Males, Females, and Maps: Evaluating Spatial Encoding Strategies

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Cognitive research suggests that there is a difference in the spatial abilities of males and females. Results of studies that examine way-finding skills indicate that the differences found may be linked to a variation in the types of strategies used in completing spatial tasks. The purpose of this study was to assess the influence of gender on different strategies for encoding spatial information in a map context. An experiment was conducted in which subjects studied a map presented to them using one of three encoding strategies: (1) a control strategy in which they viewed the map as a static representation, (2) a landmark-based strategy in which they viewed a dynamic sequencing of the map that began with landmark locations and built over time to include all map components, and (3) a path-based strategy in which they viewed a dynamic sequencing of the map that began with path locations and built over time to include all map components. Following this study phase, subjects completed a series of map recognition tasks where they indicated whether a presented map was the same as or different from the map they had originally studied. Test maps that differed from the memorized map were modified by either replacing, displacing, or reversing the perspective of a map object. Results indicated that while encoding strategy played a significant role in determining how accurately subjects could perform the recognition task, gender did not significantly influence how well any particular strategy worked for encoding map-based spatial information.

INTRODUCTION

The acquisition of spatial information from a map requires the use of several intricate cognitive processes. Scientists' knowledge of these processes comes primarily from studies conducted in psychology, where researchers have accumulated over fifty years worth of studies on human spatial abilities. Out of this wealth of research, one broad and increasingly challenged generalization is the finding that males are more skilled at executing spatial tasks than females (Maccoby and Jacklin, 1974; Self, et al., 1992; Halpern, 1992). Several of these studies have further suggested that the differences found between males and females are linked to the types of strategies they use when completing spatial tasks. Results of these studies show that females tend to rely more on *verbal-analytic strategies,* in which spatial stimuli are encoded as discrete objects. Males, on the other hand, are more likely to focus on the geometric properties of the environment and encode all spatial stimuli as one interconnected object – *a spatial-holistic strategy* (Cooper, 1976; Paivio, 1986; Galea and Kimura, 1993; Lanca and Kirby, 1995).

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Are these results applicable to encoding spatial information specifically from maps? Research conducted on the *environmental* acquisition of spatial knowledge is insightful. Results from several of these studies have produced two competing theories of spatial knowledge acquisition in the environment. *Path-based learning* emphasizes the importance of paths or routes in assembling the initial cognitive structure (Appleyard, 1970), while *Landmark-based learning* highlights discrete landmarks as the basic building blocks (Siegal and White, 1975; Golledge, 1978). Subsequent testing of these theories has shown that women tend to rely more heavily on landmark information in the spatial encoding process. Men, conversely, are more likely to rely on the geometric properties of the area in question (Appleyard, 1970; McGuiness and Sparks, 1983; Miller and Santoni, 1986; Galea and Kimura, 1993). To date, there is little evidence – cartographically or otherwise – to indicate whether such findings might also hold for spatial information acquired from a map. Information of this type, however, is essential to a cartographer's understanding of the cognitive processes used in acquiring and encoding map-based spatial information. The wide-spread use of computers to display spatial information has given cartography the potential to control how that information is presented to map users. The choice of presentation strategy may influence how efficiently the map user can process information (Thorndyke and Stasz, 1982; MacEachren, 1992) and thus needs to be studied carefully from a variety of perspectives. Just as important is an understanding of gender's influence on the effectiveness of these presentation strategies. If gender differences exist and are substantiated in a map environment, then experimental research designs in cartography will need to examine more carefully the role that gender plays as an explanatory variable (Gilmartin and Patton, 1984). With this in mind, the purpose of this study was two-fold: (1) to further previous research examining the potential use of environmental encoding theories for encoding map-based spatial information, and (2) to assess what role gender may play in the effective use of such theories in a map environment.

"The choice of presentation strategy may influence how efficiently the map user can process information . . . "

SPATIAL ENCODING STRATEGIES

Research on spatial knowledge acquisition suggests that it is a gradual process, one that begins with fragments of information about a new locality. Over time, those fragments of information are joined by newly acquired knowledge about the locality until a complete cognitive representation is formed (MacEachren, 1992). What researchers do not agree on are the actual processes used in developing this representation. For example, what are the basic components of the spatial knowledge acquisition process and how is this process facilitated? Research addressing such questions exists primarily for spatial knowledge acquisition in the environment. In fact, both *Landmark-based Learning* and *Path-based Learning* are spatial encoding strategies born of studies that examined spatial knowledge acquisition in an environmental context.

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Path-based Learning proposes that it is the paths or routes in an environment that form the primary framework for the resulting cognitive representation. After the initial paths are learned, landmarks relative to the paths are believed to be coded and stored. Appleyard (1970) was one of the first to provide empirical evidence for this theory. He asked both short-term and long-term city residents to draw sketch maps of their environment. In comparing the maps of the two groups, he discovered that paths dominated the maps of short-term residents, while long-term residents produced more integrated maps with more landmark information. Devlin (1976) obtained similar results in her study, which examined the sketch maps of Navy wives who had recently moved to a new duty station.

In another study, subjects toured an unfamiliar area and were then tested on their newly acquired spatial knowledge (Garling, et al., 1981). Results showed that subjects were better at remembering a sequence of landmarks along a road that at estimating the locations of those landmarks. Such findings led the authors to conclude that their subjects acquired a knowledge of paths before a knowledge of landmarks. Another study supporting *Path-based learning* tested the ability of drivers to estimate straight line distances and travel distances for given origin-destination locations within Paris (Peruch, et al., 1989). Results indicated that all drivers estimated the travel distance between two locations as consistently longer than the corresponding straight line distance. These findings were interpreted as supportive of *Path-based learning* . The authors concluded that the drivers in their study based their estimates of travel distance primarily on knowledge acquired from route information, suggesting that route knowledge dominated the initial cognitive structure of the city.

In contrast to *Path-based learning*, *Landmark-based learning* proposes that landmarks are the basic building blocks of the cognitive representation. Knowledge of routes is believed to be developed after landmarks have been encoded and stored in memory. Siegal and White (1975) developed one of the first landmark-based models of learning. Their model consisted of three stages: (1) development of landmark knowledge, (2) development of path-based knowledge, and (3) development of integrated, configurational knowledge. *Anchor Point Theory*, proposed by Golledge (1978), is another landmark-based model. He asserts that the cognitive organization of spatial information is hierarchical, with key landmarks anchoring regions of space and serving as endpoints for the paths in the environment.

" . . . Landmark-based learning proposes that landmarks are the basic building blocks of the cognitive representation."

Both Evans, et al. (1981) and Okabe, et al. (1986) have conducted research that lends support to *Landmark-based learning*. Evans, et al. (1981) studied changes in cognitive maps that occurred with increasing environmental experience. They asked subjects to draw sketch maps of their environment after one week's residence and again after one year's residence. Results of their study indicated that subjects used landmarks as initial anchor points in their cognitive representations and filled in path structures over time within this initial framework. In a study that examined distance and direction estimations made while traversing trails (Okabe, et al., 1986), the authors found that landmarks on trails provided an anchoring effect for subjects. Locations on winding trails were estimated more accurately by subjects when landmarks were present than when they were absent.

Both the *Path-based* and the *Landmark-based* encoding theories result from examining how humans interacted with their environment over time. Since these theories address the process of spatial knowledge acquisition, however, it also seems logical to assess their utility for explaining spatial knowledge acquisition in a map environment. MacEachren (1992) investigated this possibility when he examined how a map's presentation strategy influenced the resulting cognitive representation of that information. He presented a map to *male* subjects under four different conditions: (1) Landmark-based Strategy, (2) Path-based Strategy, (3) Region-based Strategy, and (4) Whole-Map Strategy. Because his study dealt with a two-dimensional graphic, MacEachren hypothesized that strategies derived from environmental encoding theories might not be as effective for map learning as a strategy in which individual map regions were learned incrementally. After assigning each subject to a presentation strategy group, MacEachren had them memorize a map presented to them. They then performed a series of distance and direction estimates using their resulting cognitive map of the area. Study results indicated that subjects who used a Path-based Strategy to memorize the map completed the learning phase of the experiment more efficiently and more accurately than subjects in other groups. However, in the task phase of the experiment, subjects in the Whole-Map group were the fastest at completing direction estimates. The Whole- Map group was also fastest at completing distance estimates, but this effect was not significant. The author did not find significant differences in accuracy rates between any of the groups.

THE IMPACT OF GENDER ON SPATIAL ENCODING

The gender differences found in cognitive spatial abilities result largely from psychological experiments in which researchers employed a variety of spatial tasks. Because these tasks were so varied and have produced results that often are not comparable, Caplan, et al. (1985) has suggested that a more valid measure of cognitive spatial ability would be a real world way-finding task. Appleyard's research (1970), discussed in the previous section, is one of the older studies to utilize such a strategy. In the analysis of his results, he found that females relied more heavily on landmarks than males when asked to produce sketch maps of the area in which they lived. Appleyard also noted that the maps drawn by females had more errors than those drawn by males. In a similar study, McGuiness and Sparks (1983) asked subjects at a college campus to draw maps of their environment. Their results indicated that females included more landmark information on their maps, while males include more path information. Furthermore, although males provided a more accurate spatial layout of the campus, the authors found that females more accurately displayed distances between locations.

"McGuiness and Sparks (1983) asked subjects . . . to draw maps of their environment. Their results indicated that females included more landmark information on their maps, while males included more path information."

A study by Miller and Santoni (1986) asked subjects to memorize a map and then provide written travel directions for specified origin-destination locations. Like Appleyard (1970) and McGuiness and Sparks (1983), they found that males performed the task more accurately than females, and that females used more landmarks in completing the task. In a more recent study, Galea and Kimura (1993) asked subjects to memorize a route on a novel map, then tested them on their knowledge of landmarks and geometric properties associated with that route. Results showed that females recalled significantly more landmarks than males, and that males scored significantly higher on tests of geometric properties. Furthermore, the authors reported that males initially memorized the route faster and with significantly fewer errors than females. Holding and Holding (1989) obtained similar results in their route memorization study.

Despite the similarities of the above studies, results of other researchers provide an alternative view of this proclaimed gender difference. One study, for example, tested the campus knowledge of freshmen at three weeks, three months, and six months of residence (Herman, et al., 1979). Their results showed that males displayed significantly more landmark knowledge than females, but route knowledge between the two groups was approximately the same.

Perrig and Kintsch (1985) asked subjects to memorize bodies of text describing a town. Texts were written either as one would describe a map of the town (survey style) or as a set of directions for getting around the town (route style). Recall and recognition tasks of the memorized text showed no significant gender differences; however, the authors noted an interesting trend in the responses. Regardless of the type of text memorized, females responded to inferential questions about the text more accurately when the question was framed in the same style as the text they read. Males, on the other hand, responded more accurately to such questions when the question was framed in a survey style for both types of text. The conclusion they reached was that females were more flexible than males in the type of cognitive structure they formed. While females formed cognitive representations best suited to the style of the text memorized, males seemed to insist on using an image representation for both types of texts.

In another study (Ward, et al., 1986), the authors asked subjects to either memorize a map and then provide directions to specified locations or to give directions to those locations while directly viewing the map. Results showed that when left to their own devices, males used more cardinal directions and mileage indicators than females; males also gave more accurate directions than females when the map had been memorized. When prompted to use cardinal directions and mileages, however, both sexes used the concepts equally well. The authors concluded from the findings that gender did not necessarily reflect a difference in how spatial information was constructed, but instead reflected a difference in cognitive styles when a choice was given. Even more recently, an article in the *New York Times* (May 26, 1992) reported on a psychological study in which college students repeatedly navigated mazes. Results of this study indicated that males relied more heavily on directions to navigate the maze, whereas females relied more heavily on landmarks. However, the article did point out that both sexes could navigate the maze equally efficiently, indicating that their cognitive structures of the mazes were similar and that differences were ones based purely on differences in cognitive styles.

Ward, et al. (1986) concluded . . . "that gender did not necessarily reflect a difference in how spatial information was constructed, but instead reflected a difference in cognitive styles . . ."

METHODOLOGY

This study manipulated spatial encoding strategies to determine their effect on the ability of males and females to recognize various mapped objects. Ninety subjects at the University of South Carolina participated in the experiment. Subjects received either monetary compensation or extra credit for courses in participating geography and psychology classes.

The Target Map. The target map used in the experiment consisted of a simple street pattern and pictorial landmarks, and was presented in black and white on a computer screen (Figure 1). The map was designed to fit onto the screen so that map features were represented clearly and legibly. Verbal labels were excluded from the map to provide as much control over experimental variables as possible.

The Test Groups. Subjects were divided into three groups on the basis of the learning strategy they used when viewing the target map. Within each group approximately half the subjects were male and half were female. The learning strategies, designed to manipulate how subjects

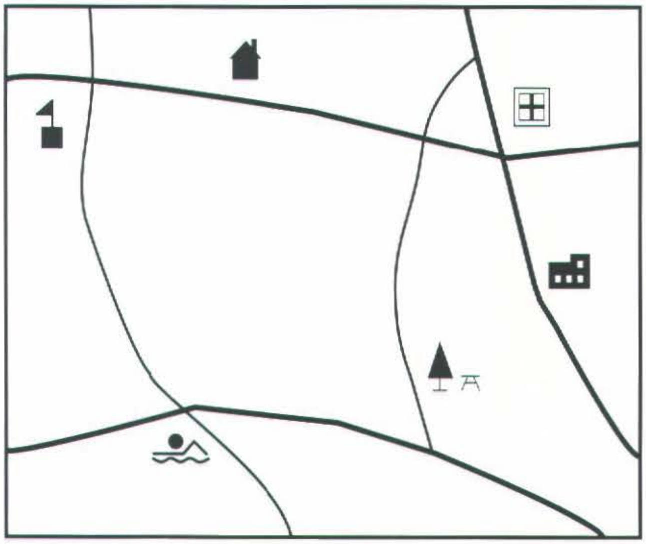

Figure 1. Target map.

acquired spatial information from a map, were modeled after those MacEachren used in his 1992 study. The Static Map group served as the control group; subjects who studied the target map using this strategy saw it as a static representation that remained on-screen for three minutes (Figure 1).

"The learning strategies, designed to manipulate how subjects acquired spatial information from a map, were modeled after those MacEachren used in his 1992 study."

Subjects assigned to the Landmark-based Strategy group studied a series of seven separate map segments designed to emulate the theory of *Landmark-based Learning*. Segment presentation was controlled by computer; each segment was displayed briefly before being replaced by the next segment, and succeeding segments were built on information presented in the previous displays. For example, the first segment in the Landmark-based cycle (displayed for three seconds) consisted of three primary landmarks (Figure 2a). Following this segment, the computer displayed three more segments, where each segment consisted of one of the primary landmarks along with a secondary landmark (Figure 2 b-d). These segments were also displayed for three seconds each. The last three segments, presented for six seconds apiece, each consisted of a pair of primary landmarks along with secondary landmarks and connecting roads (Figure 3 a-c). The entire cycle lasted for 30 seconds, and landmarks were presented more frequently than roads in the presentation process. Subjects studied this presentation cycle six times for a total of three minutes, which equaled the amount of time subjects in the Static Map group spent studying the target map. Subjects assigned to the Path-based Strategy group experienced a similar process, except that the segments used in these groups emulated *Path-based Learning* (Figures 4 and 5).

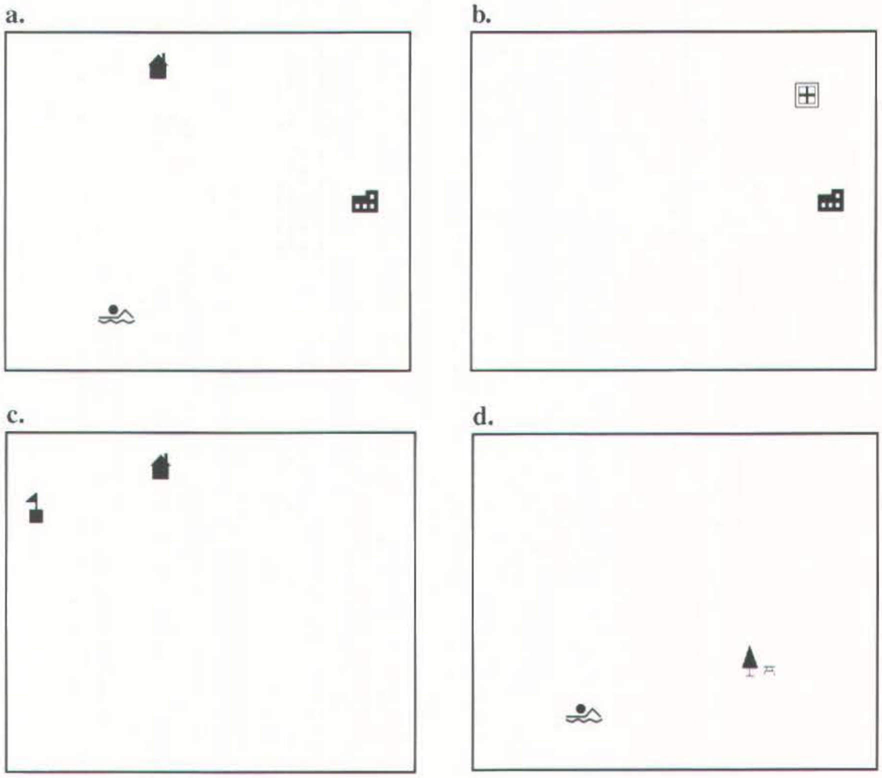

Figure 2. Landmark-based learning, segments 1-4.

Testing Procedure. After assigning a subject to one of the test groups, the task administrator instructed the subject on the steps of the experiment. Subjects then participated in a preliminary session using a practice

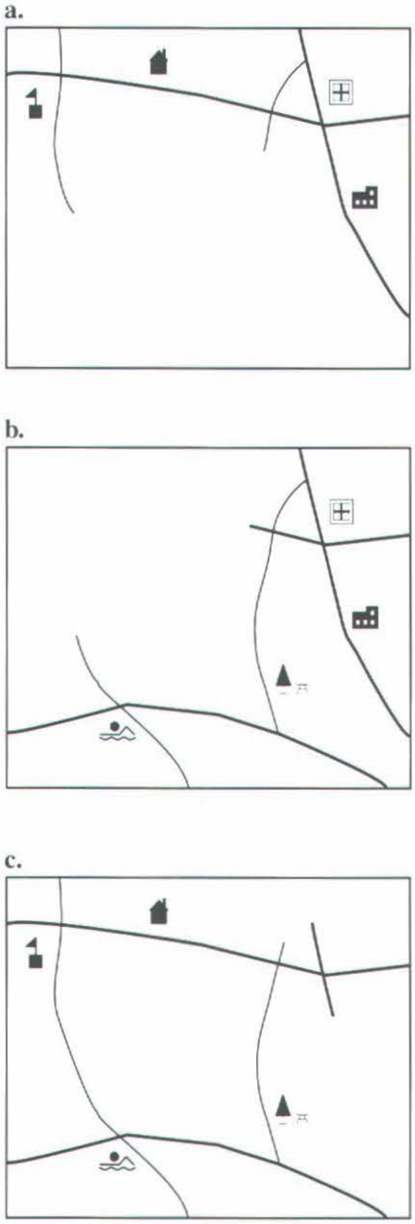

Figure 3. Landmark-based learning, segments 5-7.

map to further familiarize themselves with the process. The test procedure consisted of two phases: in the first phase, each subject studied a target map that was presented to them by computer. Map presentation corresponded to the learning strategy of the subject's test group. Following this presentation, each subject viewed a series of test maps and was asked to determine whether each map was identical to or different from the target map they had just studied.

> *"Map presentation corresponded to the learning strategy of the subject's test group. Following this presentation, each subject viewed a series of test maps and was asked to determine whether each map was identical to, or different, from the target map . . ."*

The test maps that differed from the target map were modified in one of six ways. These modifications can best be described as changes consisting of either the replacement, perspective reversal, or displacement of either a landmark or a road on the target map. Replacement objects were designed to be thematically related to the objects they replaced (i.e., replacing a park symbol with a forest symbol), as well as visually similar to the original object (Figure 6). Objects on the test map that were reversed in perspective were essentially mirror-images of the original map object (Figures 7). Both landmarks and roads could exhibit this effect, although to differing degrees. To alternate the perspective of a landmark, a mirror-image of the symbol was constructed. Perspective reversals of roads required a slightly different strategy. Because roads are connected to one another and have the attribute of length, constructing a mirror-image of a segment destroyed the overall network of road connections. Therefore, to achieve a reversal-like effect, road width was alternated from thin to thick or thick to thin. Displaced objects on the test map were moved in relation to the same object on the target map (Figure 8). Displaced landmarks were moved so that only relations to other landmarks were violated; relations between these symbols and the road network remained intact. Conversely, roads were displaced so that relations to landmarks remained intact, but relations to the road network were violated.

For each test map presented, subjects indicated whether that map was the same as or different from the target map they had originally studied. Subjects responded to each map by pressing the appropriate key on the computer keyboard to record their answer. The dependent variable used in this study was the percentage of correct responses. Each subject com-

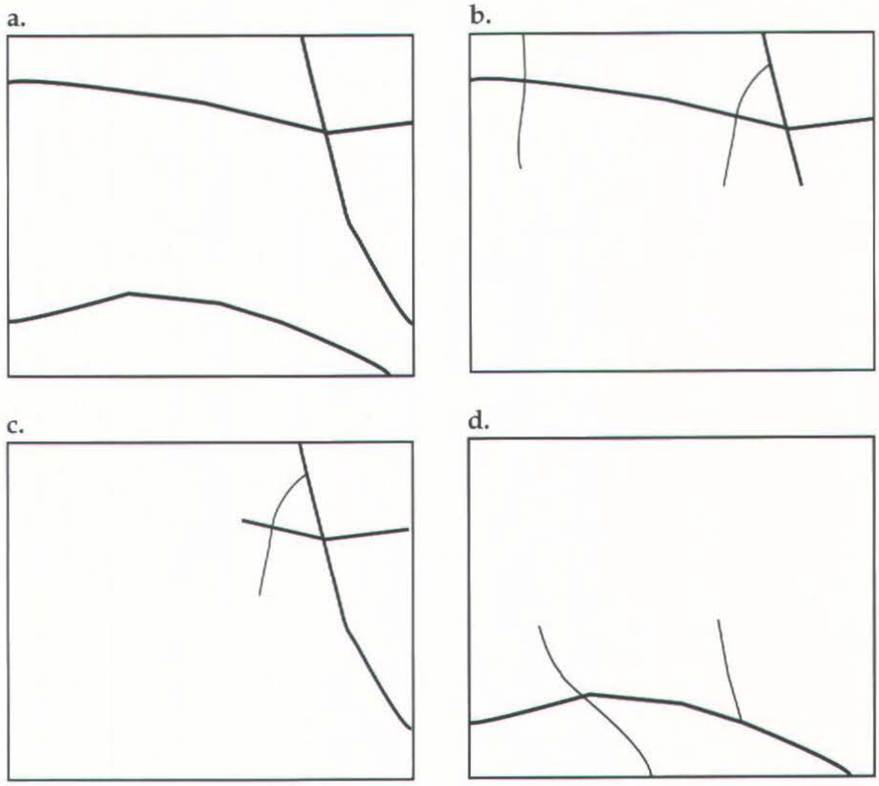

Figure 4. Path-based learning, segments 1-4.

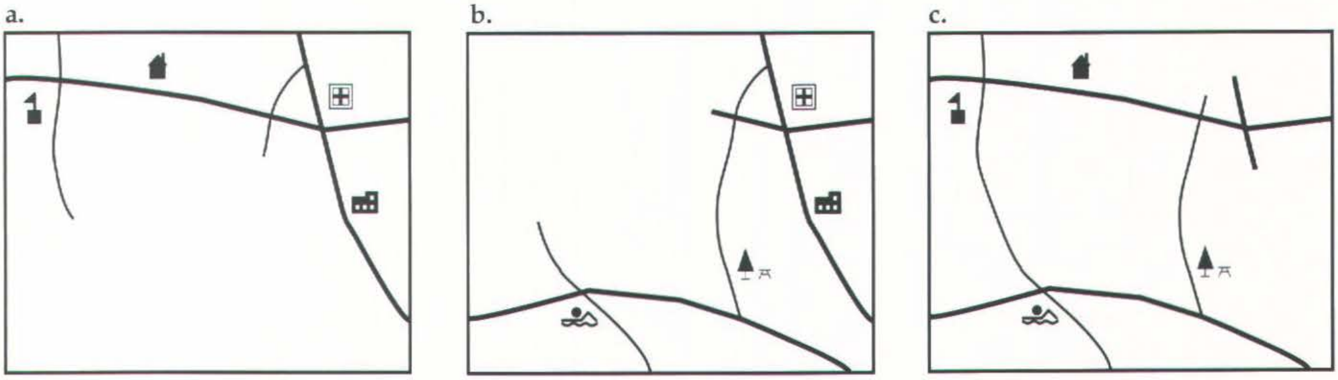

Figure 5. Path-based learning, segments 5-7.

pleted 48 map recognition trials; 24 maps were identical to the target map studied and 24 maps differed from the target map. Of those maps that differed, 12 were modified by changing a landmark (4 replacements, 4 reversals, 4 displacements) and 12 were modified by changing a road (4 replacements, 4 reversals, 4 displacements).

HYPOTHESIS

Hypotheses were generated to test the influence of encoding strategies on the ability to detect changes in mapped objects and to assess the role that gender plays in this process. Because MacEachren (1992) found no significant differences in accuracy between his presentation strategy groups, it was hypothesized that similar results would occur for the map task in this study.

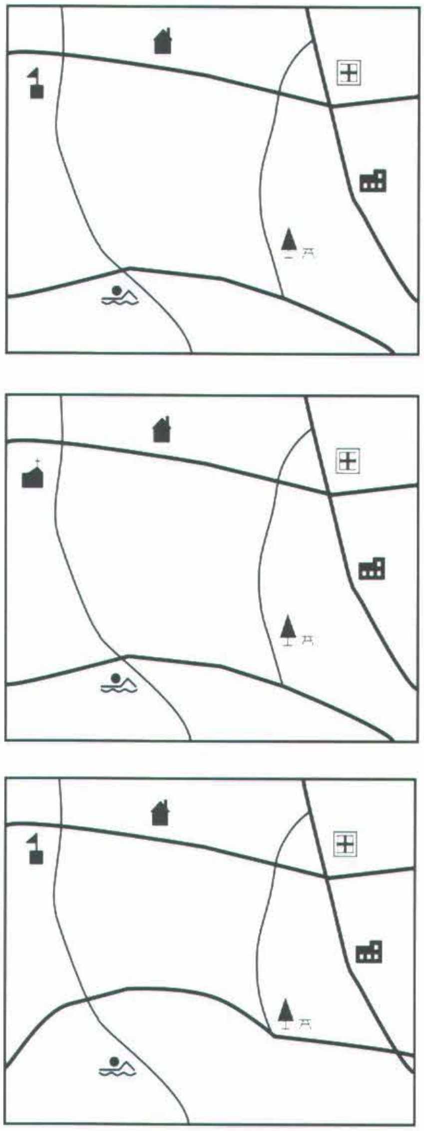

Figure 6. Target map (top), test map with replacement symbol foil (middle), and test map with reversal road foil (bottom).

Research on gender differences in environmental spatial knowledge acquisition (Appleyard, 1970; McGuiness and Sparks, 1983; Miller and Santoni, 1986) suggests that females may rely more heavily on landmarks than their male counterparts in encoding spatial knowledge. Thus, it was also hypothesized that females using the Landmark-based learning strategy would: (1) perform the recognition task more accurately than males using that strategy; and (2) specifically recognize changes in landmarks more efficiently than males using that strategy.

ANALYSIS AND RESULTS

The data for the dependent variable were aggregated over all subjects and across all variables to minimize data abnormalities. Only "Different" responses were considered in the analysis because the focus of this study was on the ability of subjects to detect modified test maps. The accuracy data were analyzed using a General Linear Model (GLM) analysis of variance (ANOVA). The main effects for the model were Learning Strategy (3 levels), Gender (2 levels), and Map Object (6 levels). All possible interactions were analyzed. The model was significant [F(35, 108) = 2.74, P > F = .0001] and explained 47% of the variance in subject accuracy rates (Table 1). Two main effects reached significance in the analysis.

" . . . Learning Strategy played a significant role in subject responses."

As Figure 9a shows, both males and females using the Path-based learning strategy were considerably less accurate in detecting modified map objects. Differences between subjects using the Static Map learning strategy and the Landmark-based learning strategy were less striking. As expected, analysis of this variable confirmed that Learning Strategy played a significant role in subject responses [F(2, 141) = 4.90, P > F = .0092]. *Post hoc* comparisons of the means of the three test groups indicated that accuracy rates for subjects using the Static Map learning strategy did not differ significantly from those using the Landmark-based learning strategy [T(94) = 0.70, P > T = .4845]. Subjects using the Path-based learning strategy, however, were significantly less accurate than subjects using both the Static Map learning strategy [T(94) = 2.99, P > T = .0034] and the Landmark-based learning strategy [T(94) = 2.29, P > T = .0239].

"Subjects using the Path-based learning strategy . . . were significantly less accurate than subjects using both the Static Map learning strategy and the Landmark-based learning strategy."

Males and females, regardless of the learning strategy employed, did not differ widely in the accuracy of their responses to the recognition task (Figure 9b). ANOVA results verified that this main effect variable did not play a significant role in explaining the overall accuracy of subject responses [F(1,142) = 0.23, P>F = .6314]. Furthermore, there was no significant interaction of gender with Learning strategy, as had been hypothesized, or with any other of the independent variables.

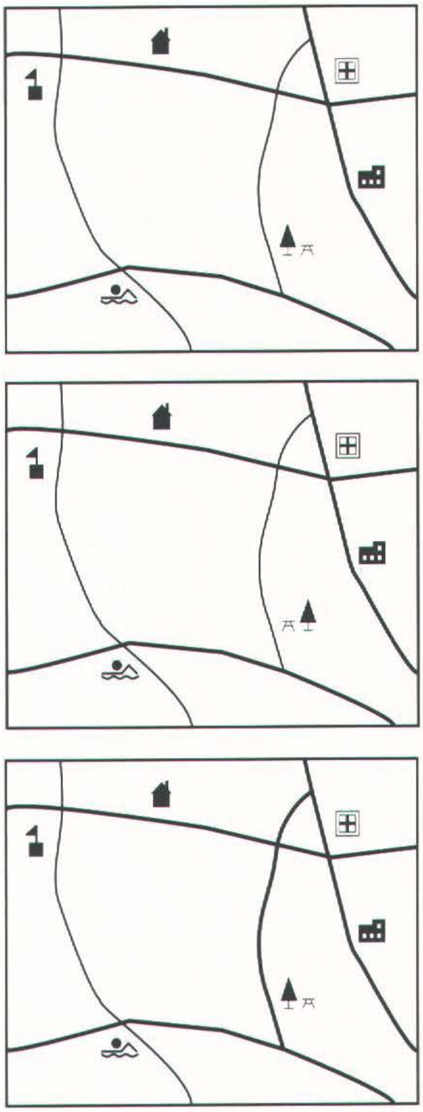

Figure 7. Target map (top), test map with reversal symbol foil (middle), and test map with reversal road foil (bottom).

Figure 9c shows that replaced objects were easier to detect in the recognition task than reversed or displaced objects. Furthermore, subjects found displaced landmarks easier to detect than displaced streets and reversed streets easier to detect than reversed landmarks. ANOVA results confirmed that Map Object was a significant effect [F(5,138) = 14.34, P > F = .0001. *Post hoc* comparisons of means for the six different types of changes that could occur on a test map indicated the following: (1) subjects were significantly more accurate in detecting reversed streets than reversed landmarks [T(46) = 2.95, P>T = .0038]; (2) subjects were significantly more accurate in detecting displaced landmarks than displaced streets [T(46) = 5.99, P>T = .0001]; (3) subjects were significantly less accurate in detecting reversed landmarks than replaced landmarks [T(46) = 4.68, P>T = .0001] or displaced landmarks [T(46) = 4.10, P>T = .0001]; and (4) subjects were significantly less accurate in detecting displaced streets than replaced streets [T(46) = 6.10, P>T = .0001] or reversed streets [T(46) = 4.85, P>T = .0001].

"*. . . replaced objects were easier to detect in the recognition task than reversed or displaced objects.*"

DISCUSSION

A number of researchers have examined the interaction of encoding strategies in an environmental context. Fewer, however, have attempted to apply such theories to spatial information acquired directly from a map. The results of the research described above contribute to the knowledge accumulated on spatial knowledge acquisition and gender in the map environment. In contrast to MacEachren's (1992) results, this study found that subjects who studied the target map using either the Static Map or Landmark-based learning strategies detected changes in map objects significantly more accurately than subjects who used the Path-based learning strategy to study the map (Figure 9a). Such results suggest that

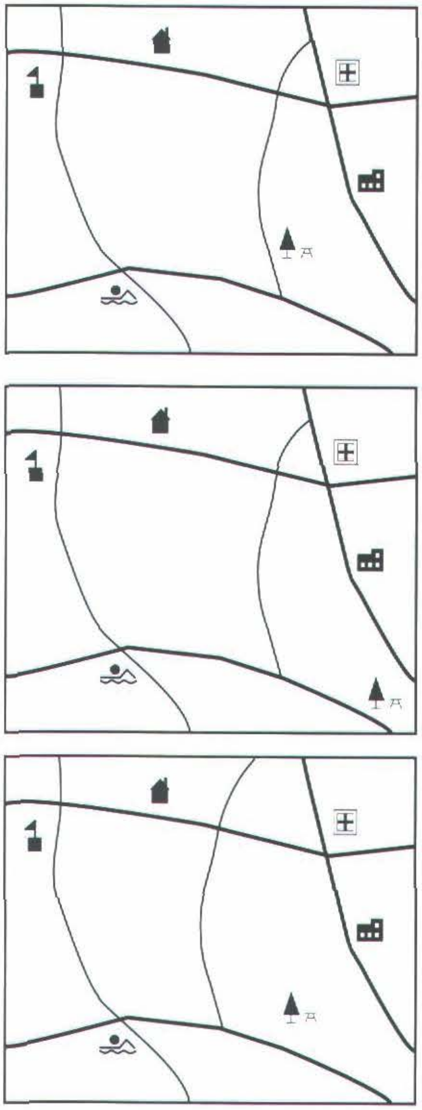

Figure 8. Target map (top), test map with displacement symbol foil (middle), and test map with displacement road foil (bottom).

the Landmark-based learning strategy and *Anchor Point Theory* (Golledge 1978) transfer better from an environmental context to a map context than the Path-based learning strategy, at least when the task is to recognize changes in a mapped area. Why are there discrepancies between these findings and those of MacEachren's? One plausible explanation is that the different task requirements of the two studies played a role in which types of encoding processes worked best. MacEachren's distance and direction estimates are linear tasks and may be better matched to an encoding process that emphasizes linear components. With the map recognition task, subjects were searching for changes to isolated objects on the map; perhaps a task such as this is better matched to an encoding process that emphasizes point locations.

It is also possible that differences in the design and presentation of the experimental maps used in both studies played a role in producing these contrasting results. The number of streets and landmarks on MacEachren's maps were unbalanced, with the maps having more streets than landmarks. Subjects, then, who used a Path-based learning strategy to

> *" . . . results suggest that the Landmark-based learning strategy and <u>Anchor Point Theory</u> transfer better from an environmental context to a map context than the Path-based learning strategy . . ."*

Independent Variables	DF	F Value	P>F
Gender	**(1,142)**	**0.23**	**.6314**
Learning Strategy	**(2,141)**	**4.90**	**.0092**
Map Object	**(5,138)**	**14.34**	**.0001**
Learning Strategy x Gender	**(2,138)**	**0.41**	**.6637**
Map Object x Gender	**(5,132)**	**0.44**	**.8192**
Learning Strategy x Map Object	**(10,126)**	**0.45**	**.9173**
Learning Strategy x Gender x Map Object	**(10,108)**	**0.66**	**.7548**

Table 1. General linear model with Accuracy rate as the dependent variable (R^2=.47).

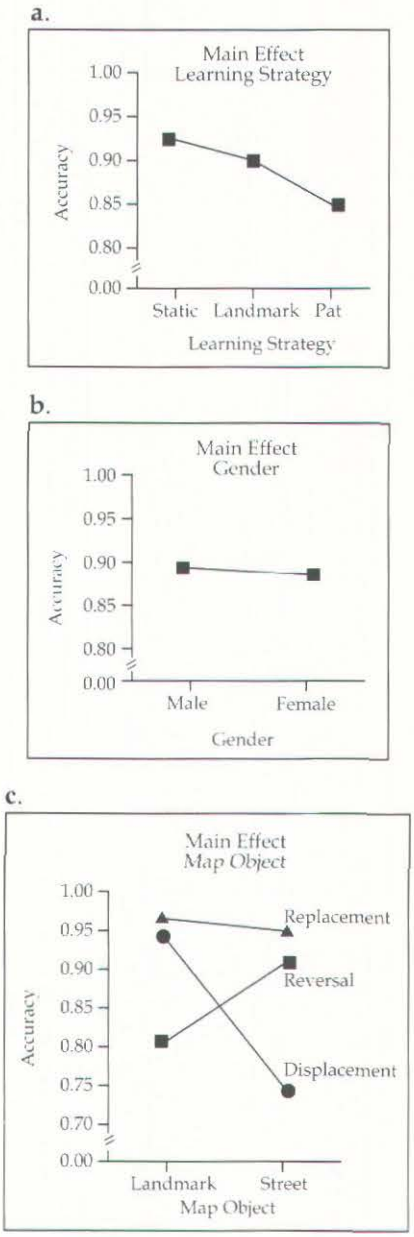

Figure 9. Results of accuracy rate analysis. Each graph shows how a main effect or interaction effect was related to accuracy.

"Gender, contrary to the hypothesis put forth, did not significantly influence the accuracy of subject responses to the recognition task."

study the map were initially exposed to more information than subjects using the Landmark-based learning strategy, a situation that was avoided in this study. Furthermore, all subjects in MacEachren's study saw the map in its entirety at some point during the simulation process. In this study, only subjects who studied the map using the Static Map learning strategy saw the map in its entirety. The Landmark-based and Path-based learning theories do not include holistic encounters with the environment as part of the learning model. Thus, subjects who studied the target map using similar learning strategies were not exposed to such a display.

Gender, contrary to the hypotheses put forth, did not significantly influence the accuracy of subject responses to the recognition task (Figure 9b). Both males and females were equally accurate in recognizing changes in map objects during the test phase of the experiment. Furthermore, females using the Landmark-based learning strategy did not exhibit an advantage in responding to the recognition task, whether the modified map object was a landmark or a street. While this is certainly not an exciting conclusion, it is worth noting because it will help geographers to evaluate the need to consider gender an explanatory variable in future studies. As Caplan, et al. (1985) has pointed out, the lack of significant differences in gender-based studies may be published less often than results that are significant. Within the context of this study, then, it appears that gender differences and gender styles do not significantly influence the ability of subjects to use one spatial encoding strategy over another. Of course, the task used in this study was a simple one and indicative of only one of many that the typical map user may need to perform. Certainly, further studies should be conducted that examine a variety of common map-based tasks in conjunction with these types of spatial encoding strategies.

An unexpected, but nonetheless interesting finding in this study is the difference in difficulty that subjects encountered in detecting various object modifications. The lack of interference in detecting replaced objects is clearly explained by examining the effect of Map Object on subject responses (Figure 9c). Subjects, regardless of the learning strategy used when studying the target map, found replaced objects easier to detect than displaced and reversed objects. Given that replaced objects were designed to be both visually and conceptually similar, the near ceiling performance of subjects in detecting these objects is striking. Furthermore, there is a huge discrepancy in the ability of subjects to detect reversed landmarks over reversed streets as well as displaced streets over displaced landmarks. Such anomalies help explain why the variance for the overall GLM model is so low. A secondary analysis using individual trials in place of Map Object showed that much of the variance not accounted for in this analysis can be explained by differences in individual trials.

Why was it so much easier for subjects to detect replaced objects? Perhaps the Landmark-based and Path-based learning strategies did not interfere as severely with the coding of object identities as object locations and object perspectives. With these particular strategies, segmentation of the map during the encoding process might very well introduce fuzziness into the locational coding of landmarks and streets. Even though the map was presented in segments, however, individual map objects were not fragmented, which may have enhanced the ability to encode object identities. Furthermore, the poorer coding of object perspectives could have resulted from a filtering process in which only the most important object characteristics were coded.

" . . . subjects found landmark displacements and street reversals easier to recognize than street displacement and landmark reversals."

These speculations, of course, do not explain why subjects found landmark displacements and street reversals easier to recognize than street displacements and landmark reversals. There are two plausible explanations for these results. First, the pictorial landmarks and street segments on the map presented considerably different types of graphic information. Symbols were easily recognizable, isolated objects; streets, on the other hand, were graphically abstract and were most likely perceived as an integrated network of segments rather than as isolated lines. If the streets were seen as a network, then the displacement of a street would have been less perceptible than the displacement of a symbol, especially since street displacements only violated street relationships. The difference in responses to reversal foils may lie in the way reversals were implemented for symbols and roads. For symbols, perspective reversal was accomplished by producing a mirror-image of the symbol; for streets, segments were reversed by alternating line thickness to approximate a reversal characteristic. Perhaps the alternation of line thickness was simply easier to detect than mirror-images of symbols.

CONCLUDING REMARKS

In this age of computer display systems, the variety of potential presentational strategies for maps compels us to evaluate their effectiveness carefully. Three possible presentation strategies were examined in this study for their effectiveness in encoding and remembering a simplified map consisting of a street network and pictorial landmark symbols. Results of the study, in contrast to the work of MacEachren (1992), indicate that subject performance of a simple recognition task was worst for subjects who used a Path-based learning strategy to study the target map. This suggests that this method of encoding, at least for recognition tasks emphasizing point locations, may pose disadvantages for completing the task with high levels of accuracy. Subjects who studied the map using a Landmark-based learning strategy, on the other hand, produced responses that did not differ significantly from subjects who studied the map using the Static Map learning strategy. It might be hypothesized, then, that *Landmark-based Learning* is a viable map encoding alternative given this comparability in levels of accuracy for task responses. Of

" . . . Landmark-based learning strategy . . . produced responses that did not differ significantly from subjects who studied the map using the Static Map learning strategy."

course, additional research is needed before such a hypothesis could be fully accepted. For instance, it would be particularly interesting to assess the applicability of these encoding processes for a variety of map reading tasks, as well as for encoding a variety of map types.

The study did not find any gender-based differences in the ability to use these encoding strategies to learn map-based spatial information. This lack of significant difference should be viewed as a positive finding for the discipline of cartography. An established difference in the cognitive ability of males and females to complete map-based tasks would certainly make the job of producing effective maps for the general population much more difficult. More gender-based studies should be conducted in cartography, however, before such findings are considered a foregone conclusion. Map use requires a variety of spatial abilities, and cartographers have not yet conducted a sufficient number of studies that establish what role gender plays in these activities as a whole.

The significant influence of Map Object on subject responses creates several new questions for cartographers in the realm of spatial cognition. Maps consist of multiple graphic elements; the suggestion that their individual characteristics may be processed differently indicates a need to assess how the map reader interacts with each of these element types. Research that investigates the mental processing of map elements, both individually and as a complete spatial unit, may shed more light on this finding. The cognitive processes essential to acquiring , storing and using map information are still not clearly understood. As computer technology continues to evolve, cartographers will need to gain a more comprehensive understanding of these cognitive processes if we hope to make a successful transition into the digital environment.

ACKNOWLEDGMENTS

I am indebted to the following organizations for their monetary support: the National Science Foundation, Grant SBR-9500196; Sigma Xi's Grants-in-Aid of Research; and the University of South Carolina, Educational Foundation Student Research Fund. I am also grateful for the support and advice I received from Dr. Patricia Gilmartin, Dr. Robert Lloyd,Dr. Theodore Steinke, and Dr. Robin Morris.

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