Sex-Specific Relationships Between Route-Learning Strategies and Abilities in a Large-Scale Environment
Jean Choi, Erin McKillop, Michele Ward and Natasha L'Hirondelle

*Environment and Behavior* 2006; 38; 791
DOI: 10.1177/0013916506287004

The online version of this article can be found at:
http://eab.sagepub.com/cgi/content/abstract/38/6/791
SEX-SPECIFIC RELATIONSHIPS BETWEEN ROUTE-LEARNING STRATEGIES AND ABILITIES IN A LARGE-SCALE ENVIRONMENT

JEAN CHOI is an assistant professor in the Department of Psychology at the University of Lethbridge. She has a PhD in experimental psychology from York University. Her research interests include the evolution of spatial behavior.

ERIN MCKILLOP received her BA in psychology at the University of Lethbridge. She is currently pursuing her MEd in school and counseling psychology at the University of Saskatchewan.

MICHEAL WARD received his BA in psychology at the University of Lethbridge and BSW at the University of Calgary.

NATASHA L’HIRONDELLE received her BA in psychology at the University of Lethbridge. She is currently pursuing her LLB at the University of Alberta.

ABSTRACT: Spatial theories identify three aspects of the environment that are used to various degrees in route-learning tasks; namely, landmarks, routes, and configurations. Although research has demonstrated sex differences in the relative predominance of each aspect in route-learning strategies, it is unclear how these sex differences correspond to route-learning abilities in a large-scale environment. The present experiment addresses this void by examining route-learning abilities in an indoor environment. Participants are taken through an unfamiliar route and instructed to find the point of origin using one of three strategies: (a) direct, (b) retrace,
and (c) choice. Results reveal sex differences in route-learning abilities in the direct condition. Furthermore, a landmark-biased strategy is used more by females and is associated with better route-learning abilities. The same relationship is not found in males. These findings suggest that sex-specific patterns of relationships exist between strategy use and route-learning abilities.

**Keywords:** sex difference; route-learning strategies; spatial abilities

**Spatial sex differences** have been studied for decades and are well established in the literature (Halpern, 2000). Greater focus has turned recently to an application of spatial abilities; namely, route-learning strategies. Based on evidence from self-reports, direction-giving paradigms, and computer simulation, distinctive strategies used by males and females have been found (e.g., Choi & Silverman, 1996, 2003; Lawton, 1994, 1996; Sandstrom, Kaufman, & Huettel, 1998). Despite this growing body of literature on sex differences in route-learning strategies, there remains little empirical evidence for corresponding behaviors in a large-scale environment. Furthermore, although the relative predominance of each strategy is presumed to reflect route-learning abilities and spatial abilities in general, the nature of the relationships remains tenuous. The present experiment sought to address this void by investigating the relationships among sex, strategy use, and route-learning abilities.

Spatial theories (e.g., Siegel & White, 1975) have identified distinguishable strategies comprising, to various degrees, landmarks, routes, and configurations, which are organized hierarchically and based on experience with the environment. This hierarchical model presumes that a landmark-based strategy emerges first in a novel environment; with repeated exposure to the environment, the landmark-biased strategy is replaced by a route strategy, in which landmarks are connected to form individual routes. Finally, with continued exposure to the environment, a strategy consisting of the spatial configuration of the environment emerges, which supersedes landmark and route information. Inherent to the hierarchical model is the assumption that the use of differential strategies reflects general differences in route-learning abilities; the ability to incorporate configuration, for example, emerges with the attainment of more sophisticated spatial knowledge of the environment, whereas it is presumed that a landmark-dominant strategy reflects less sophisticated route-learning abilities relative to a strategy based on configurations.

Adult males and females have been found to use different cues in the environment resulting in strategies similar to those described by the hierarchical model. However, in contrast to the hierarchical model, sex differences in
strategy use emerge irrespective of experience with the environment (Choi & Silverman, 1996, 2003; Dabbs, Chang, Strong, & Milun, 1998; Lawton, 1994, 1996; Rahman, Andersson, & Govier, 2005). Females show a greater tendency to use landmarks and relative directions, whereas males use more cardinal directions and distances, a pattern that has been replicated cross-culturally (Lawton & Kallai, 2002). In a direction-giving paradigm, for example, females were more likely to refer to landmarks and their relative positions, whereas males were more likely to refer to distances and cardinal directions when asked to learn routes from a novel map (Choi & Silverman, 1996). These findings are analogous to those found with Lawton’s (1994) self-report wayfinding strategy scale. More males report using an orientation strategy, comprising one’s position in the environment and using the most direct route to the point of origin; females, in contrast, describe using a route strategy, consisting of relative locations of landmarks (Lawton, 1994).

Despite converging evidence for strategy sex differences, the relationships among sex, route-learning strategies, and route-learning abilities in a large-scale environment remain tenuous; specifically, it is unclear whether sex differences in strategy use correspond to route-learning abilities in a large-scale environment. There is some indirect evidence to suggest that strategy differences emanate from differences in the abilities to use them; males, for instance, have been found to be better able to use an orientation strategy in a large-scale environment (Lawton, 1994; Silverman et al., 2000). However, there is no comparable evidence for female superiority in the use of a route-based strategy in a large-scale environment. Given that males’ orientation strategy corresponds to their greater abilities to use this strategy in a large-scale environment, it is plausible that females’ reported propensity to use a route-based strategy is due to their greater abilities to use it.

The purpose of the present experiment was to investigate the relationships among sex, strategy use, and route-learning abilities in a large-scale environment. We examined males’ and females’ abilities to use strategies requiring configuration and route knowledge and explored possible sex differences in the spontaneous use of strategies when no explicit instructions are given. It was expected that males would excel when required to use a configuration-based strategy and females would excel when required to use a route-based strategy and that males and females would spontaneously use configuration-based and route-based strategies, respectively. Sex differences in the use of environmental cues were also expected. It was predicted that females would use landmarks and relative directions to a greater extent, and based on the hierarchical model, greater landmark use would be related
to poorer route-learning abilities in a large-scale environment. A battery of paper-and-pencil cognitive tasks consisting of mental rotation and waterline tasks, two commonly used spatial measures, were used to assess general spatial abilities. An advanced vocabulary task, a measure of general intelligence, was also administered.

**METHOD**

**PARTICIPANTS**

Sixty females and 45 males were recruited from introductory psychology courses at the University of Lethbridge. The mean ages for females ($M = 21.55$, $SEM = .62$) and males ($M = 23.48$, $SEM = 1.08$) did not differ significantly. All participants received course credit for participation.

**MATERIALS AND PROCEDURE**

All participants were tested individually. The session consisted of two main segments: the route task and a battery of cognitive tasks. The order of the two segments was counterbalanced within condition and sex. The route task required the participant to follow the experimenter through an indoor route in the arts wing of a building at the University of Lethbridge. In the middle of the route, each participant was asked to lead the experimenter back to the point of origin. Prior to scheduling, all prospective participants were asked a series of screening questions to ensure minimal experience with the wing of the building.

**Route Task**

Participants were randomly assigned to one of three route conditions: direct ($n_F = 20$, $n_M = 15$), retrace ($n_F = 20$, $n_M = 15$), and choice ($n_F = 20$, $n_M = 15$). Participants in the direct condition were required to lead the experimenter back to the point of origin using the most direct route. Those in the retrace condition were required to lead the experimenter back to the point of origin using the original route. Participants in the choice condition were required to lead the experimenter back to the point of origin using any route that he or she chose. The distance of the route taken by the participant was recorded in the direct and choice route condition, and the sum of the frequencies of hesitations...
and redirects comprised the score in the retrace condition. Hesitations were defined by the number of full stops made by the participants, and redirects were defined by the number of the experimenter’s interventions when wrong turns were taken.

To ascertain the extent to which participants retraced the original route, the route was divided into 14 segments, each bracketed by a turn at the beginning and end of the segment. The number of segments of the original route used by the participants was calculated only in the direct and choice conditions, given that all of the participants in the retrace condition were redirected, when necessary, to ensure that they stayed on the original route.

Following the route task, participants were asked to provide written directions of the original route, and frequencies of landmarks, distances, and relative and cardinal directions were coded.

Battery of Cognitive Tasks

The battery of cognitive tasks was administered in the following order:

Waterline task. This measure of spatial perception consisted of an original drawing of 12 bottles tilted to varying degrees on a horizontal stand and a tilted stand. Six bottles were tilted to various degrees on a horizontal stand, and 6 bottles were on a 45-degree tilted stand. The participant was instructed to indicate how the top of the water bottle would look in each bottle if it were half filled with water. The mean angle of deviation from the horizontal line comprised the score.

Mental rotation task. Vandenberg and Kuse’s (1978) adaptation of Shepard and Metzler’s (1971) three-dimensional mental rotation task was used. The task consisted of 24 target items, each containing four options that included two rotated versions of the target item. The participant was required to identify which two of the four options were the rotated targets. Participants were given 10 minutes to complete the task. The task was scored by taking the difference between the correct and incorrect responses.

Advanced vocabulary test. The Advanced Vocabulary Test, part of the Kit of Factor-Referenced Cognitive Tests, was used to assess general intelligence to ensure that there were no general cognitive differences between the sexes (Ekstrom, French, Harman, & Dermen, 1976).
RESULTS

ROUTE TASK

Table 1 contains the descriptive data for the route-related tasks. Scores on the route task were standardized (z scores) to allow for comparisons across the conditions. A 2 × 3 (Sex × Condition) analysis of variance (ANOVA) was performed on the standardized scores. There were no statistically significant main effects for sex or condition, \( F(1, 99) = .97 \) and \( F(2, 99) = .07, ps > .05 \), respectively. There was a significant interaction, \( F(2, 99) = 3.61, p < .05 \). A Bonferroni post hoc analysis revealed that within the direct condition, males chose a statistically significantly shorter route than females, \( p < .05 \). There were no sex differences in either the choice or retrace conditions, \( ps > .05 \). Males and females used similar distances in their choice of route in the choice condition and were similar in their abilities to retrace the original route in the retrace condition.

The 2 × 3 (Sex × Condition) ANOVA on the number of segments of the original route used in the choice and direct conditions revealed that there were no main effects for sex or condition, \( Fs(1, 66) = .78 \) and \( .34, ps > .05 \), respectively, nor was there an interaction effect, \( F(1, 66) = .03, ps > .05 \). Males and females used similar numbers of segments of the original route, whether asked to use the most direct route or allowed to freely choose their route.

<table>
<thead>
<tr>
<th>Task</th>
<th>Females (n = 20)</th>
<th>M</th>
<th>SEM</th>
<th>Males (n = 15)</th>
<th>M</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Route task*</td>
<td>0.28</td>
<td>0.24</td>
<td>-0.38</td>
<td>0.19</td>
<td>0.19</td>
<td></td>
</tr>
<tr>
<td>backtrack segments</td>
<td>4.25</td>
<td>0.22</td>
<td>4.60</td>
<td>0.21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>landmark biased</td>
<td>21.80</td>
<td>1.87</td>
<td>23.40</td>
<td>2.68</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retrace</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Route task</td>
<td>-0.23</td>
<td>0.19</td>
<td>0.30</td>
<td>0.30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>landmark biased</td>
<td>35.90</td>
<td>2.70</td>
<td>24.20</td>
<td>3.30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Choice</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Route task</td>
<td>0.19</td>
<td>0.26</td>
<td>-0.25</td>
<td>0.19</td>
<td></td>
<td></td>
</tr>
<tr>
<td>backtrack segments</td>
<td>4.50</td>
<td>0.37</td>
<td>4.73</td>
<td>0.45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>landmark biased*</td>
<td>30.90</td>
<td>3.26</td>
<td>26.27</td>
<td>4.46</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*p < .05.
The frequencies of landmark and relative direction references were pooled and averaged, as were the frequencies of distances and cardinal direction references. The latter measure was subtracted from the former to yield a landmark-biased strategy mean. The results from the $2 \times 3$ (Sex $\times$ Condition) ANOVA showed main effects for condition and sex, $F(2, 99) = 3.28$ and $F(1, 99) = 3.81$, respectively, $p < .05$. A Bonferroni post hoc analysis revealed that the landmark-biased strategy was used to a greater extent in the retrace condition compared to the direct condition, $p < .05$. Furthermore, in the retrace condition, females showed a greater tendency to use a landmark-biased strategy, $p < .05$. There was no interaction, $F(2, 99) = 2.33$, $p > .05$.

**PAPER-AND-PENCIL COGNITIVE TASKS**

Table 2 contains the descriptive data for the paper-and-pencil cognitive tasks. A $2 \times 3$ (Sex $\times$ Condition) ANOVA on the vocabulary task yielded no significant main effects, suggesting that there were no general cognitive differences between males and females, $F(1, 99) = 2.35$ and no differences among the experimental conditions, $F(2, 99) = 1.24$, $p > .05$. The interaction also failed to reach statistical significance, $F(2, 99) = .92$, $p > .05$. The $2 \times 3$ (Sex $\times$ Condition) ANOVAs on the waterline and mental rotation scores yielded statistically significant main effects for sex, $Fs(1, 99) = 13.84$ and $22.32$, $p < .05$, respectively. Males were more accurate than females on both tasks. There were no main effects for condition on the waterline and mental rotation tasks, $Fs(2, 99) = .09$ and .35, $p > .05$, respectively. There were also no interaction effects on the waterline and mental rotation tasks, $Fs(2, 99) = .01$ and .14, $p > .05$, respectively.

### Table 2

<table>
<thead>
<tr>
<th>Task</th>
<th>Females (n = 60)</th>
<th>M</th>
<th>SEM</th>
<th>Males (n = 45)</th>
<th>M</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waterline task*</td>
<td></td>
<td>153.35</td>
<td>21.25</td>
<td>53.98</td>
<td>10.61</td>
<td></td>
</tr>
<tr>
<td>Mental rotation task*</td>
<td></td>
<td>20.08</td>
<td>1.70</td>
<td>31.53</td>
<td>1.57</td>
<td></td>
</tr>
<tr>
<td>Advanced vocabulary task</td>
<td></td>
<td>13.78</td>
<td>0.56</td>
<td>15.13</td>
<td>0.70</td>
<td></td>
</tr>
</tbody>
</table>

*a Higher scores indicate poorer performance.  
* $p < .05$. 

The frequencies of landmark and relative direction references were pooled and averaged, as were the frequencies of distances and cardinal direction references. The latter measure was subtracted from the former to yield a landmark-biased strategy mean. The results from the $2 \times 3$ (Sex $\times$ Condition) ANOVA showed main effects for condition and sex, $F(2, 99) = 3.28$ and $F(1, 99) = 3.81$, respectively, $p < .05$. A Bonferroni post hoc analysis revealed that the landmark-biased strategy was used to a greater extent in the retrace condition compared to the direct condition, $p < .05$. Furthermore, in the retrace condition, females showed a greater tendency to use a landmark-biased strategy, $p < .05$. There was no interaction, $F(2, 99) = 2.33$, $p > .05$.

**PAPER-AND-PENCIL COGNITIVE TASKS**

Table 2 contains the descriptive data for the paper-and-pencil cognitive tasks. A $2 \times 3$ (Sex $\times$ Condition) ANOVA on the vocabulary task yielded no significant main effects, suggesting that there were no general cognitive differences between males and females, $F(1, 99) = 2.35$ and no differences among the experimental conditions, $F(2, 99) = 1.24$, $p > .05$. The interaction also failed to reach statistical significance, $F(2, 99) = .92$, $p > .05$. The $2 \times 3$ (Sex $\times$ Condition) ANOVAs on the waterline and mental rotation scores yielded statistically significant main effects for sex, $Fs(1, 99) = 13.84$ and $22.32$, $p < .05$, respectively. Males were more accurate than females on both tasks. There were no main effects for condition on the waterline and mental rotation tasks, $Fs(2, 99) = .09$ and .35, $p > .05$, respectively. There were also no interaction effects on the waterline and mental rotation tasks, $Fs(2, 99) = .01$ and .14, $p > .05$, respectively.
CORRELATIONS

Correlations between the route task and scores on the paper-and-pencil tasks were performed separately by sex to investigate the possibility of sex-specific patterns of relationships (see Table 3). In females, the route task was negatively correlated with the use of a landmark-biased strategy; given that lower scores on the route task indicate better performance, this correlation suggests that greater use of landmarks and relative directions relative to distances and cardinal directions by females was associated with better performances on the route task. The waterline and the mental rotation tasks were also correlated with the route task such that better performances on each task were associated with better performance on the route task. In males, the route task was not related to the landmark-biased strategy, although the route task was positively correlated with the waterline task; males with higher deviation scores on the waterline task, indicating poorer performance, also showed a tendency to perform poorly on the route task.

REGRESSION ANALYSIS

To explore possible predictors of the route task and the possibility of sex-specific patterns of cognitive processes, stepwise regression analyses were performed on the route task, separately by sex, using the landmark-biased strategy and the waterline and mental rotation tasks as factors (see Table 4). Sex-specific patterns of relationships were found; in females, greater use of a landmark-biased strategy was the sole significant predictor, \( F(1, 58) = 8.94, p < .05 \). The significant relationships between the route task and the waterline and mental rotation tasks failed to emerge, suggesting that they failed to

### Table 3

<table>
<thead>
<tr>
<th>Route Task</th>
<th>Females (n = 65)</th>
<th>Males (n = 45)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landmark-biased strategy</td>
<td>−.37*</td>
<td>−.11</td>
</tr>
<tr>
<td>Waterline task*</td>
<td>.27*</td>
<td>.38*</td>
</tr>
<tr>
<td>Mental rotation task</td>
<td>−.26*</td>
<td>−.25</td>
</tr>
</tbody>
</table>

a. Higher scores indicate poorer performances.  
*p < .05.*

---

**CORRELATIONS**

Correlations between the route task and scores on the paper-and-pencil tasks were performed separately by sex to investigate the possibility of sex-specific patterns of relationships (see Table 3). In females, the route task was negatively correlated with the use of a landmark-biased strategy; given that lower scores on the route task indicate better performance, this correlation suggests that greater use of landmarks and relative directions relative to distances and cardinal directions by females was associated with better performances on the route task. The waterline and the mental rotation tasks were also correlated with the route task such that better performances on each task were associated with better performance on the route task. In males, the route task was not related to the landmark-biased strategy, although the route task was positively correlated with the waterline task; males with higher deviation scores on the waterline task, indicating poorer performance, also showed a tendency to perform poorly on the route task.

**REGRESSION ANALYSIS**

To explore possible predictors of the route task and the possibility of sex-specific patterns of cognitive processes, stepwise regression analyses were performed on the route task, separately by sex, using the landmark-biased strategy and the waterline and mental rotation tasks as factors (see Table 4). Sex-specific patterns of relationships were found; in females, greater use of a landmark-biased strategy was the sole significant predictor, \( F(1, 58) = 8.94, p < .05 \). The significant relationships between the route task and the waterline and mental rotation tasks failed to emerge, suggesting that they failed to
account for unique amounts of variation in females. In males, however, the waterline task was the sole significant predictor of the route task, $F(1, 43) = 7.05, p < .05$.

### DISCUSSION

The present experiment sought to investigate the relationships among sex, route-learning strategies, and route-learning abilities. Results indicate that although males used a significantly shorter route than females did when instructed to do so, males and females did not differ in their abilities to retrace the original route, suggesting that reported route-based strategies used by females do not emanate from greater abilities to use them. Furthermore, males and females did not differ in the distances of their chosen routes, nor did they differ in the extent to which they used the original route. Although these results initially appear to contradict previous findings that suggested that females were more likely to report using a route-based strategy (Lawton, 1994), the context of the route task may account for these differences. Lawton and Kallai (2002) speculated that females report using a route-based strategy in an unfamiliar environment because of fear for physical danger. This factor would not have played a significant role in the present experiment, given that the experimenter accompanied the participants. Despite the lack of sex differences in the retrace condition, however, females continued to use a landmark-biased strategy to a greater extent than males, suggesting that females attended to more landmarks and relative directions relative to cardinal directions and distances than males did.

The relationship between route-learning strategies and route-learning abilities appear to be sex specific. The landmark-biased strategy used by

---

### TABLE 4

Regression Coefficients and Standard Errors of the Route Task as a Function of Sex

<table>
<thead>
<tr>
<th>Predictor</th>
<th>B</th>
<th>SE B</th>
<th>β</th>
<th>t (H₀)</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Females</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landmark-biased strategy</td>
<td>−.029</td>
<td>.010</td>
<td>−.37</td>
<td>2.99</td>
<td>.13</td>
</tr>
<tr>
<td>Males</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waterline task</td>
<td>.0049</td>
<td>.002</td>
<td>.38</td>
<td>2.66</td>
<td>.14</td>
</tr>
</tbody>
</table>
females was associated with better route-learning abilities in a large-scale environment and was the sole predictor, suggesting that females who used a landmark-biased strategy to a greater extent were also more likely to perform better on the route task. This implies that in females, the landmark-biased strategy is associated with greater route-learning abilities in a large-scale environment. In males, however, the landmark-biased strategy was not correlated with route-learning abilities, suggesting that the landmark-biased strategy is independent of route-learning abilities. Both sets of findings contradict the hierarchical model. It would be expected, based on the hierarchical model, that greater landmark bias would be associated with poorer route-learning abilities in both males and females.

The hierarchical model, however, does receive partial support in the male sample when general spatial abilities are considered. Sex differences found on the paper-and-pencil tasks were expected; males outperformed females on the mental rotation and waterline tasks, and there were no differences in the vocabulary task. In males, the waterline task was the only predictor of route-learning abilities, suggesting that greater error on the waterline task was associated with poorer performance on the route-learning task. Although there is little empirical evidence authenticating the relationship between general spatial abilities and route-learning abilities in a large-scale environment (see Silverman et al., 2000, for an exception), the hierarchical model presumes that poorer spatial abilities are associated with poorer performance on a route-learning task, a relationship that was substantiated in males in the present experiment. Although spatial perception, as measured by the waterline task, and mental rotations were correlated with the route task in females as well, both failed to account for significant amounts of unique variance, independent of the landmark-biased strategy, in the route task.

Males used shorter distances in the direct condition, replicating previous findings (Silverman et al., 2000). Given that males tend to perform better when required to find the most direct route, we tested the analogous hypothesis in females; that is, do females report using a route-based strategy because they are better at using it? We failed to find empirical evidence for this hypothesis; females did not make statistically significantly fewer errors or hesitations in the route condition, although the direction of the findings was consistent with the premise. Larger sample sizes within the condition, resulting in greater statistical power, may have been required for the difference to reach statistical significance.

Overall, the present experiment suggests that there are sex-specific patterns of route-learning strategies and route-learning abilities in a large-scale environment. In females, greater use of a landmark-biased strategy predicted better performances on the route-learning task, implying that in females, this type
of strategy is related to greater route-learning abilities rather than poor route-learning abilities as assumed by the hierarchical model. It may be that females’ use of a landmark-biased strategy and route-learning abilities emanate from cognitive processes other than those measured by traditional mental rotation or spatial perception tasks, such as object location memory (Choi & Silverman, 2003). In contrast, a landmark-biased strategy was not related to route-learning abilities in males. The route task, however, was associated with the waterline task, suggesting that poorer spatial abilities are related to poorer route-learning abilities in males, providing partial support for the hierarchical model. These patterns of results suggest that although the hierarchical model may be applicable in males, it does not seem to hold for females.

REFERENCES


