How Good Are These Directions? Determining Direction Quality and Wayfinding Efficiency

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Abstract

Our goal was to specify the effectiveness of wayfinding directions in a complex indoor environment. We measured direction quality using effectiveness ratings and behavioral indices. In Study 1, participants provided effectiveness ratings for seven combinations of wayfinding descriptions. In general, ratings were higher for route details than for survey details, and ratings increased as the number of features increased. Moreover, people with a good self-reported sense of direction gave higher ratings to survey descriptions (cardinal directions and distances) relative to those with a poor self-reported sense of direction. In Study 2, participants provided effectiveness ratings for route and survey directions before and after wayfinding using these directions. Route directions resulted in fewer wayfinding errors and higher effectiveness ratings than did survey directions. People with a poor self-reported sense of direction made more wayfinding errors and provided lower effectiveness ratings than did people with a good self-reported sense of direction. We also demonstrated important relations between wayfinding errors and ratings after wayfinding, as well as links with sense of direction, wayfinding strategies, and mental rotation.

Keywords: wayfinding, survey perspective, route perspective, sense of direction, effectiveness ratings, mental rotation

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Imagine that you are finding your way through a complex building for the first time. Someone tells you how to get to the room you need, and the directions sound like they contain the right information to get you there. However, as you are following the description, you get confused regarding what was meant by, “go left at the T.” You forget the last turn because you focused too much on remembering several details at the beginning of the route, and you get lost. You must reorient yourself and try to find your way again while not getting anxious about being lost. Upon finally finding the room, you realize that perhaps the directions you received were not as efficient as you originally thought. This example illustrates several challenges people face while trying to find the way from place to place. Sometimes, directions that seem helpful have an adequate number of details to effectively lead someone from place to place. At other times, directions that originally appeared to be high in quality end up being misleading or overwhelming to remember. The primary goal of the present study was to specify the quality of wayfinding directions using effectiveness ratings and behavioral indices. Another goal was to examine how individual differences such as sense of direction and gender relate to wayfinding.

How does one determine the quality of wayfinding directions? According to Lovelace, Hegarty, and Montello (1999), the quality of directions can be measured in three ways. First, quality can be determined by calculating the number of elements included in the directions, such as landmarks, turns, or other descriptive information provided. Second, quality can be measured subjectively by having people rate the effectiveness of route directions. Finally, quality can be determined by measuring how well the directions facilitate wayfinding.

Analyzing the specific details in route descriptions can be accomplished in a variety of ways. One way is to count the number of words used in a description or count how many times different elements are used (Lovelace et al., 1999). However, the number of words and descriptive features is not nearly as important as the specific descriptors included, because not all descriptors aide wayfinding in the same way. For instance, previous research has highlighted the important benefits of including landmarks—environmental features that function as points of reference (Lynch, 1960)—that serve as sub-goals to keep people connected to the point of origin and the destination along the wayfinding path (Allen, 2000) and that help people construct a visual model of the environment (Tom & Denis, 2004). Landmarks can be at points of a route where a choice needs to be made about which direction to proceed (i.e., at choice points) or along a stretch of a route where no decision needs to be made (i.e., at non-choice points). Allen (2000) found that wayfinding errors were less frequent when following routes containing landmarks at choice points than when following routes containing landmarks at non-choice points, especially at the end of the routes when memory demands were greatest. It is possible that the performance advantage for routes with choice point landmarks results from better memory (Janzen, 2006) based on the usefulness of choice point landmarks during wayfinding (Stankiewicz & Kalia, 2007).

In addition to landmarks, previous research has highlighted the importance of cardinal directions and distance information, though the benefits and limits of cardinal directions are not consistent across studies (Allen, 2000; Hund & Minarik, 2006; Saucier et al, 2002). Allen (2000) found that wayfinding errors were more frequent when following descriptions with cardinal directions and distances than when following descriptions with landmark information, especially in the middle and final portions of the route, indicating that cardinal directions are not beneficial.

In contrast, Hund and Minarik (2006) found that participants navigated through a model town faster and with fewer errors when following cardinal directions than when following landmark directions (see also Saucier et al., 2002).

What mechanisms might explain these differences in effectiveness for different types of descriptors? It is possible that spatial perspectives provide one such mechanism. Spatial perspectives, or reference frames, help describe the spatial relations involved in wayfinding (Tversky, 2003). Previous research has identified two perspectives: route and survey (e.g., Hund et al., 2008; Pazzaglia & De Beni, 2001; Shelton & Gabrieli, 2002; Taylor & Tversky, 1996). A route perspective entails adopting the frame of reference involved in moving through an environment and includes references to segments of particular routes. The viewpoint is intrinsic and changes as a result of moving through the environment. Landmarks and left-right turns are frequently used as descriptors. In contrast, a survey perspective provides an overview of spatial layout and adopts an extrinsic frame of reference. This perspective is most commonly acquired by looking at a map or examining an environment from above. The viewpoint for survey perspectives remains fixed from a vertical outlook. Cardinal descriptions and distances often are used to describe a space from a survey perspective. Although studies have shown benefits of learning via a survey perspective (e.g., Fields & Shelton, 2006; Hund & Minarik, 2006), there still exists a general disliking of cardinal directions (Hund et al., 2008; Hund & Padgitt, 2010). For instance, several people commented that cardinal directions were not helpful, especially if one does not know which way is north (Devlin, 2003).

Another way to analyze the quality of route descriptions is to have people subjectively rate how effective they think the descriptions would be in leading them from a starting location to a destination. In Hund et al. (2008), participants rated the effectiveness of descriptions for six different routes in a model town. Higher rated descriptions contained more left-right descriptors than did lower rated descriptions. Furthermore, when participants responded to an open-ended question about their preferences regarding wayfinding directions, positive mentions of left-right and landmark information and negative mentions of cardinal directions were common. Lovelace et al. (1999) analyzed the quality of descriptions for familiar and unfamiliar routes using coder ratings. Mention of landmarks correlated positively with route direction quality. Furthermore, longer descriptions received higher ratings because they were more complete, suggesting that people prefer detailed information when wayfinding.

One question posed by Lovelace et al. (1999) was whether highly rated directions actually facilitate wayfinding efficiency. Research evaluating wayfinding efficiency when following high- and low-rated directions has yielded mixed results. Denis, Pazzaglia, Cornoldi, and Bertolo (1999) asked participants to follow the highest and lowest rated descriptions of routes in Venice (based on participant ratings in a previous experiment). As expected, participants navigated with fewer errors when following highly rated directions in comparison to poorly rated directions. Other studies have replicated these findings in similar settings, such as routes through college campuses (Daniel, Tom, Manghi, & Denis, 2003; Honda & Nihei, 2004). However, still other studies have found that the worst rated descriptions led to more efficient wayfinding in a model town (Hund et al., 2008) and in a complex university building (Hund & Padgitt, 2010) relative to the best-rated descriptions.

Why might this be the case? One reason could be the specificity of the directions. It is possible that people navigated more quickly when following the worst rated descriptions because these descriptions were concise and to the point, which facilitated wayfinding relative to the overly specific best-rated descriptions that may have exceeded working memory capacity. When participants provide ratings, they may be evaluating the descriptions abstractly rather than focusing on practical details necessary for successful wayfinding in that particular space. Another reason could be differences in processing related to different environmental scales. In the model town used in Hund et al. (2008), the environment was experienced via a survey perspective, perhaps rendering cardinal descriptions efficient for wayfinding. Furthermore, the entire environment was visible throughout the task, which reduced memory demands relative to everyday wayfinding in large-scale environments that involve ground-level views in which only part of the route is visible at any given moment. Although this seems like a viable account for the model town, it does not explain why the indoor wayfinding task involving routes through a university building yielded similar results (Hund & Padgitt, 2010). A third explanation could be related to differences in the wayfinding tasks. For instance, Denis et al. (1999) gave participants a written version of the entire route to be followed and asked them to study it for two minutes. Participants then followed the route from memory. This is in contrast to Hund et al. (2008) and Hund and Padgitt (2010), where participants read each segment on note cards while navigating the routes. Different cognitive demands may emerge from these wayfinding tasks, which may result in differences in efficiency when following the descriptions. Although descriptive features, environmental space, and cognitive demands may all account for these discrepancies in wayfinding, individual differences in spatial skills also may play a role (Hegarty, Richardson, Montello, Lovelace, & Subbiah, 2002; Hund & Nazarczuk, 2009; Kato & Takeuchi, 2003).

One important individual difference is sense of direction, or “awareness of orientation or location” (Kozlowski & Bryant, 1977, pp. 178). Sense of direction is related to wayfinding such that people with a good sense of direction actively explore and attend to details in new environments, and they remember new routes better than do people with a poor sense of direction. In contrast, people with a poor sense of direction are more likely to lose their way and worry more about becoming lost (Sholl, Acacio, Makar, & Leon, 2000). Kozlowski and Bryant (1977) asked participants to rate their sense of direction and indicate the direction of five unseen buildings, two nearby cities, and northward heading, finding that sense of direction ratings and indications of spatial features were tightly coupled. Similarly, Hund and Nazarczuk (2009) found that larger errors when indicating the direction of buildings and locations were indicative of more frequent wayfinding errors and slower navigation through a campus building relative to smaller sense of direction errors. These results show that sense of direction relates to wayfinding, but more research is needed to further specify this relation (see also Kato & Takeuchi, 2003). In particular, it is not known how sense of direction affects description ratings, which is one focus of this project.

Another individual difference factor is gender. Several instances of gender differences in wayfinding have been identified, often corresponding to perspective differences (e.g., Honda & Nihei, 2004; Lawton & Kallai, 2002; Saucier et al, 2002). For example, men often prefer survey strategies more than do women, whereas women prefer route strategies more than do men (Honda & Nihei, 2004; Hund & Minarik, 2006; Hund et al., 2008; Lawton & Kallai, 2002). In addition, men often provide more cardinal descriptions than do women, whereas women provide more landmark information than do men (Cherney, Brabec, & Runco, 2008; Ward et al., 1986; but see Devlin, 2003 for an exception). Furthermore, men typically perform better following cardinal directions, whereas women perform better following directions with landmarks (Saucier et al., 2002).

The primary goal of the current study was to specify the effectiveness of wayfinding directions by eliciting ratings and evaluating behavioral indices of wayfinding. Another goal was to specify how sense of direction and gender relate to wayfinding efficiency in a relatively unfamiliar indoor environment. Study 1 examined ratings of descriptions containing cardinal directions, distances, left-rights, and/or landmarks, focusing particularly on how sense of direction and gender affected ratings. In Study 2, participants rated and followed route and survey descriptions.

Study 1

Our goal was to assess people's responses to different types of wayfinding directions. Participants read sets of descriptions of four routes through the basement of a complex university building. They were asked to rate each description based on its effectiveness for aiding wayfinding using a 7-point scale. In contrast to previous studies where participants provided the directions to be rated (Denis et al., 1999; Honda & Nihei, 2004; Hund et al., 2008), we created the directions for this study to allow analysis of specific descriptive features indicative of survey and route perspectives. Given previous demonstrations of people's preference for wayfinding directions using a route perspective (Denis et al., 1999; Hund et al., 2008), we formulated three specific predictions based on descriptor type. First, descriptions containing typical route perspective details (left-right turns, landmarks) would receive higher ratings than would descriptions containing typical survey perspective details (cardinal directions, distances). Second, descriptions containing choice point landmarks would receive (at least slightly) higher ratings than would descriptions containing non-choice point landmarks (Allen, 2000). Third, descriptions containing multiple descriptive features would receive higher ratings than would descriptions containing fewer features. We also expected that people with a good self-reported sense of direction would give higher ratings to survey descriptors than would people with a poor self-reported sense of direction. Furthermore, we predicted that women would give higher ratings to route descriptions than would men, and men would give higher ratings to survey descriptions than would women (Cherney et al., 2008).

Method

Participants

Fifty-three college students (29 men, 24 women) participated. Their ages ranged from 19 to 31 years (M = 20.96 years). Data from two additional participants were omitted because of researcher error. Participants were recruited through the Department of Psychology college student participant pool and received credit in their psychology courses.

Apparatus and Materials

Descriptions. A set of four routes from starting locations to destinations was utilized. The starting locations and destinations were the windows overlooking the plaza and the computer classroom, the research classroom suite and the elevators, a laboratory and a classroom, and a classroom and an office, sampling every area of the basement of a university building. We created 7 descriptions of each route. The descriptions varied in their use of cardinal directions, distances, left-rights, and landmarks (either at choice or non-choice points, see Table 1 and Appendix), yielding 28 descriptions in total.

Sense of direction. Sense of direction was measured using the two-question self-report Sense of Direction Scale (Hund & Nazarczuk, 2009; Pazzaglia & DeBeni, 2001). Test-retest reliability averaged .93 when participants reported their sense of direction in sessions separated by 2 weeks to 3 months (Kozlowski & Bryant, 1977).

Environmental familiarity and demographic information. Two items measured participants' familiarity with the campus building used in the study (Hund & Nazarczuk, 2009).

These items probed overall familiarity and how often participants visited the floor during a typical week.[1] Participants also completed a brief demographic information form.

Design and Procedure

Participants were asked to rate each of the 28 wayfinding directions based on effectiveness using a 7-point scale, with 1 indicating a poor direction that does not allow one to easily reach the goal and 7 indicating an excellent direction that enables one to follow the directions and reach the goal without error or hesitation (Dennis et al., 1999; Hund et al., 2008). They were told that some directions might be excellent, whereas others may be difficult to interpret. Participants then completed the self-report measures.

Results and Discussion

The primary goal of this study was to specify the types of descriptive features contained in effective and ineffective route descriptions. We averaged the effectiveness ratings across trials for each type of description.[2] These ratings were entered into a Gender (men, women) x Sense of Direction (poor, good) x Descriptor Type (1-7) mixed model Analysis of Variance (ANOVA). A median split was used to divide men and women into poor and good sense of direction groups using the self-report measure (Median for men = 4, Median for women = 3.25). Figure 1 shows how ratings for each description differ as a function of sense of direction. As predicted, there was a significant main effect of descriptor type, F (6, 44) = 74.76, $p < .001$, *Partial Eta*^{2} = .91, and a significant Sense of Direction x Descriptor Type interaction, F (6, 44) = 2.40, $p < .05$, *Partial Eta*^{2} = .25. Simple effects tests indicated that sense of direction differences in ratings were apparent for two descriptor types. People with a good self-reported sense of direction gave higher ratings to descriptions with cardinal directions and distances (M = 3.46, SE = .19) than did those with a poor self-reported sense of direction (M = 2.96, SE = .20), F (1, 51) = 4.09, $p < .05$, *Partial* $Eta^2 = .07$. Similarly, people with a good self-reported sense of direction gave higher ratings for directions that included cardinal directions, distances, left-rights, and choice point landmarks ($M = 5.29$, $SE = .16$) than did those with a poor self-reported sense of direction ($M = 4.77$, $SE = .17$), $F\ (1, 51) = 5.76$, $p < .05$, *Partial* $Eta^2 = .10$. None of the other five simple effects tests revealed significant differences. In sum, people with a good self-reported sense of direction gave higher ratings to descriptions that included cardinal directions and distance information (among other details) relative to those with a poor self-reported sense of direction. These are common components of directions using a survey perspective, indicating a link between good sense of direction and preference for survey details. The lack of sense of direction difference for descriptions containing only cardinal directions probably resulted from the low ratings overall, suggesting that a floor effect may have attenuated detection of this difference.

Though not conventional, we report another set of simple effects to probe hypothesized differences across descriptive features. As expected, effectiveness ratings varied as a function of descriptive features for participants with poor, $F\ (6, 18) = 47.43$, $p < .001$, *Partial* $Eta^2 = .94$, and good self-reported senses of direction, $F\ (6, 23) = 37.27$, $p < .001$, *Partial* $Eta^2 = .91$. Bonferroni follow up tests were used to test pair-wise comparisons, focusing on differences based on feature type and number. Consistent with predictions, effectiveness ratings were lowest for descriptions that contained only cardinal directions and increased incrementally for descriptions containing left-rights; cardinal directions and distances; left-rights and non-choice point landmarks; left-rights and choice-point landmarks; cardinal directions, distances, left-rights, and choice point landmarks; and left-rights, choice point landmarks, non-choice point landmarks, and distances. This pattern generally confirms the preferences for route versus survey features and for more versus fewer features overall.

Nonetheless, the significant interaction effect suggests that this pattern differed for people with poor and good self-reported sense of direction. Specifically, for people who reported a poor sense of direction, only the difference in ratings of descriptions containing left-rights and choice point landmarks versus cardinal directions, distances, left-rights, and choice point landmarks failed to reach significance, suggesting an attenuated sensitivity to increased features when the increase included cardinal directions. In contrast, for people who reported a good sense of direction, the difference between descriptions containing cardinal directions and distances versus left-rights and non-choice point landmarks and the difference between descriptions containing cardinal directions, distances, left-rights, and choice point landmarks versus left-rights, choice point landmarks, non-choice point landmarks, and distances were not significant, suggesting clear differentiation based on number of features and less differentiation between descriptions containing cardinal directions and left-rights. Overall, this pattern suggests that people who reported a good sense of direction may view cardinal directions more favorably relative to people who reported a poor sense of direction, consistent with our predictions and with theoretical explanations focusing on the importance of constructing and maintaining a global sense of orientation for both sense of direction and wayfinding using cardinal descriptors (Hund & Nazarczuk, 2009; Kato & Takeuchi, 2003; Kozlowski & Bryant, 1977; Lawton, 1996; Prestopnik & Roskos-Ewoldsen, 2000). There were no other significant findings from the overall analysis, meaning that no gender differences were evident here, contrary to predictions. Additional research is needed to probe the nature and locus of such differences, including our second study.

Overall, our findings provide insight regarding effectiveness ratings for route descriptions. First, the types of features included in descriptions impacted ratings, though the pattern of differences varied as a function of self-reported sense of direction. As expected, descriptions containing only cardinal directions received lower ratings than did descriptions containing only left-rights. Similarly, other descriptions containing cardinal directions received lower ratings than did descriptions containing similar numbers of details that included left-rights, though this difference was attenuated for participants who reported a good sense of direction. Overall, ratings were higher for descriptions with choice point landmarks relative to those with non-choice point landmarks, consistent with predictions and previous results (Allen, 2000). Together, these findings confirm the general preference for route descriptors (left-rights and landmarks, especially at choice points) and disliking of survey descriptors (especially cardinal directions, Devlin, 2003; Hund et al., 2008; Hund & Padgitt, 2010).

In addition, ratings increased as the number of features included in the descriptions increased. Specifically, directions with only 1 descriptor received lower ratings than did directions with 2 or more descriptors (Denis et al., 1999), though this pattern was attenuated for people reporting a poor sense of direction. These findings generally indicate that people prefer to have more information available to them, consistent with Hund and Padgitt (2010). It is important to note, however, that this increase in available information might result in greater demand for cognitive resources, including working memory, particularly in cases where external memory aids are not available during wayfinding. As such, wayfinders must balance their desire for having additional information with the demands of the task at hand and their available resources. In fact, it is possible that working memory demands play an important role in deciding which information would be ideal (if memory were excellent and/or external aids like written directions were available) versus which information would be most usable (if memory were more limited and/or external aids were not available). These ideas are consistent with previous theory and research (e.g., Davis, Terrien, & West, 2009; Meilinger, Knauff, & Bülthoff, 2008;

Nori, Grandicelli, & Giusberti, 2009), though additional task analysis during wayfinding would be helpful.

Study 2

The goal of Study 2 was to compare wayfinding efficiency and effectiveness ratings involving descriptions containing details consistent with route and survey perspectives, which received high and low ratings in the previous study, respectively. We selected directions with left-rights and landmarks at choice points (route perspective) and directions with cardinal directions and distances (survey perspective) for this experimental examination of wayfinding efficiency (see Appendix for examples). These descriptions guided a new set of participants who attempted to navigate through the basement of a campus building. Previous research probing effectiveness ratings and behavioral indices of wayfinding has been inconsistent, with route descriptions rated as highly effective leading to faster wayfinding and fewer errors in some studies (Daniel et al., 2003; Denis et al., 1999; Honda & Nihei, 2004), but counterintuitively leading to longer wayfinding times and more errors in other studies (Hund et al., 2008; Hund & Padgitt, 2010). If these inconsistencies stem mainly from issues of spatial scale, then we would expect ratings to favor route over survey directions but wayfinding efficiency to favor survey over route directions (Hund et al., 2008; Hund & Padgitt, 2010). If, however, inconsistencies stem mainly from issues regarding task demands relative to cognitive resources such as working memory, then we would expect ratings and wayfinding efficiency to favor route over survey directions (Denis et al., 1999; Honda & Nihei, 2004, see also Meilinger et al., 2008). Unlike other studies of this type (e.g., Denis et al., 1999; Hund et al., 2008), we assessed effectiveness ratings before and after participants followed the descriptions to better understand the processes involved in providing effectiveness ratings and to further specify how these ratings relate to wayfinding efficiency. We predicted a difference in ratings across time, such that the ratings after wayfinding would more clearly align with the efficiency with which participants reached the destinations based on the directions. We examined links with spatial strategies, sense of direction, gender, and mental rotation to further explicate the overall pattern of findings, predicting strong relations among sense of direction, mental rotation, and survey details.

Method

Participants

Eighty-four participants (40 men, 44 women) were included in this study. Their ages ranged from 18 to 29 years (*M* = 20.28 years). Participants were recruited and compensated in the same manner as in Study 1.

Apparatus and Materials

A subset of 8 route descriptions from Study 1 was used here. Each route was presented on a laminated half-sheet of paper for participants to read. Participants were randomly assigned to follow one of two sets of 4 descriptions, each containing 2 route directions and 2 survey directions presented in a random order. Set A contained route directions from the windows overlooking the plaza to the computer classroom, survey directions from a laboratory to a classroom, survey directions from the research classroom suite to the elevators, and route directions from a classroom to an office. Set B contained the opposite constellation of survey and route directions. The same self-report measures of sense of direction and familiarity from the previous study also were included.

Vandenberg Mental Rotation Test. This classic paper-and-pencil test of spatial visualization (Vandenberg & Kuse, 1978) includes two-dimensional drawings of three-dimensional figures that are rotated about the X, Y, or Z-axis. Each of the 20 test items contains a target figure, two correct alternative figures (structurally the same as the target figure but rotated around the X, Y, or Z axis), and two incorrect distractor figures. The number of correct items during the 6 minutes of testing was recorded. Two coders independently assessed responses for 16 randomly selected participants (19% of the sample). They agreed on 318 out of 320 (99.38%) judgments, indicating adequate inter-rater reliability.

Wayfinding Strategy Scale. The 17-item Wayfinding Strategy Scale (Lawton & Kallai, 2002) also was included. Participants used a 5-point scale to specify their preference for each strategy. Based on standard scoring criteria, the strategies were categorized into two groups: orientation strategies and route strategies. Orientation strategies involve keeping track of global reference points, such as cardinal directions, (e.g., “I keep track of the direction in which I am going” and “I keep track of where I am in relation to a reference point”). Route strategies involve keeping track of step-by-step routes, vistas, or landmarks (e.g., “I ask for directions telling me whether to turn right or left at particular landmarks”). Scores for each subscale were summed, so higher scores indicated stronger preferences for the specific wayfinding strategies. These subscales have acceptable psychometric properties (Cronbach’s alphas reported in Lawton & Kallai, 2002 were .79 for the orientation subscale and .70 for the route subscale, Cronbach’s alphas here were .84 for the orientation subscale and .67 for the route subscale).

Design and Procedure

Participants completed the self-report measures. Then, they completed the mental rotation task by selecting rotated figures to match each target. Participants read the four descriptions and provided effectiveness ratings using the same 7-point scale used in Study 1. Next, participants were taken to the first starting location and shown which way was north, south, east and west. They were given the first route to study for 1 minute. Then, they were asked to navigate the route in the basement of the large campus building from memory. They were told to follow the directions as accurately and quickly as they could. When the researcher said, “Go!” participants started to walk the route from memory. When participants reached the destination, they said, “Stop!” The same process occurred for the next 3 routes. Wayfinding time and errors were recorded. Wayfinding errors included backing up, turning the wrong way, taking an incorrect hallway, ending at an incorrect destination, stopping short or past a destination, and giving up on a route altogether (Hund et al., 2008; Hund & Padgitt, 2010). The first three errors involved aspects of travelling the route, whereas the final three errors involved aspects of reaching the destination. Wayfinding times were averaged and errors were summed across the route and survey directions. After following all four sets of directions, participants were asked to provide new ratings regarding the effectiveness of the four descriptions.

Results and Discussion

One goal of this study was to examine the effectiveness of route and survey directions (deemed high and low in quality, respectively) in terns of ratings and wayfinding efficiency to determine whether inconsistencies in previous findings stem from differences in spatial scale or cognitive task demands. First, we examined how gender, descriptor type, and self-reported sense of direction affected wayfinding time and errors. A median split was used to divide the sample into poor and good sense of direction groups using the self-report measure (Median for men = 3, Median for women = 2.5). Two Gender (men, women) x Descriptor Type (route, survey) x Sense of Direction (poor, good) mixed model ANOVAs analyzing wayfinding time and error were conducted. Analysis of wayfinding time revealed no significant findings.

Analysis of wayfinding errors revealed a marginally significant main effect of descriptor type, F (1, 80) = 3.85, p = .053, *Partial* Eta^2 = .05. Participants made fewer wayfinding errors when following route directions (*M* = 1.96, *SE* = .25) than when following survey directions (*M* = 2.66, *SE* = .28). These findings are consistent with the broader literature demonstrating preferences for route perspective (Denis et al., 1999), but not with findings involving written directions carried during wayfinding in small-scale and indoor spaces (Hund et al., 2008; Hund & Padgitt, 2010), suggesting that task demands may be more important than scale. The analysis of wayfinding errors also yielded a significant main effect of sense of direction, F (1, 80) = 6.74, $p < .05$, *Partial* Eta^2 = .08. Wayfinding errors were higher for people with a poor self-reported sense of direction (*M* = 2.82, *SE* = .29) than for people with a good self-reported sense of direction (*M* = 1.81, *SE* = .26). Again, these findings add to a growing literature demonstrating tight links between self-reports of sense of direction and wayfinding performance (Hund & Nazarczuk, 2009; Kazlowski & Bryant, 1977; Magliano et al., 1995; Prestopnik & Roskos-Ewoldsen, 2000; Sholl et al., 2000). Finally, the analysis revealed a significant main effect of gender, F (1, 80) = 5.59, $p < .05$, *Partial* Eta^2 = .07. Surprisingly, wayfinding errors were higher for men (*M* = 2.77, *SE* = .27) than for women (*M* = 1.85, *SE* = .28). This isolated and unexpected gender difference is difficult to interpret. No other effects reached traditional significance levels.

Another goal of this study was to understand the ratings process more generally by examining how gender, descriptor type, and sense of direction affect ratings before and after wayfinding. One main question was whether this pattern was similar or different from the pattern evident in wayfinding efficiency. Ratings were analyzed using a Gender (men, women) x Descriptor Type (route, survey) x Sense of Direction (poor, good) x Time (before wayfinding, after wayfinding) mixed model ANOVA. There was a significant main effect of descriptor type, F (1, 80) = 113.93, $p < .001$, *Partial* Eta^2 = .59. Route descriptions (*M* = 5.08, *SE* = .12) received higher ratings than did survey descriptions (*M* = 3.20, *SE* = .13). Moreover, the main effect of sense of direction was significant, F (1, 80) = 7.69, $p < .01$, *Partial* $Eta^2 = .09$. Participants with a poor self-reported sense of direction (M = 3.90, SE = .13) provided lower ratings than did those with a good self-reported sense of direction (M = 4.38, SE = .12). These findings are consistent with the overall pattern of results evident for wayfinding errors reported above and generally replicate the descriptor differences evident in the first study. Moreover, these findings are consistent with theoretical assertions and previous empirical findings, particularly when working memory demands were similar (Denis et al., 1999).

In addition, analysis of ratings revealed a significant main effect of time, F (1, 80) = 12.45, $p < .01$, *Partial* $Eta^2 = .14$, and a significant Gender x Time interaction, F (1, 80) = 7.64, $p < .01$, *Partial* $Eta^2 = .09$. Tests of simple effects indicated that ratings increased from before to after wayfinding for women, F (1, 39) = 16.11, $p < .001$, *Partial* $Eta^2 = .29$ (Before: M = 3.71, SE = .16; After: M = 4.54, SE = .18), but not for men, F (1, 43) = .57, *ns* (Before: M = 4.14, SE = .14; After: M = 4.26, SE = .16). The increase in effectiveness ratings after wayfinding for women (but not men) may be related to greater uncertainty about spatial details in the absence of wayfinding interactions among women (see also Lawton, 1994). More generally, differences in ratings before and after wayfinding suggest that effectiveness ratings and behavioral indices of wayfinding efficiency provide similar, but not identical, details about wayfinding processes, particularly for women.

Correlational analyses were used to probe relations between behavioral indices of wayfinding efficiency and effectiveness ratings more directly, as well as to highlight details about wayfinding strategies, sense of direction, and mental rotation (see Table 2). As wayfinding errors using route directions increased, ratings of route directions after wayfinding decreased. Similarly, as wayfinding errors using survey directions increased, ratings of survey directions after wayfinding decreased, demonstrating tight links between wayfinding errors and ratings after wayfinding. Interestingly, wayfinding errors and ratings before wayfinding were not strongly correlated. These findings are consistent with our prediction that ratings after wayfinding would more tightly correspond to wayfinding behavior. Correlations with orientation and route strategies, sense of direction, and mental rotation were examined to provide preliminary insights regarding potential explanatory mechanisms. Effectiveness ratings for survey directions were positively correlated with orientation strategies, sense of direction self reports, and mental rotation, highlighting the shared importance of global, integrated details. Similarly, wayfinding errors using survey directions were inversely related to mental rotation, indicating that wayfinding errors decreased as mental rotation increased. These findings are consistent with the broader literature, demonstrating tight links between orientation strategies, sense of direction self reports, and wayfinding (Hund & Minarik, 2006; Hund & Nazarczuk, 2009; Hund & Padgitt, 2010; Kato & Takeuchi, 2003; Lawton, 1996; Prestopnik & Roskos-Ewoldsen, 2000). In contrast, effectiveness ratings for route directions were inversely related to ratings of survey directions and were not related to self-reports of sense of direction or mental rotation performance.

Overall, our findings demonstrate important links between mental rotation and spatial strategies, sense of direction, wayfinding errors when following directions using a survey perspective, and effectiveness ratings for survey descriptions before and after wayfinding. These findings help clarify the mixed results in previous investigations (Bryant, 1982; Lawton, 1994). Why might mental rotation and wayfinding be related? According to Hegarty et al. (2006), small-scale spatial abilities, such as mental rotation, and large-scale spatial abilities, including wayfinding, rely on overlapping but not identical processes. It is interesting that the overlap seems most pronounced when utilizing a survey perspective. According to Hegarty et al., the overlap relies on encoding of spatial information, maintenance of spatial representations in short term memory, and inference from spatial representations. As such, one potentially fruitful avenue of research would be to specify the impact of encoding, maintenance, and inference on spatial skills. Again, our focus is drawn to aspects of working memory and executive functioning more broadly, specifying their important role in successful spatial interactions (see also Davis et al., 2009; Meilinger et al., 2008; Nori et al., 2009).

General Discussion

The overall goal of this project was to specify the quality of wayfinding directions using effectiveness ratings and behavioral indices. A secondary goal was to examine how sense of direction and gender relate to wayfinding in an everyday, indoor environment. First, survey and route descriptors had an important impact on ratings of direction quality and behavioral indices of wayfinding efficiency, as we expected. In both studies, survey descriptors containing cardinal directions received low effectiveness ratings, whereas route directions containing left-right descriptors and landmarks (especially at choice points) received higher effectiveness ratings. These findings generally revealed higher effectiveness ratings for directions containing details consistent with a route perspective relative to a survey perspective, though the magnitude of difference was attenuated for people with a good self-reported sense of direction. Furthermore, descriptions containing more details tended to receive higher ratings, though this pattern was attenuated for people with a poor self-reported sense of direction when the additional details were cardinal directions. These findings suggest that people prefer multiple details in effective wayfinding directions, at least when memory demands can be managed so they can make use of the details. In Study 2, wayfinding was more efficient when following directions containing details consistent with a route perspective (left-right details and landmarks at choice points) relative to a survey perspective (cardinal directions and distances) regardless of self-reported sense of direction. That is, participants made fewer errors when following route descriptions than when following survey descriptions. Together, these results show not only a preference for descriptions from a route perspective but also better wayfinding efficiency following those descriptions. It is important to note that this pattern is consistent with findings from Denis et al. (1999).

One explanation for higher wayfinding efficiency when following route directions is based, in part, on environmental scale. In an indoor environment where navigation is dependent on finding appropriate hallways and knowing which direction to turn down these hallways, perhaps it is more beneficial to know particular routes than to know what cardinal direction to travel next (Lawton et al., 1996). Following descriptions via a route perspective may be more critical in this type of large indoor environment than in other environments, such as outdoors where more external cues are present to maintain orientation or in a model town where an extrinsic point of view is predominant.

It is also important to note the potential impact of task demands, particularly reliance on memory or external cues, in determining effectiveness. This key difference seems to explain why the present findings differ from those reported by Hund and Padgitt (2010) in which wayfinding efficiency in the same basement environment was more efficient using less desired directions. One key difference across studies was the method of direction presentation before and during wayfinding, which had clear impacts on cognitive resource demands such as working memory. In the Hund and Padgitt (2010) study, participants read the directions piece by piece during wayfinding, resulting in a low memory load. In contrast, the present study involved studying the written directions prior to wayfinding, relying on memory during the wayfinding process. These ideas are consistent with recent theoretical and empirical assertions regarding the importance of working memory for wayfinding (Davis et al., 2009; Meilinger et al., 2008; Nori et al., 2009).

For example, Meilinger et al. (2008) explored the importance of working memory in wayfinding using a dual task methodology. Participants learned two routes through a virtual environment while disrupted by a visual, spatial, verbal, or no secondary task. Then, they were asked to follow the routes again. All three secondary tasks interfered with wayfinding, though the effects were strongest for verbal and spatial tasks. The authors proposed that dual coding theory might explain these results (see also Paivio, 1971, 1986, 1991). That is, both spatial and verbal processing are important while wayfinding because details are coded in both formats. Unlike Paivio's focus on coding primarily verbal information also in spatial format, Meilinger and colleagues assert that spatial details are coded also in verbal format. This additional verbal coding adds durability and flexibility. Meilinger et al. further concluded that verbal memory is most important during wayfinding at points where a decision needs to be made. Perhaps this can explain why the route directions with more precise details about what to do at an intersection (e.g., descriptions of left-right turns coupled with choice-point landmarks) led to more accurate wayfinding than did survey directions with vague details about where to turn (e.g., descriptions of cardinal directions and distances that must be understandable to be useful). In general, the memory demands of survey directions might be greater because one must keep track of global orientation and individual position, rather than utilizing step-by-step descriptions of route segments and vistas in route directions (see Nori et al., 2009 for additional evidence supporting the importance of spatial working memory). Additional research probing the role of working memory processing during skillful wayfinding is warranted, perhaps examining both the type and number of details provided in the directions and the nature of learning and wayfinding.

Another important finding from this study is the key relation between self-reports of sense of direction and wayfinding. In Study 1, people with a good self-reported sense of direction gave higher effectiveness ratings to directions containing cardinal directions and distance and cardinal directions, distances, left-rights, and choice point landmarks than did people with a poor self-reported sense of direction. In Study 2, people with a good self-reported sense of direction provided higher effectiveness ratings and made fewer wayfinding errors than did people with a poor self-reported sense of direction, showing how important sense of direction is for successful wayfinding. As in previous studies, self-reports of sense of direction were positively correlated with orientation strategies and negatively correlated with route strategies. One limitation of these findings is that self-reports of sense of direction were utilized rather than performance-based measures such as angular estimates of locations. Nonetheless, these findings are consistent with the assumption that sense of direction is an inherent ability subject to stable individual differences. Interestingly, people's self-ratings of sense of direction are highly reliable predictors of spatial orientation and wayfinding performance (Hegarty, Montello, Richardson, Ishikawa, & Lovelace, 2006; Hund & Nazarczuk, 2009; Kato & Takeuchi, 2003; Kozlowski & Bryant, 1977; Prestopnik & Roskos-Ewoldsen, 2000; Sholl et al., 2000). This link probably results from the reliance on global orientation necessary for sense of direction and wayfinding, especially when using cardinal descriptors (Hund & Nazarczuk, 2009; Kato & Takeuchi, 2003; Kozlowski & Bryant, 1977; Lawton, 1996; Prestopnik & Roskos-Ewoldsen, 2000). This global sense depends on both the ability to construct configural (survey) models and to keep track of (i.e., update) one's current location in relation to such a model. It is possible that working memory is critical in integrating and tracking these spatial details. More research is needed to specify potential causal relations between working memory, sense of direction, and strategies with the goal of revealing important details about wayfinding processes. It is important to include performance-based measures in these future studies.

These findings do not mean that people with a poor sense of direction will always have more difficulty wayfinding. Hund and Nazarczuk (2009) demonstrated the importance of experience when they found that participants were more efficient wayfinders in an indoor environment after six training trials of following routes with cardinal directions in a model. Furthermore, people with a poor sense of direction can be accurate route followers. For instance, Hartley, Maguire, Spiers, and Burgess (2003) found that those who were not good wayfinders on novel routes could still accurately follow preordained routes after several practice trials. Although people with a poor sense of direction may be at a disadvantage finding their way through a new environment or deviating from a given path, they can overcome these shortcomings with training and preparation.

The present findings have important implications for everyday wayfinding, especially in complex indoor environments. The information about what descriptors led to the most effective wayfinding can be used to develop more effective GPS navigation systems and internet-based mapping/route planning services, striving to expand these services for complex indoor environments, such as hospitals and university buildings. In particular, incorporating left-right details and landmarks would be especially beneficial to wayfinders, whereas incorporating cardinal directions and distances would be less beneficial. Furthermore, in everyday situations in which someone is trying to provide wayfinding directions to a friend or family member, people could benefit from knowing that adopting a route perspective, including landmarks and left-right descriptions, when giving directions would lead to less difficulty than would adopting a survey perspective, including cardinal directions and distances, especially for listeners with a poor sense of direction. In general, people with a poor sense of direction can take appropriate precautionary measures to avoid getting lost, such as traveling a route the day before an important event, incorporating preparation and practice. Knowledge of spatial strategies and skills, including mental rotation, also could be informative as we strive to enhance spatial skills and encourage excellence in science, technology, engineering, and mathematics (STEM) domains, perhaps narrowing prominent contemporary cultural and gender gaps through a focus on spatial skills (e.g., Feng, Spence, & Pratt, 2007; Gilbert, 2005; Just & Carpenter, 1985; Shea, Lubinski, & Benbow, 2001; Terlecki, Newcombe, & Little, 2008; Wai, Lubinski, & Benbow, 2009). In these ways, our knowledge about the dynamic processes involved in spatial cognition can facilitate skillful wayfinding in everyday environments and successful STEM pursuits.

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Footnotes

[1] Familiarity ratings were not correlated with the variables of interest in this study (or Study 2), so familiarity was not included as a covariate in the analyses and will not be discussed further. In general, participants were relatively unfamiliar with the environment (Study 1: M = 1.68, SE = .13, Study 2: M = 2.06, SE = .10, with 1 indicating the lowest familiarity rating).

[2] An error in compiling description stimulus materials resulted in the inclusion of an incorrect detail in two trials (using cardinal descriptors and cardinal descriptors plus distance to describe the route from the research classroom suite to the elevators) for participants in Study 1. A similar error resulted in an incorrect cardinal descriptor for the first 18 participants in Study 2. Although the overall patterns of results were similar when including or excluding these trials, we present results omitting these trials to maintain a conservative approach.

Table 1

Descriptors in Study 1

Number Of Features	Descriptor(s) Included				
	Cardinal	Distance	Left-Right	Non-Choice Point Landmark	Choice Point Landmark
1	x				
1			x		
2	x	x			
2			x	x	
2			x		x
4	x	x		x	x
4	x	x	x		x