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The effects of sense of direction and training experience on wayfinding efficiency

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ABSTRACT

This study investigated the influence of sense of direction and training experience on wayfinding performance. Participants navigated through a scale model of a building using route descriptions containing left–right or cardinal descriptors, or they completed an unrelated personality questionnaire. All participants then navigated through the hallways of the same building using directions containing left–right and cardinal descriptors. Sense of direction was assessed by asking participants to identify the direction of familiar, unseen locations. Participants with a keen sense of direction evinced fewer errors and faster wayfinding than did participants with a poor sense of direction, particularly for directions containing cardinal descriptors. Moreover, participants in both training conditions evinced faster wayfinding than did participants in the control condition when following directions involving cardinal descriptors. These findings indicate that both sense of direction and training experience affect wayfinding performance. Implications for wayfinding experiences in everyday contexts are discussed.

1. Introduction

Finding the way from place to place is imperative for survival. Often, wayfinding involves using directions provided by another person or a map or model. For example, when trying to locate a tourist site or restaurant, one might ask the hotel staff for directions or consult a map (Allen, 1999). It is no great surprise that some people are more skilled than others at finding their way from place to place or that some people appear to know their exact location no matter the circumstances. However, is it possible for wayfinding ability to improve with increased experience? Does such improvement depend on sense of direction? One goal of this experiment was to examine whether training experience associated with a model environment influences wayfinding performance in an analogous large-scale environment. A second goal was to test the influence of sense of direction on wayfinding performance.

What is sense of direction, and how might we measure it? According to Kozlowski and Bryant (1977), sense of direction is "an awareness of location or orientation" (p. 178). Similarly, Sholl, Acacio, Makar, and Leon (2000) assert that sense of direction is "knowledge of the location and orientation of the body with respect to the large stationary objects, or landmarks, attached to the surface of the earth" (p. 17). One way to measure this orientation awareness is through self-report. For instance, Kozlowski and Bryant's sense of direction scale includes one question, "How good is your sense of direction?" and requires participants to respond using a Likert-type rating scale, with 1 representing "poor" and 7 representing "good." More recently, Hegarty, Montello, Richardson, Ishikawa, and Lovelace (2006) developed the 15-item Santa Barbara Sense of Direction Scale to assess this construct. In general, these researchers assume 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 wayfinding performance (Hegarty et al., 2006; Kato & Takeuchi, 2003; Kozlowski & Bryant, 1977; Prestopnik & Roskos-Ewoldsen, 2000; Sholl et al., 2000). For example, Prestopnik and Roskos-Ewoldsen (2000) assessed the extent to which sense of direction could be used to predict wayfinding ability. All participants completed a sense of direction scale. A subset of the participants imagined following 13 sets of directions with familiar starting points and destinations and were asked to indicate the direction of the starting location from each destination. As expected, sense of direction predicted wayfinding ability.

Likewise, Kozlowski and Bryant (1977) asked participants to report their sense of direction, their ability to give and follow directions, and their environmental exploration. Then, participants indicated the relative direction of five unseen locations on the circumference of a small circle. Finally, participants completed a partial drawing of a campus map by labeling several building locations and drawing arrows to indicate north and the direction of two familiar cities. As expected, the results yielded a significant

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positive correlation between self-reported sense of direction and spatial orientation. Additional analyses comparing participants reporting high and low senses of direction revealed that participants who rated themselves as having a good sense of direction pointed to unseen locations and two familiar cities more accurately than did participants who rated themselves as having a poor sense of direction. Together, these findings support the notion that sense of direction is related to spatial orientation.

Although countless studies have examined self-reported measures of sense of direction as an indicator of spatial skill (e.g., Bryant, 1982; Hegarty et al., 2006; Kato & Takeuchi, 2003; Kozlowski & Bryant, 1977; Prestopnik & Roskos-Ewoldsen, 2000), very little research has focused on behavioral measures of sense of direction, despite the recent assertion that the accuracy of pointing to unseen locations is a tractable measure of sense of direction (Sholl et al., 2000). Moreover, little is known about the empirical link between sense of direction and wayfinding. Thus, one goal of the present experiment was to determine the impact of sense of direction (measured via a behavioral orientation task) on wayfinding performance. A second goal was to specify how training experience influences wayfinding performance, particularly whether this influence depends on sense of direction.

What role does training experience play in shaping wayfinding efficiency? Gillner and Mallot (1998) sought to specify the influence of experience on wayfinding performance in a virtual maze. Participants saw target views of a virtual town and were asked to find these target views while navigating through the town. Participants made significantly more wayfinding errors when searching for the early target views than when searching for the later target views, illustrating a learning effect. However, good navigators (participants with smaller wayfinding errors), in contrast to poor navigators (participants with larger wayfinding errors), were more likely to transfer the spatial knowledge acquired from one route to the next route, resulting in fewer wayfinding errors as searching progressed (Gillner & Mallot, 1998). These findings indicate that increased experience with the environment improved wayfinding performance, though navigation prowess influenced the effects of experience on wayfinding performance. In another virtual environment study in which participants assumed the role of taxi drivers delivering passengers to stores, wayfinding improved significantly throughout the task, again indicating robust experience effects (Newman et al., 2007; see also Burigat & Chittaro, 2007). Similar work involving children revealed that both children and adults exhibit improvements in performance with experience, though children may require more experience than adults to reach comparable levels of performance (e.g., Jansen-Osmann & Fuchs, 2006). Moreover, a large study involving participants with visual impairments showed that campus wayfinding accuracy and efficiency improve with practice (Blades, Lippa, Golledge, Jacobsen, & Kitchin, 2002). Together, these findings reveal robust effects of experience on wayfinding performance.

Similar studies have examined the influence of sense of direction on the relation between experience and wayfinding performance using pointing tasks (Kozlowski & Bryant, 1977; Lawton, 1996; Magliano, Cohen, Allen, & Rodrigue, 1995; Moeser, 1988; Prestopnik & Roskos-Ewoldsen, 2000; Sholl et al., 2000). For example, Kozlowski and Bryant (1977) asked participants with good and poor senses of direction to walk through an underground maze of tunnels. After each of four trials, participants were asked to indicate the direction of the maze's endpoint. No significant difference in direction pointing accuracy appeared between participants with good and poor senses of direction after the first trial. However, participants with a good sense of direction significantly improved in direction pointing accuracy over the four trials (whereas participants with a poor sense of direction did not show such improvement), indicating that the learning effect depended upon sense of direction.

Sholl et al. (2000) found similar results in their study, in which they asked participants with good and poor senses of direction to pay attention to their surroundings during a drive to a park. At the park, participants completed a pre-test in which they were asked to point to the direction south and the direction of four landmarks. The experimenter indicated the correct direction of each target after the pre-test and then led participants to the path's end. At the endpoint, participants once again indicated the direction of the four landmarks and the starting point. In general, men with a good sense of direction and women with a poor sense of direction showed improved pointing task performance from the pre-test to the test phase. These findings indicate that the effect of training experience on wayfinding performance differs as a function of sense of direction and gender.

Although not a main focus of this investigation, gender differences are commonly reported in wayfinding studies and spatial cognition research more broadly. For instance, numerous studies have shown that men are more likely to report preferences for survey perspectives (e.g., cardinal directions and precise distances) than are women, whereas women are more likely to report preferences for route perspectives (e.g., landmarks) than are men (Galea & Kimura, 1993; Lawton, 1994; Prestopnik & Roskos-Ewoldsen, 2000; Saucier et al., 2002; Sholl et al., 2000; for a recent review, see Montello, Lovelace, Golledge, & Self, 1999). Similarly, Lawton (2001) found that when providing wayfinding directions, men included significantly more cardinal directions than did women (e.g., adopting a survey perspective), whereas women included significantly more left and right turns and landmarks than did men (e.g., adopting a route perspective). These findings suggest that similar gender differences emerge both when giving and following wayfinding directions. Additional findings have revealed robust gender differences in spatial performance across a number of tasks, particularly those involving mental rotation (MacFadden, Elias, & Saucier, 2003; Miller & Santoni, 1986; Pazzaglia & DeBeni, 2001; Ward, Newcombe, & Overton, 1986; for reviews, see Linn & Petersen, 1985; Voyer, Voyer, & Bryden, 1995). The present investigation will assess wayfinding performance among men and women to provide further clarity regarding gender differences.

The goal of the present study was to investigate the influence of training experience and sense of direction on wayfinding performance. In particular, we focused on the impact of training using a tabletop model of the basement of a complex university building on later wayfinding in the basement. We chose to examine the effect of training using a smaller-scale space (i.e., a tabletop space that is entirely viewable from one vantage point, usually an aerial/survey perspective) on wayfinding in the analogous large-scale space (i.e., a space that is not viewable from one vantage point and must be experienced over time, usually via a ground-level, route perspective) for conceptual and practical reasons. Conceptually, we assumed that the overlap in processes evoked by smaller- and large-scale spaces would facilitate training benefits across environmental scales. Practically, providing training using a small model and then measuring performance when wayfinding in a large space seems to be the most reasonable combination (see also Hunt, 1984). Although researchers are not in full agreement regarding the definitions of small- and large-scale spaces and the cognitive processes evoked by these spaces (Acredolo, 1981; Bell, 2002; Hegarty et al., 2006; Learmonth, Nadel, & Newcombe, 2002; Liben, 1988; Montello, 1993; Roskos-Ewoldsen, McNamara, Shelton, & Carr, 1998; Saucier et al., 2002; Weatherford, 1982, 1985), our contention is that the overlap in processes across scales would facilitate improvements in wayfinding in a large-scale space (e.g., a complex building) following training experience in an analogous smaller-scale space (e.g., a tabletop model).

In our experiment, participants were randomly assigned to one of two training conditions or a control condition. In the training conditions, participants followed sets of directions that contained either left–right or cardinal descriptors by moving a toy person from a starting location to a destination on a tabletop model of a complex building floor. Participants in the control condition completed an unrelated personality questionnaire. All participants took part in the test phase, during which they followed sets of directions containing both left–right (from a ground-level perspective and route orientation) and cardinal (from an aerial perspective and survey orientation) descriptors by walking through the hallways of the basement. To measure sense of direction, participants completed a circle-pointing task, in which they identified the direction of familiar, unseen locations in the building and on campus. We predicted that people who received any type of training experience would exhibit more efficient wayfinding (i.e., fewer errors, faster time) in the large-scale environment than would participants who did not receive any type of training experience. We also expected that people who exhibited a keen sense of direction would show more efficient wayfinding than would people who exhibited poorer sense of direction. In addition to these primary expectations, we also assessed the interactive influences of training experience, sense of direction, gender, and descriptor type on wayfinding efficiency, as well as the relation to spatial knowledge and self-reported sense of direction.

2. Method

2.1. Participants

Seventy-two undergraduate students (36 men, 36 women) from a midwestern university volunteered their participation in exchange for extra credit in psychology courses. Participants' ages ranged from 18 years 1 month to 41 years 9 months, with 20 years 3 months being the mean age of the sample. Data from 10 additional participants were excluded from final analyses because of incomplete data ($n = 3$), interrupted sessions ($n = 4$), experimenter error ($n = 2$), or equipment problems ($n = 1$).

2.2. Apparatus and materials

A model of a university building's basement was crafted from a 44 in. × 77.5 in. (111.76 cm × 196.85 cm) piece of white plywood (see Fig. 1). The basement's hallways were marked with blue tape, and its rooms were outlined and labeled in black. The plywood model was located on a table, providing easy access to the entire model. A 1.75-in. (4.45 cm) high × 0.75-in. (1.91 cm) wide plastic figurine was used during wayfinding within the model basement. A stopwatch was used by the experimenter to measure the duration of each wayfinding trial.

Booklets containing typed route directions on 3-in. × 5-in. (7.62 cm × 12.7 cm) note cards bound with 1-in. (2.54 cm) metal rings were used to aid wayfinding. Each route description included five to eight descriptive segments, each printed on a separate note card. The routes started at specified landmarks with given heading directions, contained four turns, and ended at specified landmark destinations. The test booklet contained 12 routes. Six of the routes included left–right descriptors ("Turn right and go until you see another hallway on the left…"), and the other six included cardinal descriptors (north, south, east, west; "Turn south and go until you see another hallway on the east…"). All participants followed the same 12 routes; however, the order of the routes was counterbalanced across participants, creating two orders.

Each of the four training booklets contained a subset of routes from the test booklet. In particular, each training booklet contained three routes presented twice for a total of six training trials. Two of the training booklets contained left–right descriptors, whereas the other two training booklets included cardinal descriptors. The particular training booklet used was counterbalanced across participants in each condition.

Participants indicated their direction estimates of landmark locations (five salient locations in the basement, such as the elevators, and five salient landmark buildings on campus, such as the library) using sheets of paper that included a printed outline of a circle with a dot indicating their current location and an arrow indicating their facing direction (Hegarty et al., 2006; Kozlowski & Bryant, 1977; Lawton, 1996; Lawton, Charleston, & Zieles, 1996; Magliano et al., 1995; Moeser, 1988; Montello, Richardson, Hegarty, & Provenza, 1999; Shelton & McNamara, 2004; Sholl et al., 2000). Participants also completed the Sense of Direction Scale to assess self-rated sense of direction with two questions (Pazzaglia & DeBeni, 2001). For example, participants responded to "Do you think you have a good sense of direction?" on a scale of 1 to 5, with 1 representing "not at all" and 5 representing "very much."

Participants in the control condition completed the Positive and Negative Affect Schedule (PANAS-X) personality questionnaire (Watson, Clark, & Tellegen, 1988). They indicated to what extent specific emotions (e.g., attentive, distressed, confident, tired) applied to them during the past few weeks on a Likert-type rating scale, with 1 representing "very slightly or not at all" and 5 representing "extremely."

2.3. Design and procedure

2.3.1. Training phase

Participants were randomly assigned to one of three training conditions: left–right, cardinal, or control. Participants in the left–right training condition followed sets of directions containing left–right descriptors, and participants in the cardinal training condition followed sets of directions containing north, south, east, and west descriptors. Participants were asked to use the written directions to "navigate" by moving a toy person from a starting location to a destination in the model basement. Participants in the control condition completed the PANAS personality questionnaire.

During the training phase of the left–right or cardinal conditions, participants stood at a location behind the model basement and faced north. The experimenter indicated which directions were north, south, east, and west. Then, participants were asked to read each set of directions in the training booklet, one segment at a time, and to move the toy person to follow the directions within the model basement. On each trial, participants began following the directions when the experimenter said, "Go," and stopped navigating when they reached the destination and read a note card that said, "Stop." This procedure was repeated for each of the six training trials.

2.3.2. Testing phase

All participants completed the testing phase. During this phase, participants followed 12 sets of directions by walking through the hallways of the basement. Participants followed the experimenter to the starting location within the basement. Before the first trial began, the experimenter indicated which directions were north, south, east, and west. Participants were asked to read each set of directions and follow the directions to a destination by walking through the hallways of the basement. They had access to the printed directions in the booklet throughout the trials, but only one piece of information was available at a time, requiring participants to keep track of their position in relation to the instructions in real time. This procedure was repeated for each of the 12 test trials.

2.3.3. Circle-pointing task

Participants followed the experimenter to a location within the basement that provided no visual access to inside landmarks or the outside environment (see Fig. 1). Participants faced a specified

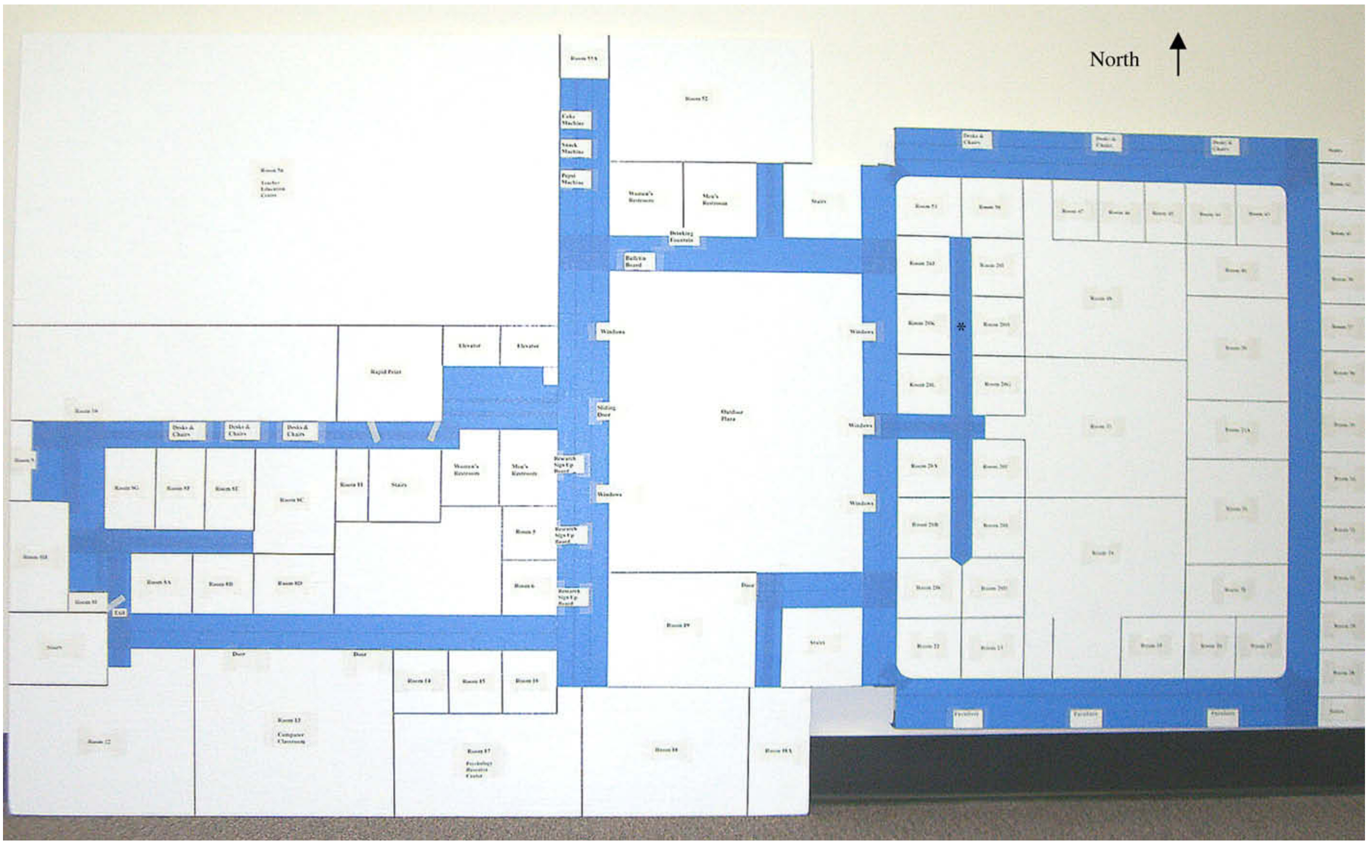

Fig. 1. Overhead view of the model of the basement used during training. The arrow indicates north, and the asterisk notes the location used for the circle-pointing task. These marks are for illustration purposes only.

direction (north, though participants were not told this detail) and were given two sheets of paper containing blank circles to be used to record their direction estimations. Participants were told that the point in the middle of the circle indicated their location and the arrow on the circumference of the circle indicated the direction that they were facing. They were asked to draw a dot on the circumference of the circle indicating the relative direction of 10 specific landmarks listed on the paper. One sheet of paper listed five landmarks that were situated within the basement (i.e., vending machines, elevators, computer classroom, large classroom, and laboratory). The second sheet of paper listed five buildings in the outside environment that were located within close proximity to the university building (i.e., university library, business building, football stadium, residence hall towers, and restaurant).[1]

2.4. Coding and measures

2.4.1. Wayfinding testing phase

Wayfinding errors (i.e., turning the wrong way at the correct hallway, entering the wrong hallway or doorway, retracing the path, stopping at the wrong destination, stopping within clear sight of the correct destination, and quitting) were noted for each trial. The total number of errors was averaged across the left–right test trials and the cardinal test trials. Wayfinding times for each trial were measured to the nearest millisecond. Timing began when the experimenter said, “Go,” and ended when the participant said, “Stop.” Wayfinding times also were averaged across the left–right test trials and the cardinal test trials.

2.4.2. Circle-pointing task

Participants' direction estimates of landmarks were recorded by calculating the angular error in degrees. The experimenter measured the participants' direction estimates (to the nearest degree) using a protractor. Angular error for each landmark was computed by determining the absolute value of the difference between the correct angular position of the landmark and the estimated angular position of the landmark. The angular errors for the direction estimates were averaged across all 10 landmarks (i.e., absolute error, see Wang & Spelke, 2000), providing a global measure of sense of direction. Although previous research has found differences in participants' ability to maintain their orientation in relation to local and global landmarks (e.g., Wang & Brockmole, 2003), we found no such differences, $F(1, 71) = 0.47$, *ns*, $\eta^2_p = 0.01$; thus, we averaged responses from all 10 landmarks to provide a stable measure of sense of direction. In addition, the standard deviation of the angular errors was calculated to determine relative accuracy, providing a measure of location knowledge independent of orientation (see Wang & Spelke, 2000 for details). Again, we found no significant differences in participants' knowledge of local and global landmark locations, though there was a trend for building landmarks to be more accurate than campus landmarks, $F(1, 71) = 3.00$, $p = 0.088$, $\eta^2_p = 0.04$. As above, we combined responses from all 10 landmarks to provide a robust measure of spatial knowledge.

[1] Pointing judgments were obtained from one location within the basement in this study. In future research, it would be beneficial to assess such judgments from multiple locations. It would also be beneficial to assess the effect of previous judgments (or access to those judgments on the rating sheet) on subsequent judgments. Although it is possible that previous judgments distort or homogenize subsequent judgments, the wide range of errors obtained here lead us to believe that these effects did not unduly hinder measurement of sense of direction and spatial knowledge more generally. Thus, we conclude that the present method was reliable given the goals of this study.

3. Results

3.1. The effects of sense of direction and training experience

The main purpose of the present experiment was to examine the influence of sense of direction and training experience on wayfinding performance. We predicted that people who received training experience in the tabletop model would show greater efficiency (i.e., fewer errors, faster times) when finding their way using directions within the basement than would people who did not receive training experience. We also predicted that people with a keen sense of direction (assessed via absolute angular error in a direction pointing task) would perform more efficiently during wayfinding than would people with a poor sense of direction. To test this latter claim, we used a median split (median absolute orientation error = 46.85°) to divide our sample into a good sense of direction group ($n = 36$) and a poor sense of direction group ($n = 36$).

3.1.1. Wayfinding errors

To examine the effects of training experience, sense of direction, and gender on wayfinding performance, mean wayfinding errors were entered into a Training Experience (left–right vs. cardinal vs. control) × Sense of Direction (good vs. poor) × Gender (women vs. men) × Test Trial Type (left–right vs. cardinal) mixed model Analysis of Variance (ANOVA).[2] This analysis yielded a significant main effect of test trial type, $F(1, 60) = 48.91$, $p < 0.001$, $\eta^2_p = 0.45$. Participants exhibited significantly fewer errors when following directions containing left–right descriptors ($M = 1.24$, SE = 0.35) than when following directions containing cardinal descriptors ($M = 6.42$, SE = 0.62). In addition, the analysis yielded a significant main effect of sense of direction, $F(1, 60) = 18.12$, $p < 0.001$, $\eta^2_p = 0.23$. Participants with a keen sense of direction exhibited fewer wayfinding errors ($M = 2.40$, SE = 0.46) than did participants with a poor sense of direction ($M = 5.25$, SE = 0.49). These main effects were subsumed by a significant Sense of Direction × Test Trial Type interaction, $F(1, 60) = 4.45$, $p < 0.05$, $\eta^2_p = 0.07$. Tests of simple effects revealed that participants with a keen sense of direction exhibited fewer wayfinding errors than did participants with a poor sense of direction on trials containing cardinal descriptors, $F(1, 70) = 20.08$, $p < 0.001$, $\eta^2_p = 0.22$, and trials containing left–right descriptors, $F(1, 70) = 5.13$, $p < 0.05$, $\eta^2_p = 0.07$, though the magnitude of difference was smaller for trials containing left–right descriptors (see Fig. 2).

The analysis also yielded a significant Training Condition × Test Trial Type interaction, $F(2, 60) = 3.21$, $p < 0.05$, $\eta^2_p = 0.10$. Tests of simple effects revealed that errors during wayfinding in the basement differed across training conditions when directions contained cardinal descriptors, $F(2, 69) = 5.35$, $p < 0.01$, $\eta^2_p = 0.13$, but not when the directions contained left–right descriptors, $F(2, 69) = 1.82$, *ns*, $\eta^2_p = 0.05$. In particular, when following directions containing cardinal descriptors within the basement, participants in the cardinal training condition ($M = 4.76$, SE = 1.16) exhibited significantly fewer wayfinding errors than did participants in the control condition ($M = 8.42$, SE = 1.06). Wayfinding errors for participants in the left–right training condition ($M = 6.07$, SE = 0.98) did not differ from those for participants in the other two conditions. When following directions containing left–right descriptors, wayfinding errors did not differ across training conditions, perhaps because the overall number of errors was quite low (see Fig. 3).

[2] Preliminary analyses revealed no differences in wayfinding time or errors across new and old routes (i.e., routes experienced during training) for participants in either training condition, so this variable was not considered further.

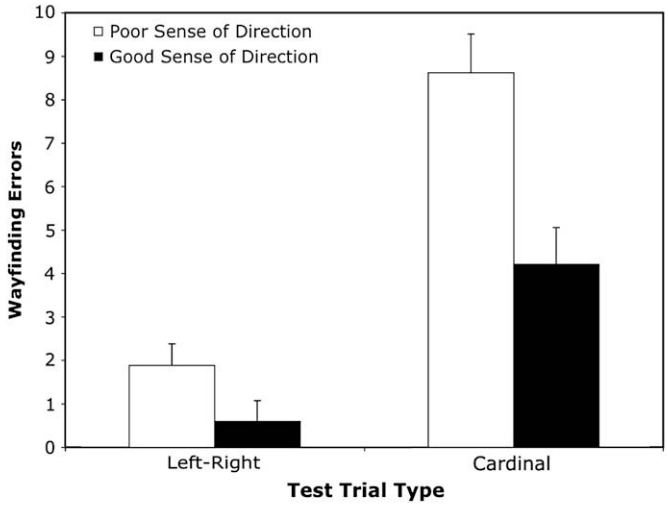

Fig. 2. Wayfinding errors when following directions containing left–right or cardinal descriptors for participants with good and poor senses of direction.

3.1.2. Wayfinding time

To further examine the effects of training experience, sense of direction, and gender on wayfinding performance, mean wayfinding time was entered into a Training Experience (left–right vs. cardinal vs. control) × Sense of Direction (good vs. poor) × Gender (women vs. men) × Test Trial Type (left–right vs. cardinal) mixed model ANOVA. This analysis yielded a significant main effect of test trial type, $F(1, 60) = 19.47$, $p < 0.001$, $\eta^2_p = 0.25$. Participants exhibited significantly faster wayfinding when following directions containing left–right descriptors ($M = 66.34$ s, SE = 1.83) than when following directions containing cardinal descriptors ($M = 75.92$, SE = 2.03). In addition, the analysis yielded a marginally significant main effect of sense of direction, $F(1, 60) = 3.20$, $p = 0.079$, $\eta^2_p = 0.05$. Participants with a keen sense of direction exhibited faster wayfinding ($M = 68.27$ s, SE = 2.21) than did participants with a poor sense of direction ($M = 73.99$ s, SE = 2.32). These main effects were subsumed by a marginally significant Sense of Direction × Test Trial Type interaction, $F(1, 60) = 3.29$, $p = 0.075$, $\eta^2_p = 0.05$. Tests of simple effects revealed that

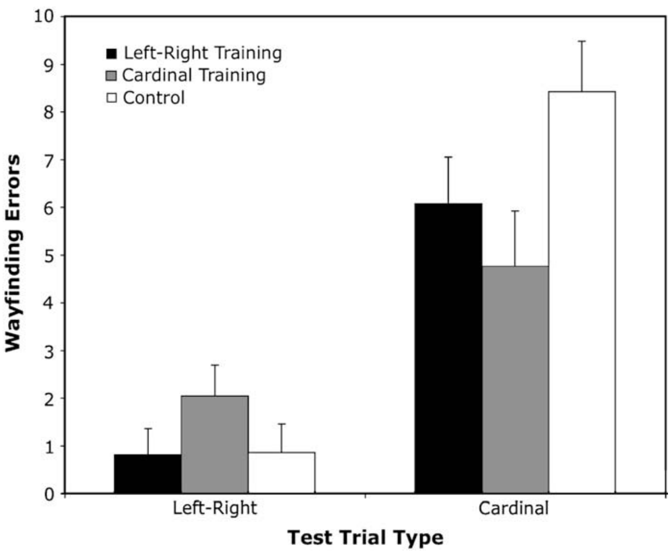

Fig. 3. Wayfinding errors when following directions containing left–right or cardinal descriptors for participants in the left–right, cardinal, and control training conditions.

participants with a keen sense of direction exhibited faster wayfinding than did participants with a poor sense of direction on trials containing cardinal descriptors, $F(1, 70) = 8.16$, $p < 0.01$, $\eta^2_p = 0.10$, but not on trials containing left–right descriptors, $F(1, 70) = 0.36$, *ns*, $\eta^2_p = 0.01$ (see Fig. 4).

The analysis also yielded a marginally significant Training Condition × Test Trial Type interaction, $F(2, 60) = 2.84$, $p = 0.066$, $\eta^2_p = 0.09$. Tests of simple effects revealed that wayfinding time in the basement differed across training conditions when directions contained cardinal descriptors, $F(2, 69) = 6.55$, $p < 0.01$, $\eta^2_p = 0.16$, but not when the directions contained left–right descriptors, $F(2, 69) = 1.77$, *ns*, $\eta^2_p = 0.05$. In particular, when following directions containing cardinal descriptors within the basement, participants in the cardinal training condition ($M = 70.84$ s, SE = 3.82) and the left–right training condition ($M = 73.32$ s, SE = 3.23) exhibited significantly faster wayfinding than did participants in the control condition ($M = 83.62$ s, SE = 3.49). When following directions containing left–right descriptors, wayfinding time did not differ across training conditions (see Fig. 5). Overall, this pattern of results closely parallels findings from analyses of wayfinding errors, providing further support for the notion that sense of direction and training experience affect wayfinding efficiency, particularly when following directions containing cardinal descriptors.

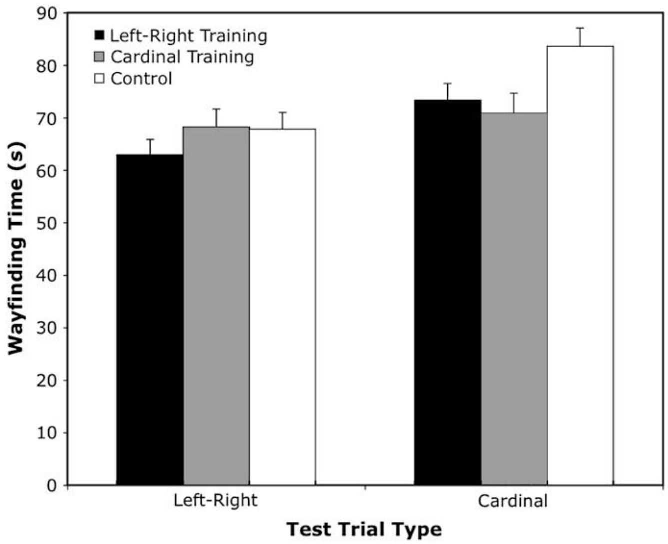

Fig. 5. Wayfinding time when following directions containing left–right or cardinal descriptors for participants in the left–right, cardinal, and control training conditions.

3.2. *The effect of spatial knowledge*

To determine whether acquired spatial knowledge (i.e., knowing the relative locations of landmarks) played a different role than inherent sense of direction ability (i.e., inherent orientation), we assessed the effect of relative accuracy of landmark locating on wayfinding performance. Given this focused goal, only effects involving spatial knowledge are reported. We expected that the overall pattern of results would closely mirror those reported above for absolute accuracy (sense of direction), indicating a tight coupling between spatial knowledge and sense of direction ability. We used a median split (median relative error = 60.12°) to divide our sample into a high knowledge group ($n = 36$) and a low knowledge group ($n = 36$).

3.2.1. *Wayfinding errors*

Mean wayfinding errors were entered into a Training Experience (left–right vs. cardinal vs. control) × Spatial Knowledge (high vs. low) × Gender (women vs. men) × Test Trial Type (left–right vs. cardinal) mixed model ANOVA. This analysis yielded a significant main effect of spatial knowledge, $F(1, 60) = 13.24$, $p < 0.01$, $\eta^2_p = 0.18$. Participants with more accurate knowledge exhibited fewer wayfinding errors ($M = 2.73$, SE = 0.47) than did participants with less accurate knowledge ($M = 5.18$, SE = 0.48). This main effect was subsumed by a significant Spatial Knowledge × Test Trial Type interaction, $F(1, 60) = 9.17$, $p < 0.01$, $\eta^2_p = 0.13$. Tests of simple effects revealed that participants with more accurate knowledge exhibited fewer wayfinding errors than did participants with less accurate knowledge on trials containing cardinal descriptors, $F(1, 70) = 18.43$, $p < 0.001$, $\eta^2_p = 0.21$, but not on trials containing left–right descriptors, $F(1, 70) = 1.46$, *ns*, $\eta^2_p = 0.02$.

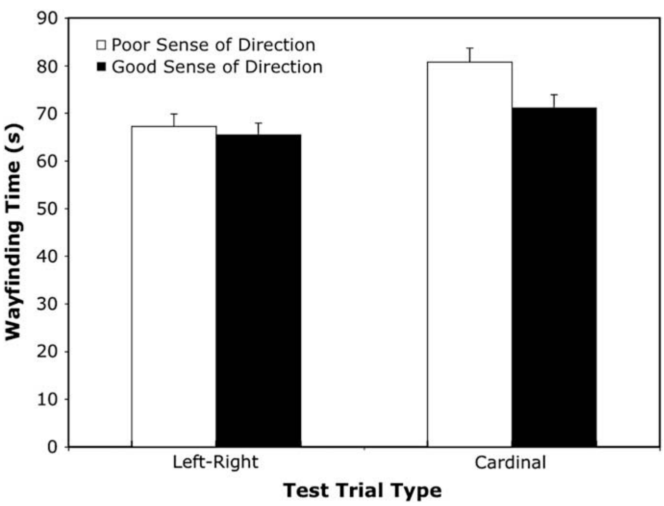

Fig. 4. Wayfinding time when following directions containing left–right or cardinal descriptors for participants with good and poor senses of direction.

3.2.2. *Wayfinding time*

To further examine the effects of spatial knowledge on wayfinding performance, mean wayfinding time was entered into a Training Experience (left–right vs. cardinal vs. control) × Spatial Knowledge (high vs. low) × Gender (women vs. men) × Test Trial Type (left–right vs. cardinal) mixed model ANOVA. The analysis yielded a significant Spatial Knowledge × Test Trial Type interaction, $F(1, 60) = 6.62$, $p < 0.05$, $\eta^2_p = 0.10$. Tests of simple effects revealed that participants with more accurate spatial knowledge exhibited faster wayfinding than did participants with less accurate knowledge on trials containing cardinal descriptors, $F(1, 70) = 6.29$, $p < 0.05$, $\eta^2_p = 0.08$, but not on trials containing left–right descriptors, $F(1, 70) = 0.01$, *ns*, $\eta^2_p = 0.00$. Overall, this pattern of results closely parallels findings from the analyses of sense of direction reported above, indicating a tight link between general sense of direction abilities and acquired spatial knowledge regarding a particular environment. Moreover, training condition had no impact on spatial knowledge or sense of direction, all Fs $(2, 69) < 1.02$, *ns*, $\eta^2_p < 0.02$, further bolstering our claim that pointing accuracy can be used to assess general sense of direction ability.[3]

[3] Although it might be surprising that spatial knowledge did not vary across training conditions (particularly when comparing the control condition to the training conditions), it is possible that the wayfinding experience acquired during the testing phase ameliorated knowledge effects based on training. From our perspective, the most important finding was that sense of direction did not differ based on training experience, lending support to the notion that it is an inherent ability.

3.3. The relations between sense of direction, spatial knowledge, and wayfinding

Correlations were used to assess the relations between sense of direction, spatial knowledge, and wayfinding performance. In addition, self-reported sense of direction (using a 2-item scale from adapted from Pazzaglia & DeBeni, 2001) was included to provide a broader view of sense of direction. As can be seen in Table 1, sense of direction and spatial knowledge (errors) were significantly positively correlated with each other, lending further support to our contention that these constructs are tightly linked. Both measures also were positively correlated with the number of errors exhibited during wayfinding (i.e., as orientation or knowledge errors increased, so did wayfinding errors). In addition, sense of direction (error) was significantly positively correlated with wayfinding time (i.e., as sense of direction error increased, so did wayfinding time). Finally, wayfinding time and errors were positively correlated. The lack of relations between self-reported sense of direction and the other variables is surprising and warrants further investigation, perhaps using expanded self-report (i.e., Santa Barbara Sense of Direction Scale, Hegarty et al., 2006) and behavioral measures.

4. Discussion

One purpose of this experiment was to examine the effect of training experience on wayfinding efficiency. As expected, participants in the cardinal training condition made fewer wayfinding errors than did participants in the control condition when following directions involving cardinal descriptors. Participants in both the cardinal and the left–right training conditions evinced faster wayfinding than did participants in the control condition when following directions involving cardinal descriptors. Wayfinding time did not differ as a function of training condition when following directions involving left–right descriptors. Together, these findings suggest that training experience affects wayfinding performance, particularly when cardinal descriptors are used. These findings confirm that training experience using a tabletop model facilitates wayfinding efficiency during a later test phase involving the corresponding large-scale environment (see also Gillner & Mallot, 1998; Hunt, 1984; Kozlowski & Bryant, 1977; Moeser, 1988; Sholl et al., 2000).

It is interesting to note that experience with a model of the environment enhanced wayfinding performance within the corresponding large-scale environment. These findings suggest that participants who received training experience "navigating" to destinations within a model of the basement were able to acquire spatial information about the environment and subsequently, use the acquired spatial information to enhance their wayfinding performance during the test phase (i.e., when navigating through the actual basement). This transfer of spatial information between two different scales is consistent with previous theoretical and empirical claims that similar cognitive processes occur across different environmental scales (Cohen & Weatherford, 1981; Hegarty et al., 2006; Siegel, Herman, Allen, & Kirasic, 1979; Weatherford, 1982). For instance, interacting with spaces of both scales involves keeping track of spatial relations between objects (Acredolo, 1981). Thus, small- and large-scale spatial abilities appear to share characteristics, and therefore, are said to overlap partially (Hegarty et al., 2006; Weatherford, 1982). The present findings add further support to the general conclusion that people demonstrate similar spatial abilities across various environmental scales.

These similarities, however, do not mean that spatial skills related to interacting with small- and large-scale spaces are completely overlapping. Aside from the obvious differences in size (Roskos-Ewoldsen et al., 1998), there are other differences between environmental scales to consider. One important difference is that people interact with information differently in large-scale spaces than they do in small-scale spaces, and the way in which people need to respond to the space is different (Acredolo, 1981; Bell, 2002). For example, using a finger to trace a route on a map or model involves using different motor movements than would be needed to walk to the destination. Another difference in environmental scale is the perspective from which it can be viewed. A map or model can be viewed entirely from one vantage point (e.g., an orientation perspective), whereas a large-scale building must be viewed from multiple vantage points, often through navigation, to be integrated (e.g., a route perspective; Lawton, 1996; Montello, Hegarty, Richardson, & Waller, 2004; Presson, DeLange, & Hazelrigg, 1989; Shelton & McNamara, 2004; Taylor & Tversky, 1996; Thorndyke & Hayes-Roth, 1982). This creates limitations in small-scale environments because they are not experienced via wayfinding, but rather only viewed from an outside perspective (Weatherford, 1982). On the other hand, the benefit of small-scale spaces is that they can be viewed entirely from one vantage point, thereby reducing the amount of information people need to hold in memory and facilitating the integration of information across local areas and over time (Acredolo, 1981; Thorndyke & Hayes-Roth, 1982). Previous findings have revealed advantages for map learners, relative to route learners, for orientation and straight-line judgments. Conversely, route learners exhibited superior imagined orientation and route distance judgments when compared to map learners (Thorndyke & Hayes-Roth, 1982). These findings suggest that map learning leads to survey knowledge suitable for determining global spatial relations, whereas route learning leads to procedural knowledge regarding the route, which may be integrated with repeated experience. The present findings extend these claims by revealing that map learning can be utilized for route navigation, at least given the present learning and testing circumstances.

Another goal of this investigation was to specify the impact of sense of direction on wayfinding efficiency. The present findings confirmed that participants with a keen sense of direction evinced fewer errors and faster wayfinding than did participants with a poor sense of direction, particularly for directions containing cardinal descriptors. These findings add further support to the notion that sense of direction impacts wayfinding efficiency (Kato & Takeuchi, 2003; Kozlowski & Bryant, 1977; Magliano et al., 1995; Moeser, 1988; Prestopnik & Roskos-Ewoldsen, 2000; Sholl et al., 2000). Moreover, they point out the tight link between sense of

Table 1
Correlations between sense of direction, spatial knowledge, and wayfinding performance.

	1	2	3	4	5
(1) Sense of direction (SoD)	–	0.77***	−0.13	0.47***	0.24*
(2) Spatial knowledge		–	−0.18	0.46***	0.19
(3) Self-report SoD			–	−0.12	−0.13
(4) Wayfinding errors				–	0.56***
(5) Wayfinding time					–

Note. $N = 72$. *$p < 0.05$; ***$p < 0.001$.

direction and wayfinding in general and wayfinding using cardinal descriptors. This link probably results from the reliance on global orientation necessary for both sense of direction and wayfinding using cardinal descriptors (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. Moreover, our results indicate that the overall pattern of findings for spatial knowledge (relative sense of direction—knowledge of landmark locations without regard to orientation) closely parallel those for sense of direction, indicating a tight link between these constructs. It is important to note that our findings are among the first to use a behavioral measure of sense of direction, assessing people's pointing errors when indicating the angular locations of salient (unseen) landmarks. Moreover, this experiment assessed wayfinding efficiency directly, rather than using a general measure of spatial skill or a self-report measure of wayfinding experiences or preferences. We view this approach as a promising one for providing details about the mechanisms underlying skillful wayfinding. Nonetheless, future research is needed to further specify the impact of sense of direction on wayfinding. Moreover, future theoretical and empirical work is needed to further clarify the origins, conceptual nature, and sequalae of sense of direction, as well as its measurement in behavioral and self-report contexts. It is particularly important to specify the extent to which sense of direction is an inherent skill or ability versus content knowledge acquired through experience. Our contention is that both aspects are important and linked in nontrivial ways, mirroring general trends in the state vs. trait debate in personality psychology (for details regarding state vs. trait anxiety, see King, Heinrich, Stephenson, & Spielberger, 1976; Spielberger, 1972, 1983).

The present results did not reveal differences in wayfinding performance for men and women. There were no main effects or interactions involving gender in any of the analyses, lending little support to commonplace notions that men and women exhibit different patterns of wayfinding preferences and performance (e.g., women are more efficient wayfinders when following left–right directions and men are more efficient wayfinders when following cardinal directions; Galea & Kimura, 1993; Lawton, 1994, 2001; Prestopnik & Roskos-Ewoldsen, 2000; Saucier et al., 2002; Sholl et al., 2000; for reviews, see Linn & Petersen, 1985; Montello et al., 1999; Voyer et al., 1995). It is possible that the lack of difference here stems from differences in task demands. That is, perhaps gender differences are nearly non-existent in wayfinding tasks involving following written directions, given the task demands are very different from mental rotation tasks that have traditionally yielded the most pronounced gender differences. Future research is needed to clarify this issue.

Interestingly, the effects of training experience and sense of direction on wayfinding efficiency were most pronounced when participants used directions containing cardinal descriptors to find their way through the basement. This suggests that a more keen sense of direction is needed to follow directions involving cardinal descriptors. This pattern of findings confirms the notion that using cardinal descriptors to interact with an environment relies on a survey perspective that integrates spatial details in relation to a global frame of reference, such as cardinal directions (Golledge, 1999; Hirtle & Hudson, 1991; Lawton, 1996; Pazzaglia & DeBeni, 2001; Shelton & Gabrieli, 2002; Shelton & McNamara, 2004; Siegel & White, 1975; Taylor & Tversky, 1996). Moreover, these findings indicate that training experience is most beneficial in cases where performance is difficult (i.e., cases requiring finding the way using an integrated, survey perspective). This suggests that perhaps efforts to facilitate wayfinding and to intervene to improve wayfinding skills should focus on cardinal descriptors and survey perspectives. Nonetheless, experience using well-designed signs and aligned you-are-here maps (in concert with reasonable layouts and numbering schemes) also are beneficial, building on people's wayfinding strengths (Butler, Acquino, Hissong, & Scott, 1993; Hölscher, Meilinger, Vrachliotis, Brösamle, & Knauff, 2006; Levine, Marchon, & Hanley, 1984).

These findings concerning the effects of training experience on wayfinding efficiency have important implications for industry settings where skillful wayfinding is required (e.g., law enforcement, transportation), as well as education settings aimed at fostering skillful wayfinding (e.g., schools, museums) and everyday settings requiring wayfinding (e.g., shopping centers, tourist areas). It is encouraging to know that people benefit from practicing their wayfinding skills, though the generalizability and temporal limits of such practice are not known. Moreover, the fact that practice involving a tabletop model was applicable to later wayfinding in the analogous large-scale environment increases the feasibility of such practice or training (see also Hunt, 1984). Certainly, it is often more practically tractable to use small models, maps, or virtual representations to facilitate such training, as opposed to practicing finding the way through large environments. Additional research is needed to assess the impact of maps and virtual representations, as well as to test the limits of transfer and generalizability across settings (see Farrell et al., 2003; Newman et al., 2007). Moreover, additional developmental research is needed to specify the impact of training across childhood (see Jansen-Osmann & Fuchs, 2006). Nonetheless, these findings provide important evidence regarding the feasibility of such work.

In summary, the present findings demonstrated the influence of training experience, sense of direction, and direction type on wayfinding efficiency. People who received training experience navigated more efficiently than did people who received no training experience. In addition, people who reported a keen sense of direction were more efficient wayfinders, particularly when following directions containing cardinal descriptors. Finally, participants navigated more efficiently when following left–right directions than when following cardinal directions. These findings clearly indicate that training using a tabletop model environment can enhance wayfinding performance. Nonetheless, future research is needed to further specify the degree to which specific individual and environmental factors shape wayfinding abilities.

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