Human Sense of Direction and Wayfinding

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One of the oldest beliefs about human wayfinding is that some people have a natural ability that distinguishes them from others. In four experiments, we asked adults to rate their own sense of direction, a promising index of orientation skills despite its simplicity and reliance on self-assessment. There were small to moderate correlations between self-ratings and accuracy of pointing to imagined landmarks, accuracy of path choices during a route reversal and detour, speed at executing shortcuts, and accuracy of choices of halls within a building complex. Although we did not find consistent gender differences in actual wayfinding, effects across experiments indicate that females rated their sense of direction as worse than males. Deliberations by females may have affected the speed of some of their performances. The results suggest that self-evaluation of sense of direction is associated with evaluation of one's familiarity with features of particular environments, as well as memories of successes and failures in recent wayfinding efforts. *Key Words: orientation, spatial cognition, wayfinding.*

Over a century has passed since the construct of a human sense of direction began to be described in scientific literature (Darwin, in Romanes 1883). As we shall see, having a sense of direction has been associated with an ability to discriminate fine-grained environmental cues, a special sensory apparatus such as a magnetic sense, memories of locations constituting a cognitive map, strategies for learning a route, a schematic representation of one's past experiences in navigation and orientation tasks, and the ability to mentally align one's current heading within an imagined frame of reference. People can estimate their sense of direction as a trait, and a simple self-rating may reflect a cluster of orienting abilities that are useful in large-scale environments. Individual differences in self-ratings of sense of direction may be important for personnel selection and training (Hegarty and Montello 1995; Heth, Cornell, and Flood 2002). In addition, the study of people who demonstrate good orientation skills may reveal the cognitive processes attributed to a good sense of direction.

The purpose of the four experiments presented in this report is to examine the construct validity of self-ratings of sense of direction. We begin by examining correlations between different ratings of sense of direction and the ability to point to familiar places from imagined vantage points. The test procedures replicate and extend research establishing the validity of self-ratings of sense of direction. We then attempt to establish correlations between ratings of sense of direction and performance on real-world wayfinding tasks. The tasks include the ability to stay on course after confronting a detour on a familiar path, the ability to make a shortcut in a new neighborhood, and the ability to infer which hallway leads to a room within a building complex that had been viewed from the outside. Table 1 previews the different experimental paradigms and predictions that groups with self-ratings of a good sense of direction (GSOD) are better at orienting and wayfinding than groups with self-ratings of a poor sense of direction (PSOD). This article reports on an assessment of the predictions shown in the table.

Sense of Direction and Geographic Experience

For at least thirty years, geographers and cartographers have been actively interested in mental representations that people construct as a result of everyday commerce in their environments (e.g., Downs and Stea 1973). Behavioral geographers consider cognitive maps to be natural sources of information and preferences for spatial choices (Gärling and Golledge 1999). The rationale for collaboration with cognitive psychology is that common and sometimes distorted interpretations of environments may explain decisions that result in patterns of migration, shopping, recreation, regionalization, and use of resources (Lloyd 1989, 1997). Similarly, cartographers have interests in designing maps and navigation aids that fit the ways that people conceptualize environmental features and plan activities (Egenhofer and Mark 1995). While sometimes thought of as a formal and conventional enterprise, the mapping of the layout and identity of environmental features is essentially symbolic and selective, a process embedded in culture, communication, and human purpose (Blaut 1991; Stea and Blaut 1996).

In this context, it is important to consider how a sense of direction is fundamental to comprehension of geographic experience. A sense of direction may be first provided egocentrically. Our heading is our facing

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Table 1. Predictions that Groups with Ratings of a Good Sense of Direction (GSOD) Should Perform Better than Groups with Ratings of a Poor Sense of Direction (PSOD)

Experiment	Orienting or Wayfinding Abilities	Performance Measures	Predicted Results
1	Pointing to nonvisible landmarks	Latency to point	GSOD should be faster
		Accuracy of pointing	GSOD should be more accurate[a]
2	Reversing a route with a detour	Recall of route events	GSOD should recall more[a]
		Recognition of scenes	GSOD should be more accurate[a]
		Ordering scenes along route	GSOD should be more accurate
		Distance estimation	GSOD should be more accurate
		Path choices	GSOD should be more accurate[a]
		Latency to point to endpoints	GSOD should be faster[b]
		Accuracy of pointing to endpoints	GSOD should be more accurate[a]
3	Devising a shortcut	Speed of execution	GSOD should be faster[a]
		Distance traveled	GSOD should travel less[b]
4	Locating site within building	Latency of choice of hallway	GSOD should be faster[b]
		Accuracy of choice of hallway	GSOD should be more accurate[a]

[a] Obtained results were statistically reliable.
[b] Obtained results were consistent with prediction but not statistically reliable.

direction, the direction that aligns our sense systems for effective guidance of locomotion. At any place on earth, our heading is linked to particular perspectives of landmarks and configurations of landscape. A sense of direction is also derived from the perception of known landmarks and landscape as we move to different places (Gibson 1979). The invariant relations between geographic features—distributions of sites and boundaries of regions—provide a spatial framework for positioning ourselves (Golledge 1995).

Levine (1982) neatly illustrates a cartographic application: forward heading and cues for matching the structure of the visible terrain are the helpful components of you-are-here displays. In the present series of studies, our concern is whether people's appraisal of their sense of direction is a valid index of their abilities to orient and find their way in large-scale environments. If self-ratings predict performance, their use may be extended to reveal the value of mapping techniques or to understand certain patterns of spatial judgment and decision making.

Ideas about Mechanisms

The scientific study of the human sense of direction typically includes observations of the ability to indicate a bearing. Of course, many sensory adaptations allow immediate perception of the layout of the environment; thus, for example, we are not amazed when a taxi driver selects routes that approach a building that is periodically visible in the skyline. The mechanisms underlying a sense of direction are more mysterious when cues for orientation are not obvious. For example, several nineteenth-century European explorers reported that native guides could keep their course across homogeneous expanses of sea, featureless ice fields, or cluttered and trackless woods and jungles. These feats of navigation were often attributed to an innate or instinctual sense of direction (Gatty 1958). Subsequent anthropological analyses usually indicated that environments that appeared to be homogeneous and featureless to the foreign explorer were extensively differentiated by the native (e.g., Gladwin 1970). These analyses lead to the appreciation that the feel of waves underneath a Puluwat canoe may be as informative as an arrowed sign on a London street.

The human sense of direction has also been considered to be mediated by an unconscious sensory apparatus, a receptor that is sensitive to magnetic fields (Baker 1981; Baker, Mather, and Kennaugh 1983). However, the evidence for a sixth or magnetic sense has been difficult to interpret and replicate (Howard and Templeton 1966; Gould and Able 1981; Able and Gergits 1985). Moreover, humans cannot reliably report magnetic sensations, so it is difficult to conceive how typically weak geomagnetic forces might influence wayfinding decisions (Tagg 1982).

Recently, sense of direction has been studied as an ability or trait that people can report that they possess to some degree (Kozlowski and Bryant 1977). College students responded to the question "How good is your sense of direction?" on seven- or nine-point bipolar scales, with 1 labeled as poor and the highest value labeled as good. This direct approach was based on interviews that suggested that laypeople have an idea of what a sense of direction is and a ready estimate of their own abilities. Moreover, when asked about their sense of direction, some individuals expressed pride in their orientation skills, whereas others disclosed incidents in which they had been lost.

As a variable that differentiates individuals, self-rating does not address how a person may have formed an impression of their sense of direction. However, Kozlowski and Bryant (1977) suggest that sense of direction is related to the accuracy of cognitive maps. In this context, cognitive maps were taken as mental representations that preserved *survey knowledge* of a familiar environment. Survey knowledge includes metric and relational information about landmarks and paths; distances, bearings, and the configuration of objects may be simultaneously represented as if seen from a bird's-eye view (Hart and Moore 1973; Siegel and White 1975; Thorndyke and Goldin 1983). Koslowski and Bryant (1977) established moderate correlations (rs -0.49 to -0.51) between self-ratings of sense of direction by college students and the magnitude of their errors when pointing to known buildings from an imagined vantage point on their campus.

The implication of these correlations, however, has been disputed. Passini (1984) argues that they may simply reflect self-evaluation of environmental knowledge; the correlations do not assess the prediction that a person with a good sense of direction can immediately establish his or her bearings in novel environments. Consistent with this criticism, Kozlowski and Bryant (1977) did not find an initial difference between students with either good or poor ratings when pointing to locations in an unfamiliar tunnel complex. Instead, students who rated themselves as having a good sense of direction showed improvements in pointing accuracy over four walks through the complex, suggesting that they might have attentive or mnemonic strategies that yield good environmental knowledge and the ability to imagine spatial relations of landmarks. Students who rated themselves as having a poor sense of direction did not improve.

Subsequent research has also indicated that people who rate themselves as having a good sense of direction have good recall of indoor locations. For example, Lorenz and Neisser (1986) used factor analysis of a variety of ecological and psychometric variables to establish relations to self-ratings of sense of direction. Interestingly, they found a strong correlation ($r = 0.78$) between the seven-point rating scale and a factor extracted from more detailed self-reports about a variety of orientation skills. Judgments of the ability to return to a place visited once, memories of being lost in buildings and cities, confusions between right and left, and the ability to remember verbal directions to find a destination constituted the general orientation factor. In contrast, this factor and the self-ratings of sense of direction did not show significant correlations with mental spatial manipulation abilities measured by psychometric tests, the ability to point accurately to places on campus or in the world, or knowledge of routes. There were modest correlations between self-ratings and the ability to place landmarks on a floor plan of the building that housed the room in which assessments were conducted. The names of the landmarks were provided by the tester and were architectural features (stairs, ramps, signs) that the participants had experienced en route to the room. That site memories were superior is consistent with the interpretation that people with a good sense of direction strategically encode events along routes. These memories could be the result of *piloting*, a process of directing travel by monitoring the identity, distance, and bearing of environmental features as they are perceived (Gallistel 1993).

A unique study by Montello and Pick (1993) also indicated the importance of recent memories of the locations of indoor landmarks (windows, signs, lockers). Eight landmarks were pointed out as college students were led through a large building complex containing two levels. At the end of the tour, students were asked to point in the direction of the landmarks; half of the landmarks were on a different level in the complex. Students were then asked to estimate how good their sense of direction was relative to that of other people. Moderate correlations indicated that students who were faster and more accurate in pointing reported a better sense of direction. However, because estimates of sense of direction were not taken prior to the pointing task, students could reflect upon their difficulty with the pointing task before reporting how good their sense of direction was.

These interpretations are consistent with the notion that people's assessment of their sense of direction may be similar to other beliefs about the self, a schematic representation of a variety of incidents in autobiographical memory (Bem 1972; Markus 1980). People likely modify ideas about themselves as wayfinders after they cleverly calculate a shortcut or after reflecting upon an episode of being lost. Many self-concepts are biased by recent experiences (Markus and Nurius 1986; Klein and Loftus 1993), and the assessment of sense of direction may unduly weigh those memories that are most easily retrieved.

What might produce memories of using one's sense of direction? Sholl (1988) has suggested a cognitive process—that people with a good sense of direction are good at imagining spatial relationships beyond their immediate position and surround. In particular, Sholl's data indicated that in contrast to students with a poor sense of direction, students with a good sense of direction were more accurate at pointing to landmarks when they had to assume a viewpoint that was misaligned with their forward facing. According to Sholl, sense of direction reflects the ability to mentally coordinate egocentric and imagined frames of references. This coordination would be important when updating one's position in obscure environments, such as when firefighters are in smoke-filled buildings or when ambulance drivers are between buildings that do not afford views of the skyline.

Relations to Wayfinding

The concept of a sense of direction was invoked in early analyses of navigation, when an organism was observed to find its way efficiently through unfamiliar territory (Trowbridge 1913). Studies of human and animal navigation have since identified methods of wayfinding that rely on landmark and route recognition, integration of feedback from locomotion, and use of survey knowledge, or representations of the distance and direction of objects to one another (Gallistel 1993). In general, it appears that humans are capable of a variety of methods of wayfinding, depending on the modes of information available to them and considerations of efficiency and aesthetics (Golledge 1999; Cornell and Heth 2000). An individual's sense of direction could be important to all of these methods. For example, a person with a good sense of direction may be better able to look for areas likely to contain landmarks and can use that information to direct actions at intersections on routes. A good sense of direction can provide a reliable reference bearing when an individual is registering the degree of a turn. Finally, people with a good sense of direction should be able to accurately orient their mental representation of a configuration of landmarks to match a scene they are presently viewing. In each of the experiments that follow, we suggest ways in which a good sense of direction may facilitate orientation and wayfinding performance. We also examine what people with high self-ratings say they do.

Experiment 1

Kozlowski and Bryant (1977) proposed that a sense of direction was a product of ordinary cognitive abilities. They argued that a sense of direction reflects a person's orienting and mapping competence and is not a special mental faculty. As suggested by Tolman's (1948) description of cognitive mapping, sense of direction was measured as the ability to indicate the bearings of nonvisible locations. Kozlowski and Bryant did not describe the sequence of reckoning that might produce accurate pointing, but reported results that indicated that survey knowledge, knowledge of routes, and attentional and memorial abilities were likely involved. In this first experiment, we also asked university students to rate their sense of direction and to indicate the bearings of sites on campus while imagining they were at central vantage points.

Estimation processes are involved both in inferring the location of nonvisible locations and in assessing one's own sense of direction. Self-ratings could include estimating how difficult one typically finds it to remember known routes and landmarks. Assessing the prowess of one's own sense of direction could also involve memories of the challenges, effort, confusion, anxiety, and satisfaction experienced during episodes of successful and unsuccessful wayfinding. Kozlowski and Bryant (1977) accepted that college undergraduates have a ready estimate of their own sense of direction, but did not ask them what they considered in making their estimate. Prefatory to the present experiment, we asked students and people in our city to list the abilities they associated with having a good sense of direction. These intuitions suggested a variety of tasks to establish the construct validity of self-ratings of sense of direction.

This experiment allows tests of *individual difference* variables that may be associated with self-ratings of sense of direction. We begin by assessing three single-item scales. Each of these scales is reported to have moderate to strong correlations with performance in pointing tasks (Kozlowski and Bryant 1977; Bryant 1982; Sholl 1988; Montello and Pick 1993). Although there may be uneasiness about using only a few measures to assess any individual difference variable, Kozlowski and Bryant (1977) pointed out that test-retest coefficients of their self-ratings of sense of direction were impressive when assessed over two weeks to three months. Moreover, subsequent research has shown that multivariate measures of orientation skills are highly correlated with the simple self-ratings, and there appears to be a single factor underlying more extensive questionnaires (Lorenz and Neisser 1986; Sholl 1988; Bryant 1991; Svennson 1994; Hegarty and Montello 1995).

Currently, a great deal of controversy surrounds the existence and importance of gender-related individual differences in real-world spatial cognition (Self et al. 1992; Self and Golledge 2000). Pertinent to the present study, there are some indications that females in Western societies are less confident of their general orientation abilities than are males, and that males are generally more accurate at pointing to environmental landmarks (Kozlowski and Bryant 1977; Bryant 1982; Holding and Holding 1989; Sadalla and Montello 1989; Montello and Pick 1993; Lawton 1994; Devlin and Bernstein 1995; Lawton, Charleston, and Zieles 1996; Sholl et al. 2000; see reviews by Harris 1981; Kitchin 1996; Montello et al.

1999). We sampled an equal number of men and women to allow further tests of gender differences in self-ratings of sense of direction and pointing abilities.

In contrast to people with poor self-ratings, people with good self-ratings may use different information or strategies for remaining oriented and estimating bearings. To explore this possibility, we asked participants to think aloud as they estimated the direction of nonvisible landmarks. Verbal protocols could indicate methods that are associated with successful performance (Lawton 1994; Lawton, Charleston, and Zieles 1996; Ericsson and Simon 1996), which, in turn, could lead participants to believe that they have a good sense of direction.

The experiment also allows tests of *environmental variables* that may influence how quickly and accurately participants point to nonvisible landmarks. Some research has indicated small correlations between measures of previous experience in test environments and the accuracy of estimating bearings (Kozlowski and Bryant 1977; Bryant 1982; Prestopnik and Roskos-Ewoldsen 2000). However, it is not clear whether the effects occur because previous experience includes a variety of visual perspectives of the outdoor skyline or because previous experience includes the perception of landmarks next to paths and their associated actions, such as turning or continuing. Here, we asked participants to rate their familiarity with short and tall target landmarks. We selected a variety of landmarks: some short buildings that receive heavy usage, such as the rapid transit station; some short landmarks that are less often visited, such as the track; some tall buildings that receive heavy usage, such as the student union building; and some tall buildings that are less often visited, such as a faculty office complex. However, because tall buildings can be seen from many vantage points on campus, we would expect that the location of tall buildings would be imagined more quickly and accurately than the location of short buildings. Asking participants to imagine that they are at different vantage points before they point also assesses the role of visual perspectives. One vantage point is an open site on campus that affords a panorama; the other is in a narrow corridor between buildings. If skyline perspectives are important for orienting, we would expect that the imagined open vantage point should allow more rapid and accurate pointing than the imagined closed vantage point.

Method

Participants. Undergraduates at our university participated to fulfill an introductory psychology course requirement. There were thirty-two males and thirty-two females (median age 19.9; range 18.1–26.1).

Apparatus. The device to record the compass bearing of points resembled a telescope. A hollow tube was mounted on a tripod fixed to the center of the floor. The tube could be freely rotated in the horizontal plane. A needle attached beneath the tube pointed along a ring with 360 equally spaced markings. The zero mark of the ring was oriented to the northwest, and the markings were not visible when the participant was sighting through the tube. A digital stopwatch was used to record latency of responses.

Vantage Points and Landmarks. Each participant was asked successively to imagine that he or she was standing at different sites on campus and facing north. The researcher asked the participants what they might see in front of them to check that they were imagining the appropriate vantage points. One of the vantage points was *open*, situated at the center of an open quad that afforded views of lines of trees and tall buildings on the skyline. Another vantage point was *closed*, positioned in a narrow corridor between buildings that allowed only a view of exterior walls and a narrow band of sky. After a moment to allow participants to imagine the situation, the researcher asked them to point the sighting tube in the direction of buildings, as they would be located from that vantage point. The target landmarks were the same for both vantage points; four of the buildings were two stories or less, and four were nine stories or more.

Procedure. Participants were tested individually in a small windowless room. The room was embedded in an obscure wing of a large building complex. The sighting tube was in the middle of the room, and a desk and chair for the researcher sat along one wall. After participants were greeted, they were told that the research concerned people's ideas about their sense of direction and that there were two procedures, a questionnaire and a pointing task. Half of the participants were given the questionnaire at the outset; the others received the pointing task first. The order of the two procedures was counterbalanced to assess whether participants biased their appraisal of their sense of direction in light of their perceived familiarity with target landmarks. However, because participants were not provided with feedback about the accuracy of their pointing, they could not adjust their estimates of their sense of direction to match their actual performance (cf. Heth, Cornell, and Flood 2002).

Questionnaire. The questionnaire was divided into three sections. Participants were asked to rate their sense of direction, to rate their familiarity with landmark buildings, and to rank order a list of qualities that they thought characterized a good sense of direction.

Three self-ratings were used. The first was based on Kozloski and Bryant (1977), who showed a correlation of 0.93 between responses on seven- or nine-point rating scales. The self-rating used here consisted of the question "How good is your sense of direction?" atop a nine-point scale anchored by "Poor" near the 1 and "Good" near the 9. We refer to this as the *How good?* scale. The second self rating was based on Montello and Pick (1993) and allowed participants to record their own numbers: "In a room with 100 people, estimate the number of people who have a better sense of direction than you do: ____." We refer to this as the *Number better?* scale. The third self-rating linked sense of direction to wayfinding abilities, a connection established by Bryant (1991). As in the first self-rating, the question was "How good is your sense of direction?" but the anchors for the scale below the question were "Easily find my way" near the 1 and "Easily lost" near the 9. Note that good ratings are at different ends of the first and third scales. We refer to this as the *Easily lost?* scale.

In the second section of the questionnaire, participants indicated their familiarity with each of the landmarks that served as a pointing target. For example, the first item on the list consisted of the question "What is your estimation of your familiarity with the main entrance of Lister Hall?" atop a nine-point scale anchored by "Familiar" near the 1 and "Not familiar" near the 9.

In the third section of the questionnaire, participants were asked to read a list of abilities "that are associated with having a good sense of direction" (see Table 2). The list included the eleven abilities most frequently suggested when a pilot sample of sixty-four undergraduates and twenty-four adults approached at a shopping mall were asked to create associations. Participants were encouraged to write in any other ability they thought to be related and to rank order the descriptions "as to how important they are to having a good sense of direction, with 1 being an extremely important component and 11 or 12 being hardly related to sense of direction."

Table 2. Mean Rank Order of the Importance of Abilities Associated with a Good Sense of Direction

The Ability to	Mean Rank
Take shortcuts	8.5
Not get lost	7.6
Imagine landmarks on the skyline	7.3
Gain one's bearing in a building	6.8
Retrace exactly a recently traveled route	6.6
Find your destination after inadvertently stepping off a familiar route	5.9
Gain one's bearing upon exiting a building	5.6
Read and follow maps	5.2
Know where a variety of landmarks are	4.8
Be able to give or follow directions	4.7
(Participants' suggestions)[a]	4.6
Know where north, south, east, and west are	4.3

[a] Ten participants suggested abilities that were not provided on the questionnaire. $N = 64$ for all other mean ranks.

Pointing Task. The researcher demonstrated how the sighting tube could be rotated in either direction. Participants were told to imagine that the tube was a telescope that allowed them to see through walls, buildings, and landscaping to the center of designated targets. Participants were told that they would be asked to point the tube as if viewing distant buildings, and that the accuracy and speed of each point would be recorded. Demonstrating a point to the steps of city hall, the researcher started the stopwatch, slowly rotated the tube in a large arc, made minor back-and-forth corrections, announced "There," stopped the watch, and read the mark indicating the azimuth of the response. After each point, the tube was oriented to the northwest corner of the room.

Participants were then invited to practice as if they were at a different vantage point: "Imagine that you are standing at the entrance to city hall and this tube is facing due north. What would you see in front of you?—The reflecting pool. When I tell you the name of a target building, I will start the stopwatch. When you are satisfied that you have made your most accurate point, remove your hand from the tube and that will be my signal to stop the watch. Now, facing north at the entrance of city hall, point through buildings, cars, and trees as if you could look at the front door of where you live."

Experimental procedures and gender of participants were counterbalanced. After the practice, half of the participants began by pointing to the landmark buildings from the open vantage point and half began from the closed vantage point. Each participant was presented landmark targets in accord with two of four prearranged random sequences of the short and tall buildings. Half of the participants were told to *talk aloud* as they made their pointing response. They were told to feel free to verbalize whatever crossed their minds as they estimated the bearing to the target. The others were asked to describe their methods of estimation *retrospective*ly after each point. Delayed reports of methods are typically not as informative as talk during task execution; however, the requirement to talk during task execution may sometimes affect task performance (Russo, Johnson, and Stephens 1989; Ericsson and Simon 1996). The random assignment of participants to these two procedures allows an assessment of differential effects.

Accuracy of pointing was measured as the absolute error of pointing, defined as the angular distance between the bearing of the point and the bearing of the target (Batschelet 1981). Using SPSS™ (2002), absolute error is computed as

$$\mathrm{MIN}[\mathrm{ABS}(\phi - \Psi), 360° - \mathrm{ABS}(\phi - \Psi)]$$

where Ψ is the compass bearing of the participant's point to the target and ϕ is the true bearing to the target. Note that absolute error does not preserve the radial direction of pointing responses: deviation around a target on a circle becomes a scalar variable limited to values between 0° and 180°.

Results

Abilities Associated with Sense of Direction. Table 2 lists the mean rank importance of the navigation and orienting abilities that participants associated with a good sense of direction. Separate listings for females and males and groups who ranked abilities before or after the pointing task indicated that the five abilities that appear at the top of Table 1 were included in the top five of all four lists.

Self-Ratings of Sense of Direction. A three-factor analysis of variance (ANOVA) was used to explore the effects of gender, order (questionnaire first versus pointing task first), and report (think aloud versus retrospective) on each of the three self-ratings of sense of direction. There were no statistically significant main effects or interactions involving any of the three self-ratings. The majority of university students had high appraisals of their sense of direction. In response to the *How good?* scale, mean self-ratings for females were 6.0 (standard deviation [*SD*] = 1.9) and mean self-ratings for males were 6.6 (*SD* = 1.4). The first two columns of Table 3 indicate reliable and moderately high correlations between the three self-ratings.

Latency to Point. *Individual Differences Variables.* A two-factor ANOVA was used to explore the effects of gender and report (think aloud versus retrospective) on the latency to point to imaginary targets. Not surprisingly, there was a reliable main effect of report ($F(1, 64) = 16.90$, mean square error [MSE] = 183.60, $p < .001$). Participants asked to talk aloud while they estimated their point had a mean latency of 27.4 sec, while those who were asked retrospectively how they estimated spent less time pointing—mean latency = 16.0 sec. There was also a reliable interaction of report with gender ($F(1, 64) = 10.49$, $p < .01$). Females who were asked to talk aloud while pointing spent the longest time making their estimations—mean latency = 35.0 sec. Females and males who reported their methods retrospectively and males who talked aloud during their pointing had mean latencies of 14.2, 17.8, and 20.3 sec, respectively.

Bivariate correlations between mean latency to point and the three self-ratings of sense of direction did not reliably differ from zero, regardless of whether calculated from the whole sample (as presented in the third column of Table 3) or calculated for the groups assigned different orders or different methods of report.

Environmental variables. A 2 × 2 repeated-measures ANOVA was conducted to examine the effects of the height of the imagined buildings (low versus high) and imagined vantage point (open versus closed) on latency to point. There was a reliable effect of height ($F(1, 64) = 3.96$, $MSE = 20.21$, $p = .05$). The mean latency to point to low buildings was 22.1 sec and the mean latency to point to high buildings was 21.0 sec. No other effects were reliable.

Accuracy of Pointing. *Individual Difference Variables.* A two-factor ANOVA was used to explore the effects of gender and report (think aloud versus retrospective) on the mean absolute error of pointing. There was a significant main effect of gender ($F(1, 64) = 6.18$, $MSE = 567.494$, $p < .02$). The mean absolute error for females was 47° and the mean absolute error for males was 33°. No other effects were reliable.

Table 3. Bivariate Correlations (r) of Self-Ratings of Sense of Direction, Measures of Pointing to Imagined Targets, and Self-Ratings of Familiarity with Target Landmarks

	Number Better?	Easily Lost?	Mean Pointing Latency (sec)	Mean Absolute Error (°)	Mean Landmark Familiarity
How good?	– 0.75**	– 0.74**	0.03	– 0.26*	– 0.29*
Number better?		0.65**	0.01	0.18	0.15
Easily lost?			– 0.03	0.18	0.32**
Mean pointing latency (sec)				0.14	– 0.25*
Mean absolute error (°)					0.25*

* $p < .05$ and ** $p < .01$, with $N = 64$ and two-tailed significance.

The rating of "How good is your sense of direction?" was negatively correlated with pointing error, and the other self-rating measures showed consistent but weaker correlations (see column four of Table 3). The pattern of results appeared to be the same when correlations were calculated for the group that was asked to rate their sense of direction prior to the pointing task; only the *How good?* rating was reliably correlated with pointing error ($N = 32$; $r = -.43$, $p < .01$, two-tailed). There were no reliable correlations between ratings of sense of direction and pointing error in the group that rated their sense of direction after the pointing task, or when the talk-aloud and retrospective-report groups were analyzed separately, although the pattern of correlations was similar to that appearing in Table 3 for the full sample.

Environmental Variables. A 2×2 repeated-measures ANOVA was conducted to examine the effects of the height of the imagined buildings (low versus high) and imagined vantage point (open versus closed) on the mean absolute error of pointing. There was a reliable effect of vantage point ($F(1, 64) = 6.32$, $MSE = 770.33$, $p < .05$). The mean pointing error from the imagined open vantage point was 36°, and the pointing error from the imagined closed vantage point was 44°. No other effects were reliable.

Familiarity with Landmarks. A 2×2 mixed-design ANOVA was used to examine ratings of familiarity with the imagined landmarks. Factors included the individual differences variable of gender and the environmental variable of building height. There was only a reliable effect of height ($F(1, 64) = 6.90$, $MSE = 1.11$, $p < .05$). The mean rating of the familiarity of low buildings was 3.8, whereas high buildings were rated as more familiar—M = 3.3.

The last column of Table 3 indicates that ratings of familiarity with the landmarks were reliably correlated with two measures of sense of direction, as well as the latency and accuracy of pointing. The extent to which environmental familiarity mediates the correlation between self-ratings of sense of direction and the mean absolute error of pointing can be estimated by a partial correlation coefficient. Controlling for the mean rating of familiarity with target landmarks, the "*How good?*" rating was still negatively correlated with pointing errors, but the magnitude was reduced to the extent that the correlation was not statistically reliable ($N = 64$, $pr = -0.20$, $p < .10$, two-tailed).

Reports of Methods of Estimation. Participants were divided into two independent groups based on self-ratings less than and greater than 5 in response to the *How good?* scale. This grouping allowed us to examine whether GSOD participants (25 females and 28 males) reported different methods of estimating points to target landmarks than PSOD participants (6 females and 4 males; only one student selected the middle rating). The verbalizations during pointing and retrospective accounts of methods to estimate points could be represented in five categories, as illustrated in Table 4. Two research assistants independently coded all responses; agreement was indicated by a Cohen's kappa coefficient of 0.83. Disagreements were resolved by discussion. A preliminary tabulation indicated no reliable differences in category assignments when the group instructed to talk aloud was compared to the group instructed to provide retrospective explanations; the

Table 4. Frequency of Explanations for Estimating Points to Landmarks by Participants with Self-Ratings Indicating a Good Sense of Direction (GSOD) or Poor Sense of Direction (PSOD)

	GSOD		PSOD	
Categories: Examples of Explanations	Frequency	Percent of Participants (of 53)	Frequency	Percent of Participants (of 10)
Survey knowledge, local framework: "The Rec Center is right across from the Student Union, by Lister Hall."	52	98	9	90
Survey knowledge, global framework: "I think the Tory Building is in the northeast direction."	47	89	10	100
Egocentric view: "I'm imagining myself looking at V-wing and I know that it's behind me and maybe looking to the left."	45	85	9	90
Route knowledge: "And I know when I got out of Biological Sciences and walk down the path past Earth Sciences, it will lead me to the Tory Building."	29	53	6	60
Guess: "I can't figure out where Biological Sciences is from here, there are so many buildings around, so I'm just going to guess."	7	13	0	0

groups were combined to provide the listings in Table 4. Forty-four of the 53 GSOD participants (83 percent) and all 10 PSOD participants described more than two methods across their sixteen points. Repetitions of an explanation by a participant did not add more to a singular count of their use of that method, but descriptions of other methods by the same participant added a count to those respective categories. Table 4 indicates the frequency of particular methods reported, as well as the percentage of participants who reported a method at least once.

Table 4 indicates that only a small proportion of participants guessed the bearing of target landmarks. Group differences were not reliable; participants with high and low ratings both reported use of survey knowledge and scene-based egocentric frames of reference with similar high frequencies and reported use of route knowledge with similar moderate frequencies. Separate listings for females and males and groups who ranked abilities before or after the pointing task did not indicate reliable differences in categories of explanations.

Discussion

People who were asked to rate their own sense of direction associated it with practical abilities. Table 2 indicates that university students believe that a good sense of direction is useful for wayfinding and orientation using natural environmental cues. Knowledge of conventional representations—such as maps, verbal directions, and cardinal directions—was not rated as important to a good sense of direction as were abilities associated with taking shortcuts, retracing routes, and navigating in unfamiliar territory. A good sense of direction was considered to be important in situations in which environmental information is limited, such as when the location of landmarks must be imagined or when in a building. In sum, the ratings suggest real-world tasks that can be used to assess the validity of self-ratings of sense of direction.

When asked to point to buildings from imagined vantage points on campus, students with high and low ratings did not differ in the frequency of reports of the methods they used. Moreover, students with high ratings did not report a wider selection of the methods for estimating bearings. Table 4 shows that explanations by both groups predominantly included survey knowledge and views that would be seen from the assumed vantage point. Buildings were located in relation to the position of other local landmarks and in relation to large-scale frames of reference, such as cardinal directions. Route knowledge was less frequently reported, although more than half the students inferred building locations by reconstructing the sequence of events they would experience as they walked on campus paths. In sum, almost every participant used a variety of modes of representation to address the requirements of pointing to imagined targets.

When asked, "How good is your sense of direction?" university students judged their senses of direction to be moderately good. A relatively small number of students rated their sense of direction as poor (cf. Sholl et al. 2000), suggesting that a broader group of participants should be selected for a more balanced assessment of individual differences in wayfinding performance. Mean self-ratings by males were a half-scale value greater than those of females, but the difference was not statistically significant. This result is consistent with recent reviews; males tend to express more confidence in their spatial and geographic abilities than females, but the difference may not be reliable in particular samples, and no studies find that females express more confidence than males (Kitchin 1996; Lawton, Charleston, and Zieles 1996; Montello et al. 1999).

In contrast, differences between males and females were reliable in our analyses of pointing performance. When participants were asked to talk aloud while making their estimates of target locations, females took more time than males. The longer deliberations by females could be the result of lack of confidence or of attempts to justify thoroughly their methods of estimation. Females also showed larger errors in their estimates than those made by males. These gender differences in estimating target locations are also consistent with reviewed findings. The pattern of results gives confidence that the rating scales and measures of pointing performance used in the present research are sensitive to known individual difference variables.

Importantly, we replicated the negative correlation between self-ratings of sense of direction and mean absolute error of pointing (cf. Kozlowski and Bryant 1977). The fourth column of Table 3 indicates that higher ratings in response to the *How good?* scale were associated with smaller errors. The two other self-rating scales showed appropriate positive correlations with pointing accuracy, but the correlations were small and unreliable.

None of the self-ratings predicted the latency to point to targets. Sholl (1988) found that latency differences between good and poor sense-of-direction groups were more likely to occur when targets were cities than when they were more familiar campus landmarks. Similarly, the fifth column of Table 3 indicates that mean pointing latency is negatively correlated with mean ratings of familiarity, indicating that participants who judged that they were not familiar with campus landmarks were slower to estimate where they were.

In general, several results suggest that familiarity with target landmarks should be taken into account when interpreting ratings of sense of direction, as well as when interpreting measures of pointing to those landmarks. In addition to the correlations that appear in the fifth column of Table 3, we found that ratings of familiarity were part of the correlation between self-ratings and pointing accuracy. This result can be interpreted in light of the explanations of methods of estimating target locations (Table 4). The estimator first needs to be familiar with the environment to imagine the layout of landmarks. The estimator can then integrate his or her own present bearing within the imagined scene, route sequence, or survey representation. Passini (1984) has emphasized that self-ratings of sense of direction may reflect self-evaluation of environmental knowledge, whereas Sholl (1988) has emphasized that self-ratings of sense of direction may reflect the ability to integrate egocentric and imagined frames of reference. Our results are compatible with the interpretation that both are components of self-evaluation of orienting abilities.

Recent theories of wayfinding have emphasized that scenes are basic units of environmental knowledge (Kuipers and Levitt 1988; Gopal, Klatzky, and Smith 1989; Chown, Kaplan, and Kortenkamp 1995; Cornell, Heth, and Skoczylas 1999). Table 4 further indicates that imagined scenes are used to estimate bearings. Most participants reported that they could infer the whereabouts of a target building by reconstructing what they would see from the imagined vantage point. As predicted, the accuracy of pointing to the target building was higher when the vantage point was imagined to be the center of an open area than when it was imagined to be in a restrictive corridor. Participants were slightly faster at estimating the location of high buildings than at estimating the location of low buildings. However, if high buildings were more prominent in imagined scenes, some would have been more rapidly localized from the open vantage point than from the closed one. The advantage for high buildings may be that they are more often seen during everyday travel and are more familiar than low buildings. The familiarity may help with retrieving the identity of the building but not its location from particular vantage points (Gale et al. 1990). As we have encountered elsewhere in this discussion, differences in participants' familiarity with environmental features makes interpretations of orienting abilities complex. In the three experiments that follow, self-ratings of sense of direction are assessed before participants are introduced to unfamiliar territory.

Experiment 2

People may judge that they have a good sense of direction if they often update their bearings during travel. There are usually many opportunities for such piloting when walking outdoors. Open areas along a route may provide opportunities to note the perspective of a tall landmark from different vantage points. Wayfinders may also monitor the angle of their line of travel relative to a line of objects along the skyline, such as trees that border a river valley. Then, when off a familiar route, wayfinders can make geometric inferences to help select paths that are consistent with goals such as returning to the familiar route or approaching their destination. In this second experiment, we asked participants to rate their senses of direction and we assessed their route and survey knowledge when their travel included a detour.

Wayfinders may also monitor their own actions, the distance and duration of their locomotion, and the direction and degree of their turning. A record of action during travel may be used for *dead reckoning*, a method of updating one's position relative to a reference point such as the origin of a walk or the place where a detour began (Gallistel 1993). Processes of dead reckoning may be especially important for reconstructing routes when distant cues for bearing are unavailable, such as in corridors between buildings or dense foliage. We assumed that continuous updating of position, or moment-to-moment *path integration*, is not necessary for people to deduce where they are in relation to a reference point (Loomis et al. 1999). People may remember that an early segment of their movement was brief and straight, that this was followed by a gradual turn to the right, and that the last portion of their movement was straight but of longer duration than the first. Translation and rotation are thus encoded as episodes, and noticeable changes in movement provide junctions for the traveler periodically to update his or her position or imagine a configural representation of the path (Cornell and Heth, 2003). We predicted that people who judge themselves as having a good sense of direction are more accurate about distance and turns along a route than people who do not.

Method

Subjects. Adults were recruited using an ad in a community newspaper. When they called in, volunteers were asked to rate their senses of direction on the seven-point scale validated by Kozlowski and Bryant (1977) as a version of their nine-point scale. The question was the same: "How good is your sense of direction?" atop a scale anchored by "Poor" near the 1 and "Good" near the 7. Volunteers were not included in this study if they rated their sense of direction as 4 (neither good nor poor) or if they had previously visited our university campus. We selected equal numbers of males and females to constitute the GSOD and PSOD groups. This allowed us to examine whether there were gender differences in wayfinding performance when male and female students had similar appraisals of their sense of direction. We tested 48 adults (median age 24.0; range 18.0–47.2).

Route. The initial route followed sidewalks, paths, and service roads and was an irregular diagonal 1,040 m in length across the northern portion of the campus (see Figure 1). It took approximately 11 min to walk. A 320-m detour was introduced during the route reversal. This detour went around a building complex and returned to the initial route.

Nine intersections of two or more continuing walkways were designated as choice points during the return. Most were crossroads or Y- or T-intersections. These were places where participants were asked to indicate the way to proceed. Five of the choice points required a change of bearing of travel or a shift from one path to another. Three of the choice points occurred during the detour and were *off* the initial route; six choice points were *on* the route.

Four sites along the return route were designated as vantage points, places where participants were asked to point to the start and destination of the route. Two *open* vantage points afforded views of the skyline and the tower of the building housing the start of the initial route. Two *closed* vantage points were located next to buildings and landscaping that occluded distant views. There was an open and a closed vantage point off route and an open and a closed vantage point on route.

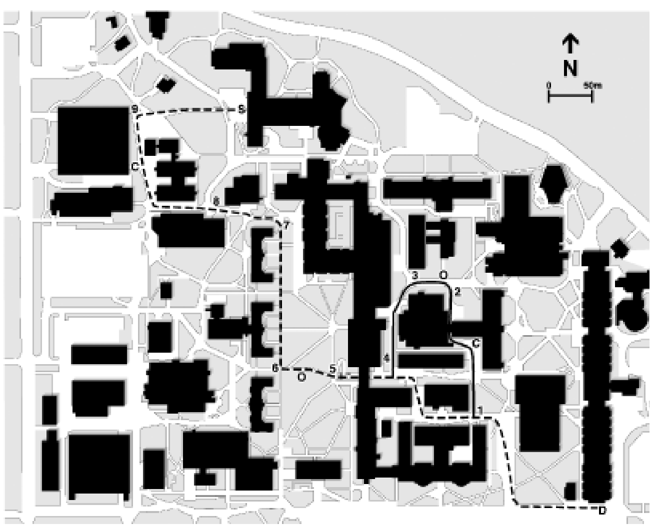

Figure 1. A survey map of the northern portion of the campus. An **S** indicates the start of the initial route (long dashes) and a **D** indicates the destination. Intersections used as choice points during the return are enumerated from the destination to the start. The detour (short dashes) begins at choice point **1** and ends at choice point **4**. An **O** indicates each of the two open vantage points and a **C** indicates each of the two closed vantage points.

Procedure. Participants arrived at the campus building featuring the tower. They were shown the seven-point rating scale for sense of direction and were given the opportunity to update their estimates. The participants were then told that they were going on a tour of the campus and that they would be asked some questions about how they find their way in new territory. They were escorted through the building to the top landing of a set of outdoor stairs. The researcher asked each participant to put one foot on the first stair and announced, "These are the stairs that mark the *start* of our walk across campus. It is important that you remember this location." The researcher then led participants to the southeast terminus of the route. During the walk, participants were told that the paths they were following would later be referred to as the "initial route." At the end of the route, participants were asked to put one hand on a post that blocked vehicle access and were told, "This post marks the end of our tour. I will be referring to it as the *destination* of the initial route, and it is important that you remember it."

Each participant was then asked to describe in detail how they would get from the destination of the route (the post) back to the start of the route (the stairs). They were instructed to describe landmarks and actions in the order that they would occur during such a route reversal. The anticipatory recall was recorded on audiotape. Next, participants were handed a shuffled set of twelve 10-by-15-cm photographs. They were told that six of the photographs were of scenes that they would encounter during the route reversal and six were photographs of campus sites they could not have seen during the initial route. They were asked to select the subset of six that were on the route they had traveled and to order the scenes in the sequence they expected to encounter during the route reversal.

The researcher then informed participants that they would be periodically asked to point to distant landmarks during the return. As a rehearsal for the measurement process, the researcher asked participants to point to the front doors of the transit station, which were visible from the post. The researcher produced an electronic stop-watch and instructed participants to be as accurate as possible after the command to begin. The researcher said, "Point to the entrance to the transit station. Begin." The researcher started the watch. When each participant's arm was stable, they were instructed to announce "There." and the researcher stopped the watch. The researcher then aligned a sighting compass along the line of each participant's arm while standing close behind. Participants were thanked for holding their arm stable and instructed that they now would be asked to point to a location that was out of sight. The researcher said, "Point to the front door of your house. Begin." and when the participant announced "There," the measurements were repeated.

The researcher then led the walk back to the stairs. Distance estimations were made at all nine choice points. To illustrate, at the center of the first choice point, the researcher stopped and showed participants the back of a 30-cm ruler. The bottom of the back was marked "Destination: Post" and the top was marked "Start: Stairs." Between these were the labels "1/4 way; 1/2 way; 3/4 way." Participants were shown how to slide a paper clip along the length of the ruler, and the clip was returned to the bottom. Participants were then told to assume that the length of the ruler represented the length of the distance between the post and the stairs and asked to slide the clip to that point that represented "how far they were along that distance." The researcher then retrieved the ruler and turned it over to record the cm from the destination label as indicated by the clip.

Participants were then asked to "Point to the path that would allow you to continue to return on the initial route." If correct, the researcher said, "Good, but we're going to assume there is construction at this intersection and we need to take a detour." If incorrect, the researcher said, "Good, but that was not the path we originally walked on. It's this one (pointing), but we're going to assume there is construction at this intersection and we need to take a detour." The researcher then led the walk to the second choice point, which was off route. At the second, third, and fourth choice points, participants were asked to "Point to the way that is the *least distance* back to the initial route." A backwards point was correct at the second choice point, a leftward point was correct at the third choice point, and a forward point was correct at the fourth choice point. Participants were corrected after pointing. For example, at the second choice point, if incorrect, participants would be told, "Actually, the shortest way back to the initial route is that way [pointing], which would be the way you would go to retrace your steps to the origin of the detour." At choice points six through nine, participants were again asked to "Point to the path that would allow you to continue on the initial route." Participants were corrected if necessary and led back on the initial route.

Participants were also stopped at the four vantage points. At these sites, they were told to prepare to point to locations that were out of sight and to be sure to announce "There." when they judged that their point was correct. The researcher said, "Point to the stairs at the start of the walk. Begin." recorded the latency and compass bearing, and then repeated the procedure to record pointing to the post at the destination of the walk.

After reaching the destination, participants were shown a survey map of the campus that included the route they had walked and the nine choice points. They were asked, for each choice point, whether they had estimated distance along the walk "as the crow flies to one end of the route" or in terms of "the total length of the actual path segments to one end of the route."

Results

Self-Ratings of Sense of Direction. Although equal numbers of females and males were assigned to groups with high and low self-ratings, we examined whether the mean response to the *How good?* scale was different across gender. It was not: the mean ratings for females and males were 4.1 and 4.1, SDs = 1.7 and 1.6, respectively, $t\ (46) = .09$.

Anticipatory Recall. Audiotapes of participants anticipating events along the return trip were transcribed, and two research assistants independently scored each transcription. The researchers counted the number of landmarks named, the number of actions linked to an egocentric direction (e.g., "we'll go left"), the number of times a cardinal reference such as "to the south" occurred, and the number of landmarks that the participant explicitly linked with an allocentric heading or turn (e.g., "head straight down a paved road, then turn toward the power plant"). Differences in counts were resolved by discussion.

Table 5 indicates that self-ratings of sense of direction were moderately associated with the number of actions linked to an egocentric direction and with the number of landmarks explicitly linked with a heading or turn. The other two measures of anticipatory recall were not reliably correlated with ratings of sense of direction. To examine individual differences, the number of actions linked to an egocentric direction was the dependent measure for a 2×2 (gender × sense-of-direction group) ANOVA. Only the main effect of sense-of-direction group was reliable, $F\,(1, 47) = 8.27$, $MSE = 4.23$, $p < .01$. GSOD participants recalled a mean of 10.7 directed actions, and PSOD participants recalled a mean of 7.8. Next, the number of landmarks linked to an allocentric heading was the dependent measure for a 2×2 (gender × sense-of-direction group) ANOVA. Only the main effect of sense-of-direction group was reliable ($F(1, 47) = 5.54$, $MSE = 18.42$, $p < .05$). GSOD participants recalled a mean of 4.0 landmarks associated with a heading or turn, and PSOD participants recalled a mean of 2.3.

Scene Recognition. There were two measures associated with scene recognition: the number of photos correctly identified as scenes that would appear during the route reversal, and the accuracy of the anticipated order of those scenes. For each participant, accuracy of order was indexed by the rank order correlation (r_s) between his or her ordering and the actual order in which the scenes would be viewed during the route reversal. Foils that were incorrectly identified as scenes along the original route were eliminated from subjective orderings. Three PSOD participants did not correctly recognize more than two scenes and were excluded from analyses of the ordering of scenes.

Table 5 indicates that sense of direction was moderately associated with the number of photos correctly identified. To examine individual differences, the number of photos correctly identified as scenes was the dependent measure for a 2×2 (gender × sense-of-direction group) ANOVA. Only the main effect of sense-of-direction group was reliable ($F(1, 47) = 3.79$, $MSE = 0.665$, $p < .05$). GSOD participants correctly recognized a mean of 4.1 photos, and PSOD participants correctly recognized a mean of 3.6. The correlation between ratings of sense of direction and the rank order correlation was not reliable. Rank order correlations (r_s) were 0.33 and 0.37, respectively, for the GSOD and PSOD groups.

Distance Estimation. Sixteen of the forty-eight participants estimated distance traveled at each of the nine choice points by using a crow's-flight representation. Eighteen of the participants estimated distance traveled at each of the nine choice points by using a representation of the length of the path segments. Fourteen participants used either of these two representations at different choice points. Use of these different representations was not associated with grouping of participants as to gender or good or poor sense of direction, or with location of choice points on or off the original route.

Two means of the accuracy of estimates of distance traveled were calculated for each participant. The first was mean accuracy at the six choice points on path; the second was mean accuracy at the three choice points off path. Accuracy at any one choice point was the absolute value of the difference between the participant's estimate and either the crow's-flight distance or the total path-segment distance to the destination, in accord with the representation that the participant reported using at that choice point.

Table 5 indicates no reliable correlation between ratings of sense of direction and accuracy of estimates of distance traveled. A $2 \times 2 \times 2$ ANOVA was conducted with gender and sense-of-direction group as between-subjects variables and all tests at choice points on and off the original route as a within-subjects variable; the dependent measure was the absolute accuracy of distance estimations. There were no significant effects. The GSOD group erred on the ruler an average absolute value of 3.2 cm (111 m scaled to the 1,040-m route); the comparable error for the PSOD group was 2.9 cm (101 m).

Path Choices. Table 5 indicates small and statistically unreliable correlations between ratings of sense of direction and the mean number of correct path choices at intersections on and off route. A $2 \times 2 \times 2$ ANOVA was conducted with gender and sense-of-direction group as between-subjects variables and tests at choice points on and off the original route as a within-subjects variable; the dependent measure was the mean percentage of correct

Table 5. Bivariate Correlations (r) of Self-Ratings of Sense of Direction ("How Good?") with Measures of Route and Survey Knowledge

	Anticipatory Recall		Scene Recognition		Distance Estimation: Mean Absolute Error (m)	Path Choices: Mean Correct	Bearing Estimation: Mean Latency (sec)	Bearing Estimation: Mean Absolute Error (°)
Number of cardinal references	0.14	Number of correct photos	0.40**	On route	−0.03	0.23	−0.38**	−0.21
Number of landmarks named	0.20	Rank order correlation	−0.10	Off route	−0.07	0.25	−0.12	−0.21
Number of linked actions	0.32*			All sites	−0.05	0.29*	−0.27	−0.26
Number of linked landmarks	0.44**							

* $p < .05$ and ** $p < .01$, with $N = 48$ and 2-tailed significance.

path choices. A main effect of sense-of-direction group was indicated ($F(1,44) = 4.00$, $MSE = 0.05$, $p = .05$). GSOD participants selected the correct path to proceed on the nine choice points an average of 7.3 choices (81 percent correct), whereas the comparable mean correct for the PSOD group was 6.5 (72 percent). There was also a main effect of choice point location ($F(1,44) = 63.470$, $MSE = 0.03$, $p < .01$). Participants were 86 percent correct at choice points on route and 58 percent correct at choice points off route.

Bearing Estimation. *Latency to Point.* Table 5 indicates that sense of direction was moderately associated with the mean latency to point to the end points of the route from sites on route. Other correlations between sense of direction and latency were not reliable. All correlations indicated that as ratings of sense of direction increased, the time taken to point decreased.

To examine individual differences, latency to point was the dependent measure for a 2×2 (gender $\times$ sense-of-direction group) ANOVA. No effects were reliable. To examine environmental variables, latency was the dependent measure for a $2 \times 2 \times 2$ repeated-measures ANOVA. The independent variables were tests at vantage points on or off the original route, tests at vantage points affording open or closed views, and pointing to the start or destination of the route. Only two main effects were reliable. Participants pointed more quickly when tested at vantage points on route than vantage points off route (mean latencies = 2.7 and 3.6 sec, respectively, $F(1, 47) = 9.57$, $MSE = 8.75$, $p < .01$). Participants also pointed more quickly when tested at open vantage points than closed vantage points (mean latencies = 2.7 and 3.6 sec, respectively, $F(1,47) = 9.89$, $MSE = 8.10$, $p < .01$).

Accuracy of Pointing. The absolute error of pointing was defined as in Experiment 1. Table 5 indicates small and unreliable correlations between ratings of sense of direction and the mean absolute error of the pointing to the end points of the route.

To examine individual differences, mean absolute error of pointing was the dependent measure for a 2×2 (gender $\times$ Sense-of-direction group) ANOVA. There was only a main effect of sense-of-direction group ($F(1, 47) = 6.96$, $MSE = 130.92$, $p < .02$). The mean absolute error of the GSOD group was 20°; the mean absolute error of the PSOD group was 29°.

To examine environmental variables, mean absolute error of pointing was the dependent measure for a $2 \times 2 \times 2$ repeated-measures ANOVA. The independent variables were tests at vantage points on or off the original route, tests at vantage points affording open or closed views, and pointing to the start or destination of the route. There was a main effect of pointing to the start or destination of the route ($F(1, 47) = 31.07$, $MSE = 764.83$, $p < .01$). This effect can be interpreted in light of an interaction ($F(1, 47) = 7.29$, $MSE = 737.44$, $p < .01$). When tests occurred at vantage points on route, the mean absolute error pointing to the stairs at the start was 28° and the mean absolute error pointing to the post at the destination was 20°. The effect of pointing target was more profound when tests occurred at vantage points off route, 37° mean error pointing to the stairs at the start and 14° error pointing to the post at the destination. Note that during the off-route detour, the post was more recent in memory and closer in distance than the stairs.

Discussion

Self-ratings of sense of direction were related to a variety of measures of route-learning and wayfinding. We did not find performance differences between males and females when there was the same number of each sex within the groups with high or low self-ratings. High ratings were correlated with recall of direction of travel and associated landmarks, recognition of scenes along the route, correct choices of paths during route reversal, and latency of pointing to the end points of the route when on the route. Consistent with predictions, the group with high ratings also showed better accuracy indicating bearings to the end points of the route when on the route. Nevertheless, high ratings were not differentially associated with superior orienting performance during the detour or when views were restricted. This pattern is consistent with the interpretation that people who judge that they have a good sense of direction competently use strategies to remember events along a route. Because participants were told before their initial walk across campus that they would be asked about how they find their way in new territory, they could reasonably infer that their wayfinding performance would be assessed. People with high ratings may have prospectively encoded landmarks and actions along the initial paths, but these memories would require inferences when pointing from sites off route or sites where distant views were limited.

If the effective use of mnemonics accounts for much of the orienting and wayfinding performance shown by people with high ratings of sense of direction, their performance may not be extraordinary after walking a route without expecting to lead the way back. The latter result has been reported twice (Koslowski and Bryant 1977; Heth, Cornell, and Flood 2002).

Two results are not compatible with our prediction that people with high ratings would differentially use dead reckoning as a method to infer their bearings during the walks. Dead reckoning typically involves fixing position on the basis of records of the direction and distance of movement from some anchor-point of travel, such as the origin of a route. If dead reckoning had been differentially used, people with high ratings would likely have shown more accurate memories of the proportions of distance traveled than people with low ratings. In addition, dead reckoning by humans involves parsing movements into episodes of straight travel and turns. With some reflection, a reconstruction of locomotion could provide a configural representation of the path for situating external events (Cornell and Heth 2003). However, people with high ratings were not superior to people with low ratings in ordering scenes photographed along the route.

Of course, bearings can be estimated by means other than dead reckoning. For example, in the present study, recall by people who judged they had a good sense of direction indicated that they had associated landmarks with headings and turns. These memories suggest that travelers were keeping up to date on their changing direction relative to the visual surround—that they were piloting. In addition, bearings could be estimated from well-organized static knowledge. Path landmarks near the wayfinder could be used to self-localize or fix one's position within a representation of the route (Loomis et al. 1999). The direction of the endpoints of the route could then be derived if the representation was in survey form, as if seen from above. We see evidence for route configuration knowledge in the next experiment.

Experiment 3

In this third experiment, we examined whether self-ratings of sense of direction are associated with the ability to create shortcuts across unfamiliar territory. Of course, some shortcuts are easily seen when a wayfinder spots a landmark that appears beyond an upcoming turn in the path. Approaching the landmark by line of sight may allow the wayfinder to reduce travel without knowing much beyond the immediate scene. More abstract processes are required to infer a shortcut by imagining the configuration of the route from an overhead or survey perspective. For example, if the border of a path shows a gradual curve, even if the end of the curve is impossible to see from its origin, the wayfinder may imagine how a chord could connect the end points of the curve. If the territory on the inside of the curve is judged to be negotiable, the chord could serve as a shortcut when returning along the path.

Notice that we have described the latter process as a Euclidean inference from a cognitive map. Path integration could also allow a return to a particular reference point on the basis of continual integration of angular and linear components of locomotion. Laboratory studies indicate that path integration by humans is replete with cumulative error (Loomis et al. 1999) but a shortcut based on this dynamic sensing of direction may take the wayfinder into familiar territory near the intended destination. The destination can then be found by recognition of local environmental features (Baker 1981; Gallistel 1993).

These descriptions of different processes of shortcutting are familiar extensions of the descriptions of processes of orienting during detours. It is of interest to compare what wayfinders say they do when they attempt shortcuts. Hence, in this experiment we required participants to make a shortcut through an unfamiliar suburban neighborhood. We then asked for an explanation of how they chose routes. We expected that people who judged themselves as having a good sense of direction would devise more efficient shortcuts than people who did not. Because shortcuts may require deliberations en route, efficiency can be revealed by either the duration or distance of travel. Ratings of sense of direction were also requested after the attempted shortcut. The repetition was to assess whether sense of direction was considered to be a relatively stable trait or whether participants altered their self-ratings based on their perception of their success on the shortcutting task. In particular, Heth, Cornell, and Flood (2002) found that some wayfinders increased their self-ratings after reaching their destination via unfamiliar routes.

Methods

Subjects. Eighty undergraduates (median age: 21.10; range: 17.07–48.0) at our university participated to fulfill a course requirement. When participants arrived for their research appointments, they were first asked to rate their senses of direction on the seven-point scale. Participants were not included in this study if they rated their senses of direction as 4 (neither good nor poor), if they had ever visited the neighborhood where the testing occurred, or if they were unfamiliar with the lecture theatre that served as the destination for the return. As in Experiment 2, we selected equal numbers of males and females to constitute GSOD and PSOD groups. This allowed us to examine whether there were gender differences in wayfinding performance when male and female students had similar appraisals of their senses of direction.

Route. The outgoing walk followed a quiet road bordering a river valley park (see Figure 2). Beginning at a large building featuring a tower on the north edge of the campus, the walk progressed off university grounds and entered an established neighborhood. On one side of the road were large single-family houses, most situated for views. Features on the other side of the road included viewpoint benches, a slope to the river, and a boreal forest green belt. As can be seen in Figure 2, the road followed a bend in the river valley, so that initial progress to the northwest curves toward the southwest. The extent of the turn is difficult to judge; because neighborhood streets intersect the river valley road at T-intersections, travelers often assume that the river valley road runs east to west. After 1,125 m of travel along the river valley road, the route entered the neighborhood at the fourth T-intersection. With the river road directly behind them, participants were halted prior to the first alley and asked to find a new route to a lecture theatre on campus. Figure 2 illustrates the shortest possible route to reach this destination (958 m).

Three sites along the river valley road were designated as vantage points, places where half of the participants were asked to update their position with reference to landmarks. Each of the vantage points afforded a panoramic view, including a large apartment complex in the distant skyline.

Procedure. Participants arrived at the campus building featuring the tower. They were shown the seven-point rating scale for sense of direction and were given the opportunity to update their estimate. The participants were then told that they would be led on a tour into the nearby neighborhood and that they would be asked some questions about how they find their way in new territory.

Figure 2. A survey map of the northwest portion of the campus and the residential neighborhood. Houses are not represented within neighborhood lots. The origin of the outgoing walk (dashed line) is indicated by **O**, the three vantage points are indicated by **V**s, and the starting point for the shortcut is indicated by **S**. The path between **S** and **D** represents the least distance shortcut to the destination.

Half of the participants were randomly assigned to receive instructions en route, with the constraint that equal numbers of males and females and equal numbers of participants with good or poor ratings of sense of direction received the instructions. These participants were stopped at vantage points and asked, "Can you at this point update your position with reference to some landmarks that you have previously seen from a distance? For example, you might use the position of the sun." After the participant had looked around and appeared ready to resume the walk, the researcher asked, "Ready? Tell me the landmarks that you chose."

Upon arriving at the alley, participants were told, "I want you to imagine that you live in this house and you are late for class one morning. You need to get to the physics lecture theatre by taking the shortest, most direct route you can find. Would you choose to return along the same route that we traveled to get here, or would you attempt a new route through the neighborhood?" After recording the response, the researcher said, "I would now like you to lead all the way to the entrance doors of the lecture theatre by taking a shortcut through the neighborhood. You cannot choose any of the paths that we just used. I'll be walking right behind you, and I know this neighborhood quite well, so be assured that you will not get lost. There are many ways to go to the lecture hall, and you can choose alleys, streets, or a variety of paved paths." The researcher then inconspicuously started a stopwatch and began recording the participant's route on a survey map mounted on a clipboard.

If the participant stopped or asked for help, the researcher simply said, "You're on a possible route, keep trying." Upon arrival at the entrance doors, the researcher stopped the watch, asked the participant to rate his or her sense of direction again, and asked the participant to "explain the method they used to select the route through the unfamiliar neighborhood." The actual distance traveled was estimated by retracing the participant's route with a map wheel on a 1:2,400 cadastral map. The map wheel was precise to 10 m. Two experienced map-wheel users retraced each route.

Results

Self-Ratings of Sense of Direction. Self-ratings of sense of direction were compared using a $2 \times 2 \times 2$ ANOVA, with between-subjects factors of gender and instruction condition (instructed to update position versus no instruction) and the within-subjects factor of self-rating prior to and after the walk. Only the latter indicated a reliable effect ($F(1, 76) = 15.57$, $MSE = 0.85$, $p < .001$). The mean rating of sense of direction was 4.1 prior to the walk and 4.6 after the walk. Table 6 presents the correlation between the two ratings by individuals. As in Experiment 2, equal numbers of females and males were assigned to GSOD and PSOD groups, and this may have precluded reliable gender differences in the magnitude of the ratings. The mean ratings for females and males prior to the walk was 3.9 and 4.3, SDs = 1.7 and 1.6, respectively.

Landmarks Named. The forty participants who had been instructed to note distant landmarks during the outgoing walk named features of the environment that were close to the road (intersections, houses, street signs) and objects that appeared at a distance (downtown buildings and features of the river valley park such as a golf course, a bridge, and a lake). The total number of landmarks named across the three vantage points was analyzed in a 2 × 2 × 2 ANOVA, with gender and good or poor sense of direction as between-subjects factors and close and distant landmarks as a within-subject factor. There was a significant effect of distance of landmark ($F(1, 38) = 44.32$, $MSE = 10.61$, $p < .001$). Participants named a mean of 7.8 distant landmarks across the three vantage points and also named a mean of 3.0 landmarks that were close to the path. No other effects were reliable.

Electing To Take Shortcuts. When asked at the end of the outgoing route, fifty-nine participants chose to try a new route through the neighborhood and twenty-one participants preferred to return along the same route that they had traveled to reach that point. The number of males and females who elected to try a shortcut was thirty-one and twenty-eight, respectively. The number of participants who elected to try a shortcut was nearly equal in the GSOD and PSOD group—twenty-nine and thirty, respectively. The number of participants who elected to try a shortcut was also not significantly different in the groups who did or did not receive instructions to update their position along the outgoing walk—twenty-seven and thirty-two, respectively.

Distance of Attempted Shortcut. Regardless of preferences, all participants attempted a shortcut through the neighborhood when requested. The length of chosen paths in meters was examined in a 2 × 2 × 2 ANOVA, with gender, good or poor sense of direction and instructed or not instructed to update position as between-subjects factors. There were no significant effects or interactions. The mean length of the shortcut to the lecture hall was 1194 m ($SD = 195$) for the GSOD group and 1,259 m ($SD = 240$) for the PSOD group. Five participants with good ratings and four participants with poor ratings were able to create shortcuts that minimized travel to the goal. Table 6 indicates the correlation between individual ratings of sense of direction and meters traveled during the shortcut.

Duration of Attempted Shortcut. The duration of the shortcut in minutes was examined in a 2 × 2 × 2 ANOVA, with the same between-subjects factors as in the preceding analysis. All three main effects were reliable. Males took 13 min 24 sec to complete their shortcuts, whereas females took 15 min 12 sec ($F(1, 79) = 9.02$, $MSE = 6.73$, $p < .01$). The mean duration of the shortcut to the lecture hall was 13 min 38 sec for the GSOD group and 14 min 56 sec for the PSOD group ($F(1, 79) = 5.08$, $p < .05$). The mean duration of the shortcut to the lecture hall was 15 min 6 sec for the group that received instructions to update their position during the outgoing walk and 13 min 28 sec for the group that was not instructed ($F(1, 79) = 8.06$, $p < .01$). Table 6 indicates the correlation between individual ratings of sense of direction and minutes of travel during the shortcut.

Explanations of Shortcutting Strategies. Table 7 lists seven categories of explanations that participants provided when asked how they selected their route through the unfamiliar neighborhood. Two research assistants assigned responses to these categories independently; agreement was indicated by a Cohen's kappa coefficient of 0.80. Disagreements were resolved by discussion. Ten (25 percent) of the GSOD group and seventeen (43 percent) of the PSOD group described more than one method used along the return walk, $\chi^2(1, N = 80) = 2.01$,

Table 6. Bivariate Correlations (r) of Self-Ratings of Sense of Direction ("How Good?") with Measures of Shortcutting Effectiveness

	Ratings after Shortcutting	Distance of Shortcut (m)	Duration of Shortcut (min)
Ratings before shortcutting	0.65**	– 0.20	0.35**
Ratings after shortcutting		– 0.26*	– 0.47**
Distance of shortcut (m)			0.80**

*$p < .05$ and ** $p < .01$, with $N = 80$ and two-tailed significance.

Table 7. Frequency of Explanations for Choosing a Shortcut by Participants with Self-Ratings Indicating a Good Sense of Direction (GSOD) or Poor Sense of Direction (PSOD)

Categories: Examples of Explanations	GSOD Frequency	GSOD Percent of participants (of 40)	PSOD Frequency	PSOD Percent of Participants (of 40)
Configuration of original route: "I knew that Saskatchewan Drive is a big curve." "I wanted to take a straighter path than the original route."	10	25	2	5
Cardinal direction: "I had a good idea of where north, south, east, and west are."	3	8	5	13
Use of distant landmarks: "I saw the top of Lister Hall." "I kept going in the opposite direction to the sun."	8	20	12	30
Route features: "I followed straight roads." "I looked for busy roads." "I paid attention to street numbers."	7	18	13	33
Keyed on original route: "92nd Avenue looked parallel to Saskatchewan Drive." "I went left to stay close to the original path."	6	15	9	23
Aesthetic preference: "I chose the route because it's shady." "I was afraid of getting lost."	1	3	4	10
Intuition: "It felt like the right way back." "I knew the general direction."	14	35	19	48

n.s. Repetitions of a method by a participant did not add more to a singular count of their use of that method, but descriptions of other methods by that participant added a count to those respective categories. Table 7 indicates the frequency that particular methods were reported, as well as the percentage of participants who reported a method at least once.

The configuration of the original route was more frequently reported by GSOD participants than PSOD, $\chi^2(1, N = 80) = 4.80$, $p < .05$. Table 7 further indicates that methods to estimate shortcuts varied and that the most frequent explanations were classified as intuitive. Separate listings for females and males did not indicate reliable differences in categories of explanations.

A successful strategy is likely to become a mainstay of wayfinding, and continuing successes may lead to high ratings of one's sense of direction. A significant proportion of participants who reported the configuration of the original route had high ratings, so it is of interest to determine whether this encoding strategy is effective for devising shortcuts. We report here post hoc ANOVAs of the distance and duration of attempted shortcuts by the twelve participants who reported the configuration of the original route. The four females and eight males were matched on a case-by-case basis with participants who gave identical ratings of sense of direction, and where possible, were of the same gender and group assignment with regard to instructions to update their position during the outgoing walk.

There was a main effect of reported method of estimation of shortcut on meters traveled during the shortcut ($F(1, 23) = 5.47$, $MSE = 36{,}366.57$, $p < .03$). Participants who reported the configuration of the original route traveled a mean of 1,087 m during their shortcuts, whereas the comparison group, who reported a variety of strategies other than noting configuration, traveled a mean of 1,269 m. The effect of group methods on the duration of the shortcuts was consistent with the analysis of the whole sample, but unreliable: participants who reported the configuration of the outgoing route traveled for a mean of 12 min 56 sec, whereas the comparison group, who reported a variety of other strategies, traveled a mean of 14 min 15 sec.

Discussion

Our predictions concerning efficient shortcutting were only partially supported. Self-ratings of sense of direction prior to attempting the shortcut did not predict distance walked. Instead, participants with good ratings spent less time executing their shortcuts. Records indicated that it was not unusual for participants with poor ratings to slow or stop while reading street signs, scanning the skyline, or deliberating at intersections. One of these wayfinders asked the research assistant to wait while she ran ahead to check the view from an alternative road. Similarly, female participants and members of the group that received instructions to update their positions during the outgoing walk were slower to estimate shortcuts than males and participants who did not receive instructions to update. The slower participants may have taken time to determine relations between distant landmarks during their shortcutting attempt. Three of these wayfinders reported that they paused to look for buildings they had seen when the shortcut afforded views of the downtown skyline. Hence, it seems that the efficiency of shortcutting was associated more with the time to consider landmarks and routes in novel territory than the ability to find the least-distance solution. Wayfinders who are confident of their senses of direction while en route may take less time to deliberate than those who are not.

Interestingly, self-ratings of sense of direction increased after completion of the shortcutting task. Moreover, the ratings after completing the shortcut were reliably and negatively correlated with both distance traveled and duration of travel. These changes indicate that raters have labile estimates of their sense of direction and that evaluation of sense of direction is sensitive to recent wayfinding experiences. Heth and colleagues (2002) also found that ratings by adults were reliable in hindsight but not useful as predictors of route and bearing knowledge before retracing a campus route. They incidentally reported that some children expressed pride in finding the endpoint of their original route, even though they had wandered off the paths that they were supposed to retrace. Although not all of our participants commented at their arrival at the goal, some volunteered that the shortcut through the neighborhood was a risk that they would not normally take, some considered it to be an adventure, and some expressed that they now knew better routes for making the shortcut. We suggest that unassisted arrival at the goal was considered a success, boosting many participants' estimations of their abilities to handle wayfinding challenges.

Participants with good ratings did not report using more landmarks or more distant landmarks than participants with poor ratings. Both groups seemed to attend to landmarks in similar ways when instructed to update their position. Moreover, students with high ratings did not report a wider selection of the methods for devising shortcuts. However, the use of cues to monitor the configuration of the route during the outgoing walk may distinguish effective shortcutters. Participants who noted the configuration of the original route reduced distance traveled more than participants who reported other strategies. Interestingly, some of the other strategies—such as fixing one's position in reference to cardinal directions or the position of campus buildings—can be based on an azimuthal representation of self, perceived landmarks, and goal. Fixes involve estimations of bearings, or lines from self as a point on the horizon to landmarks as points on the horizon. However, there are several possible routes that can connect places where fixes are taken. In contrast, a report of the configuration of the original route indicates that the wayfinder was monitoring their pattern of movement more continuously. They could infer a shortcut in relation to a recent curve. The curve could be directly perceived by seeing that the road ahead turned to the left. The extent of the curve could also have been perceived as bilateral asymmetry of self-movement (path integration of turning) or as differential rates of movement of environmental events to the left and right (optical flow; Gibson 1979). These processes should be considered suggestive, because the verbal protocols did not contain such detail and were derived from small groups who were identified after they had completed their shortcuts. Nevertheless, the results fit with the interpretation that people who effectively make shortcuts represent the configuration of routes as they travel.

Experiment 4

A good sense of direction should help when wayfinding indoors. Views to the outside are often restricted in buildings. Halls may only occasionally afford glimpses through windows, making it difficult to monitor travel in relation to a large-scale or familiar frame of reference (Weisman 1981). Landmarks in the skyline and vectors such as the direction of shadows and wind on the face are typically not available to provide a bearing. The configuration of routes within a building complex may be complicated, and the burden of wayfinding information for the new visitor may be left to peculiar graphical supports (Passini and Shiels 1987). Most of us are familiar with the difficulty of interpreting you-are-here maps, remembering color codes for wings, or searching for directional signs in visually cluttered and sprawling malls or hospital complexes.

Perhaps more often than when outdoors, wayfinders in buildings may monitor their own actions, the extent of walking within a corridor, and the direction of turning at vestibules. Dead reckoning indoors may be supplemented by piloting, as wayfinders link actions with interior architecture and signage (Arthur and Passini 1992). Dead reckoning may be used to represent one's position relative to a reference point, such as the external entrance to the building. Visitors in buildings may also imagine their actions within a representation of the layout of the building as seen from outside or from a you-are-here map (Passini 1980; Gärling, Lindberg, and Mäntylä 1983). Because sense of direction has been associated with the ability to mentally coordinate egocentric and imagined frames of references and to localize landmarks within buildings (Lorenz and Neisser 1986; Sholl 1988; Montello and Pick 1993), we predicted that people who judge themselves as having a good sense of direction will more efficiently find their destination within a building than people who do not. Efficiency is indicated by the speed and accuracy of choosing halls that lead to that destination.

Method

Participants. Seventy-two adults participated (median age 20.10, range 17.7–46.6). There were equal numbers of males and females. As in Experiment 1, participants were not preselected on the basis of their self-ratings of sense of direction; this allowed examination of correlations using the full continuum of ratings. To ensure a broad distribution of performance, we recruited both undergraduate university students ($N = 36$) and volunteers from the larger community ($N = 36$). All participants reported that they were unfamiliar with the building complex that served as the test site. The students participated to fulfill a requirement of their introductory psychology course. Nonstudent volunteers participated in response to an ad placed in community newspapers. The ad promised feedback about wayfinding abilities, and all participants were debriefed about their performance.

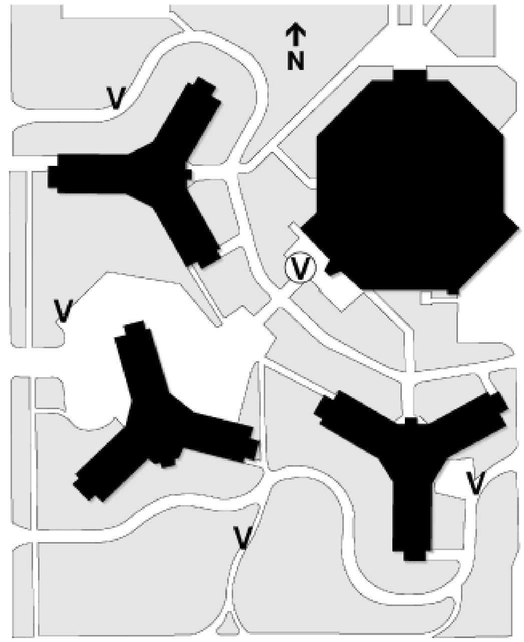

Figure 3. A survey map of the building complex. The three residence halls are Y-shaped. The vantage point at the start of each walk is indicated by **V** in a circle at the rear porch of the main entrance building of the complex. Unenclosed **V**s indicate other vantage points on the grounds.

Buildings. The study was conducted in Lister Hall, a multiple-unit residence at the periphery of the university campus. Lister Hall consisted of three similar but separate residence towers and a main entrance building housing a common cafeteria, administration, and recreation room. The entrance building consisted of two levels, and the towers each had ten floors. Underground walkways connected all three towers to each other and to the main entrance. Each tower consisted of a Y-shaped floor plan, with three wings that converged on a central foyer. The towers were situated on the grounds in such a way that the Y-shaped floor plans were rotated relative to each other (see Figure 3). Upon arrival on a tower floor, the elevator opened to the central foyer. Three doorways were equally spaced along the perimeter of the foyer. The doorways indicated access to the wings of rooms, and there was a large exterior window between two of the doorways. In all three towers, this window overlooked the main entrance building, albeit from different perspectives. In one tower the window faced north, in another the window faced east, and in the third the window faced northeast. Window blinds allowed control of natural light for a common waiting and leisure area in the central foyer.

Procedure. The researcher met the participants at an information desk in the main reception area. Participants were told that the study concerned how people orient themselves in buildings, in particular how firefighters might find a room within a building when smoke is seen from outside the building coming from that room's window. Participants were told they would have to point to a wing containing a room immediately after they arrived on a floor by elevator. The researcher gave a demonstration of how pointing latency and accuracy would be recorded. Then participants were asked to rate their own senses of direction on the three scales used in Experiment 1. All three scales were used because of the possibility that one might be especially sensitive to orienting while indoors (Montello and Pick 1993). Next, the participants were led on the first of three walks outside and inside of the residence complex.

Sequence of Walks. Each walk began at the center rear of the main entrance building, where there was an entrance to the residence grounds. Vantage points on the residence grounds were selected to afford a view of the appropriate wing, and the researcher stopped at one of these sites to point to a target window. A prominent poster, flag, or aluminum-foil covering marked target windows. The participants were told to take a moment to remember the location of the window and to think about how they would get to that room once inside the tower. The participants were then taken back to enter the center rear of the main entrance building, to progress through the underground walkways and to go up in the elevator of the tower that included the target window. When the elevator opened on the fifth floor, participants were asked to point to the wing that contained the targeted room. Participants were told to be quick and accurate in their pointing, but were told they could look at whatever they wanted. An electronic stopwatch was used to record the latency of pointing, defined as the time between the opening of the elevator doors and when each participant stated "There" while stabilizing his or her arm. After recording the direction and latency of pointing, the researcher escorted participants down the elevator to return through the underground walkways to the main entrance building. After completing the three walks, the participant was asked for each tower how they estimated the location of the wing that contained the target window.

Experimental Conditions. Each participant visited each tower once. The order of visit to the towers was counterbalanced across participants. Across participants, each of the three wings of each tower served equally often as the site for the target window. Across participants, the target window was equally often on each side of each wing. Equal numbers of males and females were randomly assigned to one of two similar conditions for the pointing task. In one condition, blinds on the foyer windows of all three towers were open, so that participants had the opportunity to use cues from the outdoors to orient. In the other condition, the blinds were closed, allowing only diffuse light from the edges.

These conditions allow tests of several hypotheses. We expected that participants who rated themselves with a good sense of direction would point to the targeted wing faster and more accurately than those who rated themselves with a poor sense of direction. We expected that speed and accuracy of pointing would decrease when blinds were closed, requiring the participants to remember their courses of travel to the choice point or otherwise imagine their orientation within the tower. We expected that pointing would be more rapid in the tower that contained a north-facing window. The view to the north is seen as especially discriminative because of the cardinal grid that is the basis of most buildings and streets in the city. In addition, a river valley defines the northern edge of the campus.

Results

Self-Ratings of Sense of Direction. Analyses of variance indicated that differences between self-ratings by males and females were not reliable, although all three measures indicated higher ratings by males. For example, the mean rating of sense of direction on the nine-point scale asking "How good is your sense of direction?" was 5.1 by females and 6.0 by males ($F(1, 71) = 3.56$, $MSE = 4.138$, $p < .07$).

Table 8 indicates moderate to high correlations between the different scales presented for participants to rate their own senses of direction. Table 8 also indicates three small correlations that are reliable and consistent with the construct validity of self-ratings of sense of direction. The self-ratings on the *How good?* scale were positively correlated with the accuracy of pointing. The number of people (out of 100) estimated by participants to have a better sense of direction was negatively correlated with the accuracy of pointing and positively correlated with the latency to point.

Latency to Point. A between-subjects variable was formed by assigning participants to GSOD and PSOD groups, depending on whether their self-rating of sense of direction was less than or greater than 5 on the *How good?* scale. This resulted in a GSOD group of eighteen females and twenty-four males and a PSOD group of sixteen females and seven males; seven participants rated their senses of direction as 5 (neither good nor bad). To examine individual differences in latency to point to the entrance door of a wing, gender and ratings group were between-subjects variables in a 2×2 ANOVA. There were no main effects or interactions, although the GSOD group pointed after a mean of 8.1 sec and the PSOD group pointed after a mean of 11.7 sec.

To examine environmental variables, latency was the dependent measure for a 2×3 repeated-measures ANOVA. The independent variables were the between-subjects condition of blinds open versus closed and the within-subjects condition of window orientation to the north, east, or northeast. There was only a main effect of blinds open ($F(1, 70) = 5.36$, $MSE = 197.35$, $p < .05$).

Table 8. Bivariate Correlations (r) of Self-Ratings of Sense of Direction and Measures of Pointing to the Targeted Wing

	Number Better?	Easily Lost?	Mean Pointing Latency (sec)	Mean Accuracy
How good?	– 0.83**	– 0.76**	– 0.20	0.32**
Number better?		0.73**	0.24*	– 0.30**
Easily lost?			0.20	0.20
Mean pointing latency (sec)				– 0.02

* $p < .05$ and ** $p < .01$, with $N = 72$ and two-tailed significance.

Contrary to our prediction, participants took longer to point when the blinds were open, a mean of 11.4 sec in comparison to 6.9 sec when the blinds were closed. This effect reflected that participants took time to scan the view when the blinds were open. Nine males and ten females of the thirty-six participants in the blinds-open condition walked toward the window to look outside before responding; four males and four females of the thirty-six participants in the blinds-closed condition approached or requested to look out the window.

Accuracy of Pointing. A point to the door of the wing containing the room with the target window was scored as 1, and a point to either incorrect wing was scored as 0. To examine individual differences, accuracy of pointing was defined by the total correct divided by the three tests of a participant. Accuracy of pointing was the dependent measure in a 2×2 (gender $\times$ ratings group) between-subjects ANOVA. There was only a main effect of ratings group ($F(1, 61) = 7.56$, $MSE = 0.70$, $p < .01$). Mean accuracy of the GSOD group was 0.64, and mean accuracy of the PSOD group was 0.43. The accuracy of pointing by the GSOD group was reliably above chance performance (0.33), $t(42) = 8.86$, whereas the accuracy of the PSOD group was not, $p < .001$, $t(22) = 1.57$.

To examine environmental variables, accuracy was the dependent measure for a 2×3 repeated-measures ANOVA. The independent variables were the between-subjects condition of blinds open versus closed and the within-subjects condition of window orientation to the north, east, or northeast. None of the main effects or interactions was reliable.

Explanations of Methods of Estimation. Table 9 lists five categories of explanations that participants provided when asked how they chose the hallway that contained the target window. Two research assistants assigned explanations to these categories independently; agreement was indicated by a Cohen's kappa coefficient of 0.76. Disagreements were resolved by discussion. Thirteen of the forty-two GSOD participants (31 percent) reported more than one method for choosing across the three towers; three of the twenty-three PSOD participants (13 percent) reported more than one method, $\chi^2(1, N = 65) = 1.69$, n.s. Repetitions of an explanation by a participant did not add more to a singular count of their use of that method, but descriptions of other methods by the same participant added a count to those respective categories. Table 9 indicates the frequency of particular methods reported, as well as the percentage of participants who reported a method at least once.

The explanations indicated that GSOD participants tended to use global or community landmarks that were beyond the foyer window to fix their positions within a large-scale spatial framework. Fewer PSOD participants reported this method, $\chi^2(1, N = 65) = 4.69$, $p < .05$. Separate listings for females and males indicated one reliable difference, in the same category: environmental features distant from the building complex were reported to be used by nine females and twenty-one males, $\chi^2(1, N = 65) = 6.91, p < .01$.

Discussion

As noted in Experiment 1, there are high correlations between the different self-rating scales. The results addi-

Table 9. Frequency of Explanations for Choosing a Hallway by Participants with Self-Ratings Indicating a Good Sense of Direction (GSOD) or Poor Sense of Direction (PSOD)

	GSOD		PSOD	
Categories: Examples of Explanations	Frequency	Percent of Participants (of 42)	Frequency	Percent of Participants (of 23)
Building configuration: "I used the shape of the building." "I knew the elevator was in the middle."	6	14	5	22
Updating during travel: "I think as I go along." "I constantly kept track of where we looked at the window."	10	24	5	22
Global or community landmarks: "I used the sun to confirm." "I used the Butterdome as a reference."	26	62	7	30
Vantage point and grounds: "I thought about the right or left hand side from outside, then reversed it once inside." "I looked down to the place where you showed me the window in the right wing."	7	17	9	39
Intuition: "I just knew where I was." "It was instinctual." "I guessed."	7	17	5	22

tionally indicate that particular scales show reliable correlations with some measures of orientation and wayfinding. Nevertheless, all of the latter correlations are small to moderate, and there is no evidence that one rating is more sensitive to performance variables than any other.

The correlations reflect that participants with poor self-ratings of sense of direction are slower and less accurate than those with good ratings. The task was difficult, requiring participants to point to a target that they had seen from outside a building complex after an obscure trip inside the complex. A group based on high ratings of their sense of direction was more accurate than a group with low ratings. As in Experiment 3, long latencies seem to reflect that participants were considering cues and deliberating before making their response. Most participants took the time to consider what could be seen from the foyer window. The reliance on visual cues for confirming bearings was especially obvious when some participants asked to open the blinds. Many participants took the time to walk toward the open window to scan outdoors. With a few steps, a participant could see salient campus buildings, the position of the sun, and the border of the river valley—external cues for fixing one's position. Although there were no gender differences in the ability to indicate the correct hallway, fewer females reported using these distant environmental references to direct their pointing. Sholl and colleagues (2000) similarly found that females were less likely than males to orient on the basis of distal landmarks in the large-scale surround. Closer to the window, participants could see the grounds and layout of the building complex, including the central vantage point. There were no gender differences in the frequency of reports of these configurational cues.

Participants with high ratings did not report a wider selection of the methods for choosing hallways. The ability to coordinate imagined perspectives with the immediate surround was a component of one method. Table 9 indicates that sixteen participants reported that they noted whether the target window was in the left or right wing when they looked at a tower from the vantage point outside. They also noted whether the main entrance to the tower complex was behind them or in front of them. Then, when the elevator doors opened inside the tower, they assumed that the window they were facing, whether open or closed, overlooked the main entrance to the tower complex. The position of the target wing could then be inferred by imagining a rotation from facing the main entrance to facing the tower wing. The method is consistent with the notion that people with a good sense of direction are good at mental rotation, which would be required even if the window were open. However, psychometric assessments do not show reliable correlations between sense of direction and performance on mental rotation tests (Lorenz and Neisser 1986; Sholl 1988). Sense of direction may not be involved, because these tasks typically require an object-centered frame of reference, rather than the requirement to consider oneself within an environmental frame of reference.

As indicated in Table 9, fifteen participants said that they updated their positions relative to the outside vantage point as they progressed through the underground halls. These reports are consistent with the dead-reckoning method of navigation. The length and complexity of the route would have made dead reckoning extremely difficult if only proprioceptive cues associated with locomotion were used. In fact, two participants who reported they updated their position jokingly asked as they walked the underground halls, "Where are the windows?" Thus, imagination may have been part of dead reckoning, to the extent that wayfinders registered characteristics of optic flow in relation to an imagined outdoor surround (Rieser 1999).

Notice that the ability to imagine a vantage point could account for our finding that pointing accuracy did not decline significantly when windows were occluded. The tendency to approach the window and the levels of pointing accuracy indicate that the task was moderately difficult even when the blinds were open. It is impressive that participants who rated themselves with a good sense of direction were significantly better than chance across both of these conditions.

General Discussion

Self-ratings of sense of direction were indeed related to a variety of abilities associated with being oriented in large-scale environments. As summarized in Table 1, construct validity is indicated by convergent results in divergent tasks. Participants could accomplish several of the tasks by using survey knowledge, or fixing their positions within a spatial framework that at least represented bearings. Survey knowledge was first indicated when people with higher ratings of their senses of direction pointed more accurately to local landmarks that were out of sight. People with higher ratings also more rapidly and accurately pointed to the endpoints of a recently learned route. In addition, people who judged that they had a good sense of direction reported that they were able to use a community or global frame of reference to choose a hallway within an obscure building complex. A good sense of direction was also associated with route knowledge: retention of actions, headings, and scenes at route intersections was better for people with high ratings.

These performances suggest several interpretations concerning the cognitive processes that might be associated with sense of direction, gender differences, and the utility of the rating scales for selection of personnel.

Process Explanations

Within and across experiments, there were a variety of descriptions of methods used to solve orienting and wayfinding tasks in large-scale environments. These descriptions suggest that orienting and wayfinding, like reading and many other complex human performances, involve several interactive and compensatory cognitive processes. The majority of participants usually reported a single method to approach any one task, but in Experiment 1, different methods were reported for landmarks with different representations in memory. Similarly, in Experiments 3 and 4, many participants reported using more than one method to devise a response and reported using different methods for responses at different sites or as the task progressed. The shifts to accommodate features of the environment suggest why factor analyses may differ in characterizing patterns of wayfinding strategies (Lawton, Charleston, and Zieles 1996; Prestopnik and Roskos-Ewoldsen 2000). The pattern of reports is consistent with models of executive selection of processes to use readily interpretable information, to monitor progress, and to react to anomalous outcomes. Protocol analyses, task analyses, and an array of field and laboratory experiments will probably be necessary to unravel the coordination of processes of orienting and wayfinding (Ericsson and Simon 1996).

We found indications of some of the information people use when they evaluate their own sense of direction. Correlations obtained in Experiment 1 show that self-ratings are associated with evaluation of one's familiarity with landmarks in the task environment. The correlations with accuracy of pointing further indicate that familiarity with landmarks includes knowledge of their spatial relations. These results suggest that a person may consider their sense of direction to be better in familiar than unfamiliar environments. There are also indications that people adjust their estimates of their sense of direction in accord with recent wayfinding experiences. In Experiment 3, self-ratings showed only moderate stability following a 45-minute task, and more correlations of self-ratings with performance were reliable after the task than before. Heth and colleagues (2002) reported similar post-task adjustments. Taken together, the results suggest that people consider their sense of direction to be situationally specific.

Gender Differences

Females gave lower estimates of their sense of direction than males when participants were not preselected on the basis of their self-ratings (Experiments 1 and 4). The difference was not reliable in either of these experiments, but the direction and magnitude of the effect across experiments was consistent. Moreover, the lower self-ratings by females agree with other findings involving sense of direction scales and other measures of uncertainty and anxiety about wayfinding tasks (Self et al. 1992; Montello et al. 1999).

In contrast, we found little evidence that females performed poorly in actual wayfinding tasks. Females were less accurate than males in estimating bearings from imagined vantage points (Experiment 1), but did not reliably differ from males when estimating bearings from real vantage points (Experiment 2). Females were somewhat slower than males when estimating bearings from imagined vantage points and executing shortcuts in unfamiliar territory. The slowness may be attributed to more deliberations and elaborations of explanations for orientation methods by females, which, in turn, may reflect lack of confidence in the methods they were using to solve the task at hand. Montello and colleagues (1999) summarized evidence that, on average, females perform worse than males on speeded spatial reasoning tasks, especially those involving a component of mental rotation.

In general, females also report reliance on route knowledge for wayfinding (Lawton 1994; Lawton, Charleston, and Zieles 1996). Route knowledge involves a sequence of procedures (continuations or turns) linked to landmarks and paths. Route-based knowledge allows for safe and simple repetition of travel, concatenation of routes, and geometric inferences by considering the relations between route segments (Bovy and Stern 1990; Golledge, Bell, and Doherty 1994). If, as Montello and colleagues (1999) suggest, the predominant female style of environmental cognition is route-based, females may feel less practiced and take more time in tasks that require attention to bearings and distances between landmarks. The latter are components of survey knowledge, which may be predominantly used by males. However, theorists have argued that survey knowledge includes knowledge of the configuration of elements of a spatial array (Shemyakin 1962; Siegel and White 1975). In Experiment 3, we found no gender differences in the frequency of reports of shortcutting methods involving the configuration of the original route or of the parallel layout of nearby routes. In Experiment 4, we found no gender differences in the frequency of reports of methods involving the configuration of buildings and grounds. Knowledge of configurations allows estimations of bearings, so it is possible that females preferentially use configural components of survey representations and that other components take longer to derive.

Utility

The results obtained in the present series of experiments indicate small to moderate relations between self-ratings of sense of direction and wayfinding abilities. This suggests the possibility that a simple and inexpensive method could be used to predict performance. For example, a local disaster official might be seeking a volunteer to lead a group charged with contacting evacuees. The official could ask some candidates, “On a seven-point scale, with 7 being the highest rating, how good is your sense of direction?” Our results do indicate some limits on such applications. In Experiment 1, the ability to point to nonvisible landmarks was related to the participant’s familiarity with those landmarks, and familiarity was part of the correlation between sense of direction and pointing performance. Features are unknown in new terrain, so estimates of one’s sense of direction could not be supplemented by an estimate of familiarity. Nevertheless, we have seen that people with high self-ratings may have effective strategies for encoding and organizing memories of features of environments as they travel. Their evaluation of their sense of direction may reflect a recent history of using these mnemonics successfully (Experiment 3; see also Heth, Cornell, and Flood 2002). Given that people with high self-ratings are informed that they will be directing travel, they may be prepared to enact prospective strategies, such as encoding the configuration of a route.

The study of the strategies used by people considered to have a good sense of direction may help with the design of training to boost the wayfinding performance of other people. For example, observations of hunter-gatherer cultures indicate that novices are often instructed to look back when experienced travelers show them a route leading away from an important site (e.g., Gould 1969; Nelson 1969). Pathfinders and explorers also look back to become familiar with the location and perspective of landmarks they will see when returning along a route (Gatty 1958). In recent experimental studies, modern urban children and adults were instructed in how to use the look-back strategy. The result was that they were less likely to make errors at intersections when reversing a newly learned route than were members of uninstructed groups (Cornell, Heth, and Rowat 1992; Heth, Cornell, and Flood 2002). Following this example, our third experiment provides an explanation of effective shortcutting by participants with high ratings of their sense of direction. It remains to be determined whether the skill may be taught by instructing novices to attend to the configuration of the route they are shortcutting.

Conclusions

The findings indicate that a sense of direction is a valid component of human wayfinding experience. People readily summarize their ability to remember routes and comprehend their surroundings in terms of a sense of direction. Moreover, the ability to maintain a sense of direction can be monitored during travel and incorporated into people’s ideas about themselves.

The findings suggest basic implications for behavioral geographers and cartographers. The construct of a sense of direction may be important to models of spatial decision making and choice. It may account for why certain shopping malls profit by proximity to well-known landmarks. The construct of a sense of direction may also be important to models of spatial action and activity. It may account for why drivers prefer certain routes that are aligned within a cardinal grid. Finally, assessments of sense of direction may be important for evaluating the aesthetics and effectiveness of maps.

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