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Cognitive Style and Cognitive Maps: Sex Differences in Representations of a Familiar Terrain

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Experiments on cognitive mapping demonstrated that males and females exhibit significantly different imagery for topographical domains. Males are particularly aware of routes and connectors and show a superior sense of geometric space. Females are more sensitive to landmarks, and exhibit a more accurate sense of distance.

Cognitive-mapping studies originated from the interests of geographers, environmentalists, etc., who investigated memory for the layout of towns, landscapes and campuses. Subject similarities and differences in ability to sketch maps, estimate distances and find their way about, have led to an interactionist position in that although a functionally similar memory process is at work, discrepancies reveal that no two cognitive maps contain the same features or landmarks or reproduce identical layouts of space. Kirk (1963) has conceptualized this interaction as one in which the *phenomenal environment* is transformed into a distorted version by one's particular *behavioral environment*. Some of the aspects of individuals' behavioral environments are obvious, like the buildings, walks, streets, etc., that are relevant to their lives. But other individual differences are less straightforward. Chase and Chi (1979) found that the four subjects who accurately depicted two roads as a 45° intersection in their maps of Carnegie-Mellon, were students of architecture. All other subjects in the sample normalized the intercept as a 90° angle. Downs and Stea (1973) point out that cognitive maps are always distorted with respect to Euclidean geometry, and thus might be particularly sensitive to individual differences.

Chase and Chi (1979) conclude in a lengthy review of problem-solving

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tasks related to mapping terrains (large and small) such as chess, physics, architecture, that cognitive maps are *constructed* in chunks and organized hierarchically. Individual differences arise at one level because of the nature of the chunks (item information), and at another because of the number of levels in the hierarchy (layout). Further differences arise at the choice of entry into a hierarchical schema. Some subjects, usually the most sophisticated, work in a top-down fashion; others, bottom-up. The greater the number of levels, or the more richly constructed, the greater facility for accurate and rapid processing of complex spatial events. This rule applies in chess (Chase & Simon, 1973), architecture (Akin, 1980) and physics (Chi, Feltovich, & Glasser, 1979).

For this reason, it might be expected that sex differences would be particularly noticeable in mapping three-dimensional terrains, as one of the more robust findings is a male superiority on a number of three-dimensional visual tasks (Harris, 1976; McGuinness & Pribram, 1978). Recent findings by Benbow and Stanley (1980) have demonstrated male superiority in advanced mathematics in very large populations. Male superiority in mathematics is most robust in tests of geometry, less so in algebra, and nonexistent in arithmetic (Dwyer, 1979). Geometry is especially highly correlated to three-dimensional visual problem-solving (Stallings, 1979). Although a number of authors have proposed a social hypothesis to account for these data (e.g., see Nash, 1979), the ubiquitous nature of the male superiority in three-dimensional visual tasks and in geometry as opposed to algebra argue for more inherent differences between the sexes, possibly in the way the brain codes and stores images in three dimensions.

Thus it is likely that sex differences in three-dimensional visualization would emerge in more common situations such as imagery for familiar terrains. The use of cognitive mapping techniques are particularly relevant because this procedure would take 3-D visualization methodology a step beyond the pen-and-paper tests currently employed. Furthermore, an approach comparing subjects known to have dissimilar strategies might also benefit the cognitive-mapping literature, as a central problem in all research on cognitive mapping has been one of methodology.

The simplest approach has been to count items in subjects' maps. Thus Lynch (1960) concluded from his study on people's maps of the Boston Peninsula, Jersey City and Los Angeles that cognitive maps contain five basic elements: paths, edges, modes, districts and landmarks. Other research has also focused on the elements contained in maps and how these relate to what is available to perception. Ladd (1970) found that details are often omitted even when these occur *between* items that are included in the map. Subjects do not always report what they see (Carr & Schissler, 1969). Saarinen (1973), in his study of students' maps of the University of Arizona, found that centrally located buildings were included whereas peripheral buildings were not. He also found that memory for buildings organized in regular or rectilinear fashion was better than for those arranged haphazardly. This apears to aid the pre-existing tendency to "normalize" information in memory (Chase & Chi, 1979). A second methodological approach is that of distance estimation. Cadwallader (1979) points out that there are several techniques for investigating distance estimation: drawing maps, ratio or mileage estimates between landmarks and route or straight-line estimates. Several problems arise with these studies. First, Cadwallader's own data show that these various methods do not correlate strongly with one another. Second, as noted above, the size of the distances involved may be a key factor in whether or not correlations are weak or strong, a point not emphasized sufficiently in Cadwallader's conclusions from his own data. Third, some individuals may show high correlations between responses and others may not.

In other approaches to the problem of distance estimation using short distances like paths or roads, it has been found that the number of turns or bends can affect distance estimation. In general, the less familiar the path, the more distance is overestimated as bends and angles increase (Lee, 1963; Sadalla & Magel, 1980). With familiarity these errors tend to disappear (Briggs, 1973). Experimenters using distance estimation have generally assumed that subjects' responses are related to their imagery for geometric coordinates, but this assumption is not necessarily valid, especially if the estimate is for distance between two points, like the length of a path, or if distances are so great that no vantage or viewpoint is possible without the aid of a map. A true sense of topology can only arise when the subject moves around repeatedly in a terrain which can be explored equally well in several directions. Such a terrain might be a neighborhood or college campus.

In the following experiments subjects were asked to draw maps of the University of California campus at Santa Cruz. This campus is unique for several reasons. First, there are no roads, paths or buildings which are laid out rectilinearly. The layout of buildings and paths also follow the natural contours of the land. Second, the campus is built in a forest of redwood trees. There are few buildings directly visible from any other. Third, because of the nature of the terrain, the layout of the major roads, and the number of steps, the distance between any two major buildings is shorter by foot, or bicycle (with some difficulty). In fact, it is quicker and easier to get around the central campus area by walking than by any other means. Thus, it seemed that student maps of the Santa Cruz campus would provide excellent information on subject's abilities to reproduce geometric space without excessive normalizing errors imposed by a rectilinear organization of buildings and overuse of vehicles. The maps were scored in all the ways outlined above — number of central and peripheral buildings, the number of roads, paths, bridges included, and the measurement of distances between buildings. A new measure was also incorporated, that of superimposing geometric coordinates on subjects' maps and calculating the number of misplaced buildings. This we felt would provide a truer picture of whether or not subjects' imaginal sense of space was geometric or otherwise. It was considered highly likely that male subjects would produce maps quite different from the maps produced by females. However, the direction of these differences can only be predicted with repect to geometric coordinates. Here males are expected to be superior.

Experiment 1

Subjects

Subjects were 18 males and 18 females attending psychology classes at the University of California at Santa Cruz. Of the females, nine lived off campus and nine lived on; of the males, ten lived off and eight lived on. The mean age was 19.3 years.

Apparatus

Subjects were supplied with a 9" × 11" sheet of white paper. An ordinance survey map (1:400) of the same overall dimensions was employed in the scoring procedure.

Procedure

The experimenter supplied each subject with a 9" × 11" piece of paper. Subjects were told that this represented the perimeter of the campus. The subjects were requested to draw a map of the campus and were asked to imagine that a friend was coming to visit and that they were unable to accompany them around the campus. The subjects were given up to 30 minutes to complete their maps; they then filled out a short questionnaire concerning the length of their attendance at UCSC, the buildings they most frequently encountered, whether they lived on- or off-campus, their modes of transportation, major, age, and extra-curricular activities.

Scoring and Results

The maps were scored in the following way. The major buildings were tallied. These included the buildings reproduced by at least nine students of each sex. A tally was also made for the number of roads and paths for each person. Absolute spatial coordinate errors were scored by dividing both the ordinance map and the subjects' maps into 16 equal radial segments. Segments containing the bookstore were aligned and all buildings placed incorrectly in the remaining segments were totalled. This procedure made it possible to score the *relative* orientation of buildings. The main library was taken as the center, as it is on the ordinance map. It was also the only building that all the subjects included on their maps. Only the *major* buildings were scored as being misplaced. Measurements of the distance between the center (the main library) and each major building were obtained on the ordinance map and then applied to the subjects' maps. Scoring the relative deviation to the central target point was then performed by taking the mean of the difference between each subject's placement of each major building and the actual placement of these major buildings on the ordinance map. Finally, extra items were tallied by taking the *total* number of extra items that were included in the subjects' maps.

Because none of these assessments are related, each set of scores was analyzed by t-test for the five variables. When scoring the number of missing buildings, (absolute number) there was no significant sex difference found ($t = .7548$, $p > .20$, $df = 35$). There were significant differences found in the other four variables. These are presented in Table 1.

TABLE 1
Mean Scores and t-values for Males and Females

	MALES	*FEMALES*	*t-value*
Major roads and paths included (absolute number)	11.3888 (sd=3.48)	6.111 (sd=2.54)	5.19 $p < 0.001$
Spatial coordinate errors (absolute number)	4.3888 (sd=2.25)	6.222 (sd=2.69)	2.52 $p < 0.025$
Relative deviation error (mean of differences in inches)	1.7345 (sd=.48)	1.3782 (sd=.44)	2.32 $p < 0.05$
Extra items included (absolute number)	4.3333 (sd=4.30)	7.4444 (sd=4.16)	2.21 $p < 0.05$

The males included many more roads and paths than did the females. The absolute spatial coordinate errors showed males scoring far fewer misplaced buildings than the females. In assessing the relative deviation to a central target point, the females were more accurate, and females included more extra items in their maps.

An analysis of the questionnaire data revealed that the subjects' age, major, whether they lived on or off campus, the length of their attendance, and mode of transportation were unrelated to these results, although one or two subjects who had only been at UCSC for one quarter included very few items on their maps. The subjects almost always included the buildings they had mentioned as the most frequently encountered, such as dormitories and buildings related to curricular activities (i.e., the running track, tennis courts, soccer fields, pinball machines at Kresge College, the computers at Applied Sciences, and the bike trail).

Discussion

It is clear from the results that all students, male and female, were sufficiently familiar with the campus to include most of the major buildings. Thus as a fundamental strategy both men and women paid particular attention to centrally located buildings.

In all other respects the maps were very different. The most striking difference, perhaps, was that the women included so few connectors (roads, paths and bridges) between the landmarks. This could arise either because women do not consider that connectors are as important as the relative location of the buildings, or because they are uncertain about the exact pattern of roads and paths. The emphasis on buildings over roads and paths was further evident in the significantly greater number of peripheral buildings included by women.

Finally, as predicted, men had a greater topographic sense of the campus terrain, placing buildings more accurately with respect to spatial coordinates. On the other hand women demonstrated a more accurate sense of distance. As one might predict that an accurate spatial layout would automatically provide more accurate distances between buildings, this result seems paradoxical. A further analysis of the errors in estimating distances between buildings was carried out, using a college dormitory (Crown College) as referent and tallying all deviations from this point to all major buildings. Females again were found to show more accurate placements of buildings with respect to absolute distance than males ($t = 2.64$, < 0.02). As all subjects underestimated distance, for males 97% of the time and for females 93% of the time, the only possible conclusion is that males tend to constrict space more females while maintaining a more accurate geometric layout. Nevertheless, it is clear from these data that measures of absolute distance do not provide an accurate estimate of geometric layout.

Experiment 2

To determine why females omitted roads, paths and bridges in their maps a further study was carried out. The purpose of this study was to determine whether these omissions were due to memory difficulties or lack of relevance of these items. Subjects were requested to sketch in all possible routes to three campus buildings drawn to scale on an 8″ X 11″ sheet of paper (see Figure 1).

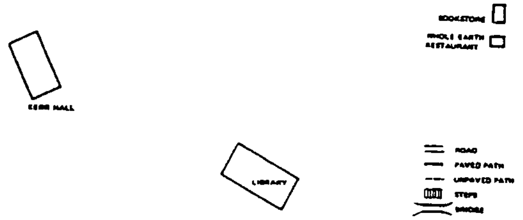

FIGURE 1

Map given to subjects in Experiment 2. Subjects were asked to sketch in all possible routes to the three campus buildings drawn to scale.

Subjects

Subjects (50 males and 50 females) were recruited in classrooms and in various locations on campus by 4 experimenters (2 male, 2 female).

Procedure

Subjects were handed a "map" which contained three centrally located buildings. They were asked to provide information concerning their age, sex, residence, mode of transportation on campus, and number of years (months) as a UCSC student. Next they were asked to draw in all roads, paths, bridges and steps using the symbols provided by the legend (see Figure 1). Subjects were also asked to estimate the amount of time it would take to walk between each pair of these buildings.

Scoring and Results

A detailed map of the roads, paths, etc., was prepared by the four experimenters from an ordinance survey map and from agreed locations of footpaths not on the map. This map was drawn onto a transparent sheet and was used to score the subjects' maps by an overlay technique (see Figure 2). Each subject's score was then assessed for accuracy by two judges independently. Rater reliability was .92 for roads, .94 for bridges, .90 for paved paths, .87 for unpaved paths, and .83 for steps.

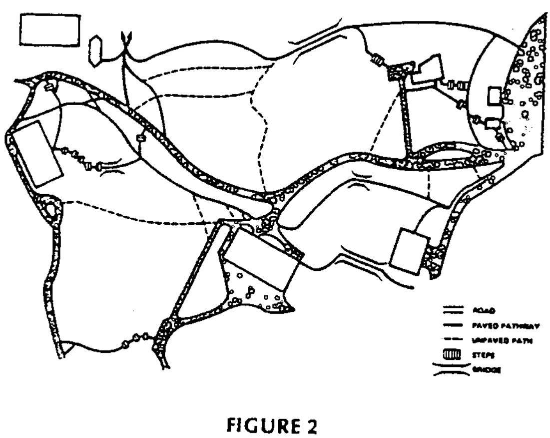

FIGURE 2

Example of the original transparent map used to score subjects' maps.

Of the individual items only the roads and bridges show a significant difference due to sex, with males more accurate. The mean scores show a consistent advantage for males over all conditions, and the total score combining all connectors shows a significant effect due to sex (see Table 2).

TABLE 2
Mean Scores and Statistical Values for Males and Females for the Number of Items Correctly Represented

	$\bar{X}$ M	$\bar{X}$ F	t	p 1-tail
Roads	3.14	2.43	2.37	<.01
Bridges	1.43	1.09	1.79	<.05
Paved paths	5.01	4.35	1.31	N.S.
Unpaved paths	1.41	1.03	1.36	N.S.
Steps	2.82	2.47	.78	N.S.
Total	13.82	11.37	1.79	<.05

For those students who filled in the question items concerning time to walk between the buildings ($F = 49, M = 43$), the preferred mode for 74% of the females was walking; 18% took the mini-bus, and the remaining 8% biked or took their car. For the males, 79% walked, 7% took the bus, 9% biked and 5% drove. Thus the large majority preferred walking.

Though the time-estimation data cannot be objectively assessed due to individual differences in walking speeds, different routes taken, etc., it is interesting nevertheless that the means and variance indicate that males produce lower estimates than females and that they are considerably less variable in their judgment. The lower time estimates could relate to the finding in Experiment 1 that males underestimate distance considerably more than females.

TABLE 3
Mean Time Estimation, Range, and Standard Deviations for Males and Females for Three Distances

	Kerr - Library			Library - Bookstore			Bookstore - Kerr		
	$\bar{X}$	range in minutes	S.D.	$\bar{X}$	range in minutes	S.D.	$\bar{X}$	range in minutes	S.D.
MALE	4.01	1½ - 10	1.60	4.56	2 - 9	1.72	7.83	3 - 15	2.53
FEMALE	4.41	2½ - 8	1.69	5.38	1 - 12	2.44	9.07	2½-17½	3.48

Discussion

The large reduction in the levels of significance ($p = 0.0001$ to $p = 0.05$) for connectors between Experiment 1 and Experiment 2 illustrates that females do know where some of the routes are located but do not tend to include them in their maps unless specifically requested to do so. The results for roads and bridges also indicate that *even* when instructed, females are not as accurate as males. For females, it appears that connectors, especially roads, are not only not relevant in maps, but are also less memorable.

Further support for this conclusion came quite independently, when an international town planner described his experience with students during 20 years of teaching town planning (Galantay, 1981). Females typically began their plans by delineating areas for specific purposes (residential, factory, school, etc.) and later connecting the buildings with roads, or omitting them altogether. Males more often did the reverse and began by carving up the site with a grid of roads — arranging the buildings as a secondary consequence of the road system. It turns out that both of these extremes are ineffective strategies. Although Galantay's observations have yet to be quantified, they do suggest that the female's approach to organizing topographic space operates from principles of grouping (proximity) whereas the male approach is to establish a set of coordinates, for example, the road system, along which efficient motion is maximized. One reason, therefore, why males show a superior sense of topography might be because they frame space by the layout of roads and paths.

General Discussion

If subjects, male and female, are equally familiar with pathways (Experiment 2) and major landmarks (Experiment 1) and spend equal amounts of time traversing identical routes, then their representations ought to be similar. That they are not appears to be entirely due to the nature of the constructional process involved: Females focus more on the landmarks and the distance between individual elements, and males focus more on the topographic network of roads and other connectors which provide a geometric framework for the location of buildings.

The results lead to certain qualifications for the theories on cognitive-mapping. First, Lynch's (1960) suggestion that item information consists of five basic elements — paths, edges, nodes, districts and landmarks — is more appropriate when applied to males. Many females omitted the first three items from their maps entirely. Second, while distance estimation can operate to produce an approximation to a three-dimensional arrangement of landmarks, it is not a useful index of three-dimensional space. Imposing geometric coordinates is not only more accurate but a far simpler methodology.

It might be speculated that females produce their maps by a local sense of grouping and proximity (what lies before, behind, next to) rather than by a meta-level analysis of an overall structure or pattern. Applying the theorizing of Chase and Chi (1979) to this approach, females seem to adopt a bottom-up strategy in that the map proceeds from part to whole. The item information largely consists of buildings and landmarks which are represented more extensively in the women's maps. Because the item information for most males begins at the level of roads and connectors, this axiomatically produces a more top-down strategy.

We have just begun to explore this hypothesis in more detail, by videotaping students drawing maps at the blackboard. Students who drew the most accurate maps most typically began by framing the entire space with the peripheral road system. We had assumed that this strategy utilized a specific type of imagery, essentially the ability to adopt a "bird's eye" perspective. So far our results have not confirmed this view. The most efficient cartographers turned out to be those students who had most internalized their experience. The two students who drew nearly perfect maps were both male and mathematicians. When asked to give verbal reports of their imagery, they were unable to do so. When asked to report on where they were in their imagination, both replied: "Standing here in this room." This was in dramatic contrast to the 10 remaining subjects who gave extensive reports of their imagery but who drew very inaccurate maps. We would suggest in accord with Chase and Chi, that good cartographers use a top-down strategy in which the apical level contains or enfolds the entire map, in much the same way that an expert chess player perceives the pieces on the board as a single chunk of information.

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