoom level of 1”=500 linear feet. Each target image depicted a single yellow (75 x 75 pixel) star occupying one of eight locations along the northern or southern border of the image (see Figure 1, top panel). For the attribute images (482 x 333 pixels), we used 12 photographs, 6 of which depicted mountains and 6 depicted level terrain; within each group of 6 images, 3 were from a cold/snowy and 3 from a warm/sunny climate (see Figure 1, middle panel).[1] Additionally, because previous studies have shown that low-level features can affect how images are processed (e.g., Epstein & Ward, 2010), we equalized the luminance of all of the stimuli. For stimulus presentation and data collection, we used an iMac with a 24" widescreen display running SuperLab 4.0 (Cedrus, Inc.) software.

Procedure. Each participant was presented with seven blocks of trials. Block 1 involved an initial target concept discrimination, during which the participant practiced categorizing the 16 north/south images in correspondence with designated left (F) and right (J) keys over the course of 20 trials. Block 2 involved

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[1] All stimulus images are available for download at http://ase.tufts.edu/psychology/spacelab

an initial attribute discrimination, during which the participant practiced categorizing the 12 mountainous (F key) versus level (J key) terrain images, over the course of 20 trials. Block 3 involved 40 practice trials of the initial combined task, which involved categorizing both the target and attribute images into the learned key positions; Block 4 was identical to Block 3, but was considered an experimental block. Block 5 involved 20 trials of practicing an opposite target concept and key pairing from that learned in Block 1 (north/south images). Block 6 involved the reversed combined task, which was identical to Block 3 except that the target concept was now associated with the opposite keys (F or J). Finally, Block 7 was identical to Block 6, but considered an experimental block. To avoid order effects, across participants we counterbalanced whether the first or second set of practice and experimental blocks involved linking the target concept with keys F or J; attribute categorization always used the same keys (mountainous terrain: F, level terrain: J). In this way, half of the participants performed the congruent task (north/mountainous, south/level) first, and half performed the incongruent task (south/mountainous, north/level) first. Written instructions were provided preceding each of the 7 blocks; in general, participants were instructed to classify each image as quickly as possible without compromising accuracy.

On a given trial, a single image was presented in the center of the computer monitor and the participant was tasked to categorize the image as either north/south or mountainous/level. For the experimental combined blocks, each trial presented an image chosen at random (without replacement) from the set of 28 images. Once the set of 28 images was exhausted, the script randomly selected a set of 12 additional images from the pool of 28. Overall, each image appeared a minimum of 1 time and maximum of 2 times during an experimental combined block. Trials were self-paced, and participants were given as much time as necessary to respond. Accuracy and response time data were automatically collected.

Results

Scoring and Analysis. We analyzed error rates and response latencies using the improved scoring algorithm described by Greenwald and colleagues (2003). This algorithm removes trials with response latencies below 300msec or above 10,000msec (no trials met these criteria), and replaces response latencies for error trials with the mean for the corresponding block plus 600msec.

This analysis method results in a single response latency mean for both the practice and experimental blocks for each of our two combined tasks (congruent, incongruent), and further allows us to separate data as a function of whether the participant performed congruent versus incongruent as their first combined task. We do note, however, that substantial literature has demonstrated little to no effect of the order of task compatibility conditions with the current design (e.g., Greenwald et al., 1998; Greenwald et al., 2003; Nosek, Greenwald & Banaji, 2005).

Statistical test results are accompanied by eta-squared (ANOVA) or Cohen's *d* (t-test) effect size measures. To promote direct comparison to the extant literature, we also provide mean IAT-specific D values (Greenwald et al., 1998) for each of experiment; a D value significantly greater than zero indicates an effect of congruent versus incongruent pairings. For a discussion of differences between Cohen's *d* and the IAT-specific D measure, and validation of the latter, see Greenwald et al. (1998). Our primary analyses include experimental blocks only, and D values include both practice and experimental blocks.

Implicit Associations. An omnibus 2(Combination Type: Congruent, Incongruent) x 2(Combination Order: Congruent first, Congruent second) mixed models ANOVA on error rates for experimental blocks demonstrated a marginal effect of Combination Type, $F(1, 38)=2.86$, $p=.099$, $\eta^2=.07$, with somewhat higher error rates during incongruent ($M=.10$, $SE=.01$) versus congruent ($M=.075$, $SE=.01$) trials. A second 2 x 2 mixed models ANOVA on response latencies for experimental blocks demonstrated an effect of Combination Type, $F(1,38)=18.5$, $p < .01$, $\eta^2=.32$, but no effect of Combination Order, $F(1,38)=4.16$, $p > .05$, $\eta^2=.10$, and the two variables did not interact ($p > .05$). The effect of Combination

Type is illustrated in Figure 2. A paired t-test comparing Incongruent versus Congruent response latency, collapsed across Combination Order, revealed higher latencies in the incongruent relative to the congruent condition, $t(39)=3.44$, $p < .01$, $d=.54$. The overall D value for the effect of incongruence was .30, significantly greater than 0, $t(39)=5.89$, $p < .01$, $d=.94$.

Experiment 1 Conclusion

Our first study used an adapted IAT to examine whether people show implicit associations between cardinal direction target categories (northern/southern) and topographical attributes (mountainous/level terrain). In line with the hypothesis that the north-is-up heuristic may be at least partially driven by implicit associations between cardinal direction and topographical space, participants showed significantly higher response latencies with the incongruent relative to congruent combinations. That is, participants were faster to categorize north with mountainous and south with level terrains than they were to categorize south with mountainous and north with level terrains. This is the first evidence that participants implicitly associate topography and cardinal direction.

One limitation of the present stimuli, however, is that they potentially biased the spatial allocation of visual attention as a function of whether the target images showed a star at the top or bottom. That is, it is possible that upward looking behavior in response to a northern star transferred to upward looking behavior in recognition of a mountain peak (or vice-versa). Indeed there is a possibility that if both the attribute image (e.g., mountain peaks) and target image (e.g., star in the north) promoted upward or downward visual attention, this could lead to faster categorization relative to when visual attention patterns were incongruent (e.g., star in the south and mountain peaks).

Experiment 2

To test the possibility that congruent versus incongruent spatial visual attention biases influenced the results of Experiment 1, we replicated Experiment 1 with one critical change: the target stimuli depicted a compass rose with either an N (north) or S (south) depicted in the center. If the congruency effects in Experiment 1 are solely due to congruence between the looking behaviors elicited by our target and attribute images, then there should be no evidence of a response latency advantage for either combination type. In contrast, if the effects in Experiment 1 were driven by implicit associations between topography and cardinal direction, then we should replicate the previous pattern of results.

Method

Participants & Design. 40 Tufts University (Medford, MA) undergraduate students (age M=21.1, SD=3.2; 21 female) participated for monetary compensation ($10). In a within-participants design, each participant was tasked to perform both congruent and incongruent combination types.

Materials and Procedure. All materials and procedures matched those of Experiment 1, with one exception. The target (north/south) images were replaced with new images that depicted a compass rose with either an N or S in the center (see Figure 1, bottom panel). Sixteen target images were developed, using eight differently-styled grayscale compass roses; half of these 16 images depicted the letter N in the center (north), and half the letter S in the center (south). The letter N was always depicted in red 60-point Times New Roman font. Image luminance was equated using the same method as in Experiment 1.

Results

Scoring and Analysis. As in Experiment 1, we used the improved scoring algorithm proposed by Greenwald and colleagues (2003), and no participants met the criteria for removal.

Implicit Associations. An omnibus 2(Combination Type: Congruent, Incongruent) x 2(Combination Order: Congruent first, Congruent second) mixed models ANOVA on error rates for experimental blocks demonstrated a marginal effect of Combination Type, $F(1, 38)=3.02$, $p=.09$, $\eta^2=.07$, with somewhat higher error rates during incongruent (M=.08, SE=.01) versus congruent (M=.06, SE=.01) trials. A second 2 x 2 mixed models ANOVA on response latencies for experimental blocks demonstrated an effect of Combination Type, $F(1,38)=4.89$, $p < .05$, $\eta^2=.11$, but no effect of Combination Order, $F(1,38) < .01$, $p >$

.05, $\eta^2 < .01$, and the two variables did not interact ($p > .05$). The effect of Combination Type is illustrated in Figure 2. A paired t-test comparing Incongruent versus Congruent response latency, collapsed across Combination Order, revealed higher latencies in the incongruent relative to the congruent condition, $t(39)=2.23$, $p < .05$, $d=.36$. The overall D value for the effect of incongruence was .20, significantly greater than 0, $t(39)=3.2$, $p < .01$, $d=.51$.

Experiment 2 Conclusion

Our second experiment tested the possibility that biases in visual attention contribute to the differences in response latency found between incongruent and congruent N/S and mountainous/level combinations. With a new target image that consistently promoted central visual attention, we replicated the effects of Experiment 1. Overall, participants were faster to categorize north/mountainous and south/level terrain together relative to the opposite pairings. In conjunction with Experiment 1, we consider this compelling evidence that participants implicitly associate topography and cardinal direction.

As mentioned in the Introduction, however, it is possible that our participants were predisposed to associate North and up because of the topography characterizing the New England region with which they were presumably familiar. In fact, northern New England areas are characterized by generally higher elevations (e.g., the white mountains in New Hampshire, green mountains in Vermont), and southern areas by sea level regions in Rhode Island and Connecticut. Although most (approximately 70%) Tufts University undergraduate students are from outside of the New England area, it is possible that the local topographical features are quickly learned and that they influenced the categorization task, driving the differences between congruent and incongruent combinations.

Experiment 3

In Experiment 3, we attempted to replicate the results of Experiment 1 in a United States region that is topographically dissimilar to New England. The Midwestern United States, specifically Ohio, is suitably characterized by mountains to the southeast (Appalachian) and increasingly level areas to the north. To examine whether similar results would hold in this region, we conducted Experiment 3 at Miami University in Oxford, Ohio. If the results of our first two Experiments cannot be solely attributed to the characteristics of the New England topography, then we should find similar response latencies varying as a function of the congruence versus incongruence of our combination types.

Method

Participants & Design. 40 Miami University (Oxford, OH) undergraduate students (age M=18.9, SD=.88; 30 female) participated for partial course credit. In a within-participants design, each participant was tasked to perform both congruent and incongruent combination types.

Materials and Procedure. All materials and procedures matched those of Experiment 1.

Results

Scoring and Analysis. As in Experiments 1 and 2, we used the improved scoring algorithm proposed by Greenwald and colleagues (2003), and no participants met the criteria for removal.

Implicit Associations. An omnibus 2(Combination Type: Congruent, Incongruent) x 2(Combination Order: Congruent first, Congruent second) mixed models ANOVA on error rates for experimental blocks demonstrated similar error rates across all conditions (M=.09, SE=.02). A 2 x 2 mixed models ANOVA (see Figure 2) on response latencies demonstrated an effect of Combination Type, $F(1,38)=10.04$, $p < .01$, $\eta^2=.18$, but no effect of Combination Order, $F(1,38)=.63$, $p > .05$, $\eta^2=.02$. The two variables interacted, $F(1, 38)=6.44$, $p < .05$, $\eta^2=.12$, with faster response latencies for congruent versus incongruent trials across both Combination Orders ($t(39)=2.97$, $p < .01$, $d=.47$), but a more pronounced effect when the incongruent block followed the congruent block. This is a common finding with the IAT, and is not thought to undermine the sensitivity of the task in measuring implicit judgment (Greenwald et al., 1998). The overall D value for the effect of incongruence was .22, significantly greater than 0, $t(39)=3.4$, $p < .01$, $d=.54$.

Experiment 3 Conclusion

Our third experiment attempted to replicate the results of Experiment 1 in an area topographically dissimilar to the northeastern USA. A participant sample from Oxford, OH showed similar results to Experiment 1: overall faster response times for congruent relative to incongruent trials.

Experiment 4

Our final experiment tested the relative contributions of implicit and explicit associations toward predicting route planning asymmetries. We asked participants to complete the IAT as described in the preceding experiments, and an explicit verbal free association task that included the cues *north, south, east, west, up, down, left, right*. Participants were also asked to perform the original route planning task that was used to identify the southern route preference (Brunyé et al., 2010). Given the apparent strength of implicit associations between canonical and vertical/topographical space, and our earlier work showing very little explicit awareness of southern route preferences, we hypothesized that implicit associations between topography and canonical direction would prove stronger predictors of real-world route planning biases than explicit associations.

Method

Participants & Design. 64 Tufts University (Medford, MA) undergraduate students (age *M*=19.4, *SD*=1.6; 42 female) participated for monetary compensation. In a within-participants design, each participant was tasked to perform a free association task, the IAT, and a route planning task. To avoid carry-over effects the free association task was always completed first, and the IAT and route planning tasks were completed in counterbalanced order across participants.

Materials and Procedure. The IAT matched that used in Experiment 2 (using the compass rose depiction).

The free association task presented participants with 50 single words one at a time in the center of the computer monitor. Participants were asked to type the first five words that came to mind in an empty text box situated below the cue word. Cue words included eight spatial cues (*north, south, east, west, up, down, left, right*), four of which were of critical interest (*north, south, up, down*), and forty-two (noun and adjective) filler items equated to the spatial cues in terms of mean frequency and word length (using the MRC psycholinguistic database).

The route planning task was modeled after that used by Brunyé and colleagues (2010). In this task, participants plan and verbally report routes between origins and destinations depicted on adapted Google^{TM} Maps of suburban Pittsburgh, PA and Chicago, IL. For each of the two maps, participants plan 20 routes, 10 of which pose dilemmas and 10 non-dilemmas; dilemma routes have origin-destination pairs positioned either north-south (5) or east-west (5) of one another with equal-length routes connecting them. The former is an east/west dilemma, the latter a north/south dilemma. Non-dilemma routes present only one clearly efficient route between the origin and destination. Across participants the task controls for turn directions (by swapping route origins and destinations), and relative route complexity (by rotating maps 180°). The two maps and corresponding sets of 20 route planning trials are presented in two blocks; in each block the map remains on the computer monitor and participants type their route plan into an empty text box in response to each route planning trial. On each trial participants are asked to respond by typing *the best route from the [origin] to the [destination]*, and trials are presented in random order.

Results

Scoring and Analysis. As in Experiments 1-3, we used the improved IAT scoring algorithm proposed by Greenwald and colleagues (2003), and no participants met the criteria for removal.

For analysis, we first confirmed replication of the incongruence effect found with the IAT, and investigated the extent of explicit associations between the vertical axis (up/down) and canonical direction (north/south) in the free association task. We then confirmed replication of a southern route preference in the route planning task. Finally, we conducted a multiple regression with two predictors indicative of implicit versus explicit associations.

Implicit Association Test. As in Experiments 1-3, the IAT showed a congruence effect. A 2 x 2 mixed models ANOVA (see Figure 2) on response latencies demonstrated an effect of Combination Type, $F(1,62)=22.91$, $p < .01$, $\eta^2=.26$, but no effect of Combination Order or interaction (all *p's* > .05). The overall D value for the effect of incongruence was .44, significantly greater than 0, $t(63)=4.86$, $p < .01$, $d=.61$.

For the regression, we used each participant's D measure, indicative of the extent of implicit association. This measure subtracts mean congruent from incongruent response latencies (incongruent-congruent), and divides by the pooled standard deviation; in this manner, higher difference scores indicate greater difficulty in pairing incongruent versus congruent concepts. This first score ranged from -1.68 to 3.01 ($M = .44$, $SD = .72$). Note that this score did not vary as a function of task order (i.e., IAT then route planning, versus route planning then IAT; $p = .77$).

Free Association Task. The free association task showed overall low rates of explicit association between the vertical (up, down) and canonical (north, south) spatial dimensions, as suggested by free association norms (see Table 1 for the complete response list and descriptive statistics). For the regression, we calculated a score indicative of the extent of explicit association by examining the frequency and rank of spatial terms that were produced in response to the four critical cues (*north, south, up, down*) and described direction on the possibly associated vertical axis: for instance, responding "up" to the *North* cue, or "south" to the *Down* cue. This score was calculated for each trial by considering the sum of two ratios: the number of relevant terms produced (out of the number possible), and the rank of the first produced relevant term (highest rank is 5). In this manner, higher scores indicate more frequent and earlier spatial terms; for instance, if a participant produced the term "summit" as the third response to the *North* cue, they received a score of (.20 + .60 = .80). For an individual trial this second score had a minimum of 0 (no relevant terms produced) and limit of 2 (5 relevant terms produced).

For the regression, we used each participant's scores produced in response to four critical cues (*north, south, up, down*). These scores ranged from 0 to 2 ($M = .20$, $SD = .49$).

Route Planning Task. As in Brunyé and colleagues (2010), the route planning task showed evidence for a southern route preference exceeding that of chance (50%), $t(63)=5.96$, $p < .01$, $d=.74$. In other words, during north-south dilemma trials, participants showed an overall bias towards selecting southern routes (southern selection: $M = .62$, $SD = .16$); no effect was found when examining east-west dilemma trials (east selection: $M = .54$, $SD = .17$).

The sole criterion measure in the multiple regression was the proportion of north/south dilemma trials where participants selected the southern route; higher scores thus indicate a stronger southern route preference. The criterion measure had a minimum of 0 and limit of 1, and ranged from .3 to 1 ($M = .62$, $SD = .16$). As with the IAT measure, this score did not vary as a function of task order ($p = .92$).

Multiple Regression. We conducted a multiple regression with five predictors, four indicative of explicit associations between canonical and vertical space (free association scores in response to *north, south, up, down*), and one indicative of implicit associations (IAT D scores). There was one criterion measure, the southern route bias. The overall model produced an R value of .492, $F(5, 58) = 3.71$, $p < .01$. Of the five predictors, only the IAT D score reached traditional significance levels in predicting the southern route bias, $\beta_{std} = .32$, $t(58) = 2.59$, $p = .01$. Explicit associations in response to the *North* cue marginally predicted the southern route bias, $\beta_{std} = .21$, $t(58) = 1.71$, $p = .09$ (all other predictors, $p > .29$, $\beta_{std} < .13$). In other words, implicit associations were the strongest predictors of the southern route bias.

Follow-up multiple regressions showed that explicit associations between left/right and east/west (e.g., producing *east* in response to a *right* cue) showed no value in predicting route planning patterns along the north/south or east/west dimension (all p's $> .10$). Further, neither implicit nor explicit associations reliably predicted a tendency for participants to select generally east- or west-going routes (all *p's* > .10). Finally, though the four explicit scores tended to be intercorrelated, explicit and implicit measures were not (*p* > .19).

Experiment 4 Conclusion

Our final experiment assessed whether implicit and/or explicit associations between canonical direction and the vertical spatial axis predicted route planning asymmetries. We replicated the original southern route preference effect with participants preferentially selecting south-going routes on approximately 62% of dilemma trials. We also replicated Experiment 2 results, demonstrating implicit associations between cardinal direction and topography. A free association task showed some evidence of explicit associations between cardinal direction and topography, supporting results found in free association norms and latent semantic analysis. Finally, a multiple regression analysis demonstrated that while both explicit and implicit associations positively predicted the southern route preference, only implicit associations proved statistically reliable predictors of route planning behavior. Specifically, individuals who tended to show stronger implicit associations on the IAT also tended to show greater southern route biases during a real-world route planning task.

General Discussion

The powerful influences of spatial heuristics on judgment and decision making, such as during route planning and while making trip duration and fuel consumption estimates, underscore the importance of understanding the cognitive mechanisms that underlie their application. To examine whether people implicitly associate topography with coordinate space, we developed an adapted IAT that involved categorizing topography (mountainous versus level terrain) and spatial coordinates (north, south). If the north-is-up heuristic is at least partially driven by implicit associations, we expected that trials requiring the pairing of incongruent concepts (north and level terrain, south and mountains) would induce higher response latencies relative to congruent pairings. Results from our first three experiments support this hypothesis.

Our first experiment demonstrated that participants were faster to associate the north with mountains and south with level terrain, relative to the opposite pairings. Our second experiment ruled out the possibility that Experiment 1 results were due to stimulus-driven upward and downward biases in the orienting of spatial attention. Our third experiment ruled out the possibility that our results could be attributed to the local topography characterizing the New England region, by replicating our findings in an area that is characterized by generally mountainous topography to the south and east. Taken together, this work demonstrates that some spatial heuristics, specifically the north-is-up heuristic, can be at least partially attributed to strategy selection that occurs outside of a participant's awareness. Indeed results from latent semantic analyses and free association tasks suggest that participants very rarely make an explicit connection between north and up, or south and down. This finding supports earlier work suggesting (but not testing) that spatial heuristics may be primarily driven by implicit associations (Christenfeld, 1995; Bailenson et al., 1998, 2000; Sadalla & Staplin, 1980).

Our final experiment tested whether the tendency to select generally south- relative to north-going routes might be predicted by the extent of implicit associations between cardinal direction and topography. We provide some evidence that southern route preferences are at least partially driven by implicit associations that operate generally outside of navigators' awareness. We also found some limited support that explicit associations predict the southern route bias. Future research will investigate alternative non-verbal methods for eliciting evidence of explicit associations that might underlie route planning behavior; indeed the most parsimonious account may be one involving both implicit and explicit influences.

Why might individuals associate canonical direction with the vertical spatial axis? On maps, atlases, and even GPS devices, people are accustomed to viewing north in a physically upward orientation. Of course, there is no enduring logic that dictates which canonical direction should be oriented upward on a map, though convention dictates a north-up orientation for stationary maps (i.e., Montello, 2005). Through the process of correlational learning, people begin to implicitly associate canonical space with the vertical axis. Given physical experiences associating upward mobility with relative difficulty (Staab et al., 1992), the north-south canonical axis becomes misperceived as indicative of physical effort. Thus, if participants misperceive northward areas as higher elevation (or 'uphill') then it logically follows that they would strategically avoid traveling through what they perceive as relatively demanding areas. Indeed everyday colloquialisms such as *heading down south* or *going up north* may reflect how pervasive such associations are throughout cognition.

Understanding and moving through space is a complex task involving the interactions between individual differences, internal states, and contextual factors. We have provided experimental evidence that implicit associations may modulate performance on spatial tasks. In some cases, selecting routes based on incorrect implicitly-guided judgments may lead individuals on suboptimal routes, and such a pattern may be critical to predicting pedestrian and driver behavior in city planning and civil engineering contexts. There is some suggestion that associations between vertical and canonical axes may drive route planning behavior in both small- and large-scale environments. For instance, when planning routes through relatively small-scale town environments, participants show strong southern route preferences, and evidence for the north-is-up heuristic also reveals when planning routes between distant U.S. cities (Brunyé et al., 2010). Further work might consider how contextual factors such as time pressure or cognitive workload might increase the application of heuristics during route planning, as suggested by decision making theory (Shah & Oppenheimer, 2008).

Planning routes and navigating through space is a fundamental human behavior, and we continually strive to optimize efficiency during these processes (Gärling & Gärling, 1988). The *coarse-to-fine* route planning hypothesis (i.e., Chown, Kaplan, & Kortenkamp, 1995) proposes that people first develop a coarse route plan that considers relatively global aspects of an environment. This coarse route plan is then broken down into relatively fine-grained route plans that dictate movement between locations along defined routes. We propose that a north-up heuristic is likely to be assigned at the relatively coarse and abstracted level of the route planning process, and potentially becomes instantiated as a regional bias that is aligned with the north-south coordinate axis. In this manner, when a route planner begins to plan a relatively fine-grained path through an environment, attention has already been preferentially oriented towards the southern region. As a result, optimal routes are more likely to be sourced from southern regions when an origin and destination are aligned along the horizontal axis. Future work might attempt to integrate this type of north-up heuristic into formal models of route planning, such as those that consider larger-scale environmental features in predicting navigation behavior (e.g., Leiser & Zilbershatz, 1989; Wiener & Mallot, 2003).

Although making judgments about space and decisions on how to move through space are exceedingly common, people typically do not realize that their judgment and decision processes may be partially driven by strategies that occur outside of their awareness. Determining the full range of implicit associations is necessary for the development of comprehensive theories of spatial understanding, and ultimately modeling and predicting spatial behavior in complex environments.

Figure 1. Example stimuli used in the adapted Implicit Association Test. *Top row:* Experiment 1 and 3 cardinal indicator stimuli, with examples of a south (left) and north (right) indication. *Middle row:* Experiments 1 through 3 topography stimuli, with examples of mountains (left) and level terrain (right). *Bottom row:* Experiment 2 and 4 cardinal indicator stimuli, with examples of a south (left) and north (right) indication.

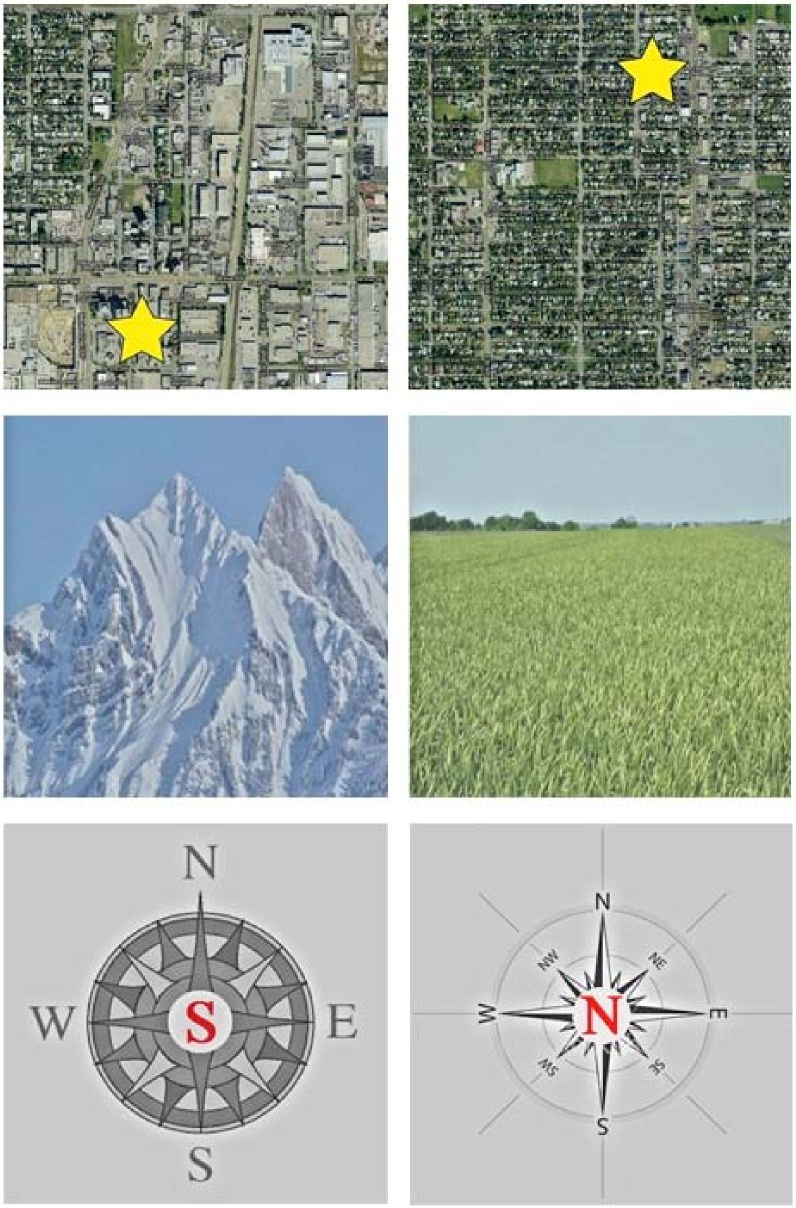

Figure 2. Mean and standard error response latencies for each of the two Combination Types (congruent, incongruent) and across each of the four experiments.

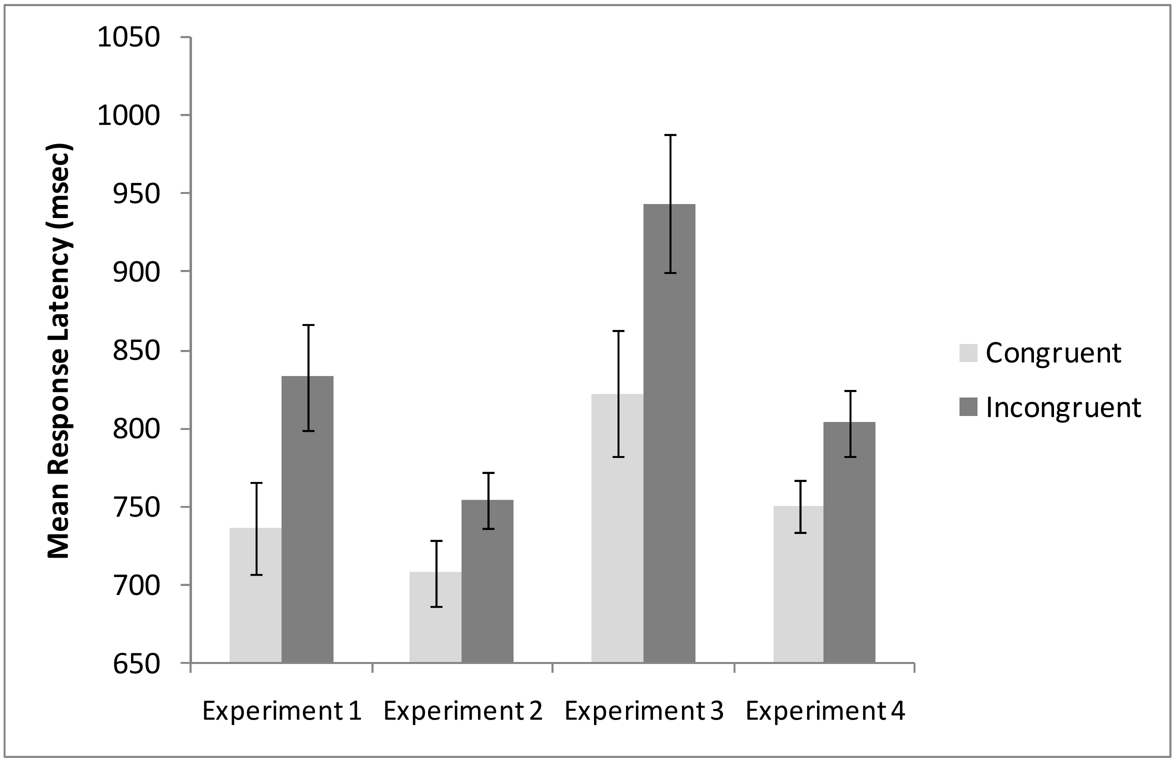

Table 1. The most frequently produced spatially-relevant directional terms in response to each of the four critical free association task cues (north, south, up, down).

Cue	Frequent Item 1	Frequent Item 2	Frequent Item 3	Frequent Item 4
North	up/upward (5.6%)	high/higher (0.6%)	above (0.6%)	summit (0.3%)
South	down (1.3%)	below (0.9%)	low/lower (0.6%)	floor (0.3%)
Up	north (1.3%)			
Down	south (4.4%)			

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