

Original Article

## Non-Euclidean Navigational Strategies Of Women: Compensatory Response Or Evolved Dimorphism?

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**Abstract:** The proposition underlying this study was that females' use of topographical, rather than Euclidean navigational strategies emanate from a separate evolved mechanism rather than a compensatory response due to lesser Euclidean abilities. In support of this contention, it was found that, in terms of ontogenetic development, females' advantages in object location memory emerged during the same age interval as their greater use of a landmark route learning strategy, while the male advantage in Euclidean abilities appeared during the same age interval as their greater use of an orientation route learning strategy.

**Keywords:** Navigation, Route learning, Sex differences, Object location recall, Euclidean abilities.

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### Introduction

It has been well established that in route learning and other navigational tasks, males tend to employ a Euclidean, or orientation, strategy, featuring distances, vectors, and cardinal directions (e.g. north, northeast, 90 degrees). Females, on the other hand, are more inclined to use a topographical, or landmark strategy, comprised of landmarks and relative directions (e.g. right, left, in front of, behind) (e.g. Dabbs et al., 1997; Joshi, MacLean and Carter, 1999; Lawton, 1994; McBurney et al., 1997; Moffat et al., 1998). One interpretation (Galea and Kimura, 1993; Lawton, 1994; Miller and Santoni, 1986; Moffat et al., 1998), stemming from the observation that males generally outperform females in Euclidean based spatial tests (see Kimura, 1999), contends that the female's use of topography is a compensatory response. An alternative interpretation, however, was proposed by Choi and Silverman (1996), based on Silverman and Eals' (1992) theory of spatial sex differences as an evolved

dimorphism, related to the ancestral division of labor between sexes as hunters and gatherers.

Basic to Silverman and Eals' theory (1992) is the premise that Euclidean spatial skills were essential for successful hunting, which entails searching for and tracking prey across unfamiliar territory while maintaining the necessary spatial orientation to take a direct route home. They proposed that if spatial attributes associated with hunting evolved in males, spatial specializations that facilitated food gathering may have similarly evolved in females. Successful food gathering, the authors surmised, requires locating edible plants within diverse configurations of vegetation and relocating them in ensuing growing seasons; that is, the capacity to rapidly learn and remember the contents of object arrays and the relationships of objects within these arrays to one another.

In support of their theory, Silverman and Eals (1992) predicted and found that females consistently surpassed males in spatial tasks that mimicked those involved in the gatherer role; specifically, incidental and directed learning of objects and their locations. These findings have been replicated in a number of research designs (e.g. Eals and Silverman, 1994; Dabbs et al., 1998; McBurney et al., 1997; McGivern et al., 1997). Silverman et al. (2000) also confirmed that males prevailed over females in a task requiring wayfinding by orientation in a forested area; that is, following the experimenter on a winding, random path while remaining cognizant of the most direct route back to the starting point, with no visible landmarks to serve as a guide.

Following upon Silverman and Eals' (1992) theory, Choi and Silverman (1996) reasoned that males use vectors and distances in route learning because they are better able to maintain a Euclidean or "birds-eye" perspective of their route, while females correspondingly use landmarks because they have superior visual memory of objects and their relative locations in their proximate environment. Sex differences in the use of cardinal vs. relative directions would also follow from this analysis. Cardinal directions are critical for a Euclidean orientation strategy, such that they allow the user to project directions in relation to fixed points on the planet. The use of relative directions, however, would better serve a topographical landmark strategy, in that it would facilitate visual recall of landmark locations, in relation to each other and to the viewer.

Support for this interpretation resided in Choi and Silverman's (1996) finding that performance on map learning tasks was positively related to the use of Euclidean strategies for males only, and topographical strategies for females only. Saucier et al. (2002) reported like findings for both laboratory and field navigational tasks, in which participants were required to use either an orientation or a landmark strategy. Males did better when using the former, while females had higher scores with the latter.

On the other hand, a problem does exist in explaining human sex differences in navigational strategies in terms of the hunter-gatherer theory, in that it cannot readily account for the findings that infrahuman animals feature the same sex-specific strategies as people. When navigating in radial-arm mazes, male rats are

capable of using distal cues such as the shape of the room, while females require landmarks (Williams et al., 1990; Williams and Meck, 1991).

Ecuyer-Dab and Robert (2004), however, proposed a theoretical model, based on an integration of Gaulin and Fitzgerald's (1986), Silverman and Eals' (1992), and their own theories, that pertains also to species that are not divided by sexes into hunters and foragers. They pointed out that Gaulin and Fitzgerald (1986) demonstrated an adaptive value of an orientation strategy beyond hunting ability, specific to males of polygynous species, which is the capacity to maintain larger home ranges in which to seek mating opportunities. They also provided and documented a unique interpretation of the selection factors underlying the evolution of a landmark navigational strategy in females, that the primary factor was the need for physical security for themselves and their offspring, with increased abilities for food gathering representing a by-product. According to the authors, a landmark strategy bears a lower risk of getting lost, renders it easier to learn potential escape routes, and enables one to detect small changes in the environment which may signal the presence of a predator or other source of danger.

Based on this inclusive theory of evolutionary origins, the present study attempted a further test of the dual mechanisms hypothesis in humans, using a developmental approach. Male and female participants, aged 9 to 17 years, were tested on route learning strategies, object location memory, and Euclidean based spatial abilities. Hypotheses were that the increased use of an orientation strategy by males, relative to females, would begin at about the same age as their corresponding increase in Euclidean abilities, while the increased use of a landmark strategy in females, relative to males, would begin at about the same time as their corresponding increase in object location memory.

An ancillary test of the dual mechanism theory was based on individual differences within sex groups, across ages. The hypotheses were that object location memory would be positively correlated to the use of topographical strategies for females only, and Euclidean abilities would be positively correlated to the use of Euclidean strategies for males only.

## **Method**

### *Participants*

The present study comprised a secondary analysis of data from two prior studies, one with primary and the other with secondary school students (Choi and Silverman, 2003). Tests of the present hypotheses were based on the combined sample, but included only those tasks that were used in identical form in both studies.

The data from five hundred and eighty-one participants were used, grouped by age: 9-11, 12-14, and 15-17 years, with respective ns by sex of 68, 104, and 136 females and 65, 108, and 100 males. Tests had been administered in individual classes of about 20 to 30 by teams of graduate research assistants. All participants

had been informed that the tests were intended for group research purposes only, and permissions were obtained from both students and parents. Students were given token rewards for their cooperation.

### *Tests*

*Route learning strategy:* Following the method of Choi and Silverman (1996), two maps were used. Each depicted a fictional town with streets and landmarks throughout, and contained a compass indicator and distance scale. For each map, participants were told they would have two minutes to silently learn the shortest route from a marked point of origin to a marked destination and would then be allowed an additional two minutes to provide written directions to an imaginary friend from memory. The routes were simpler than those of Choi and Silverman (1996) to accommodate the younger subjects.

For each respondent, frequencies across the two maps were calculated for distance and landmark references, and for cardinal and relative directions. Frequencies were then converted into standardized (*z*) scores for each of these four distributions, with the zero point for each distribution set at the mean across all ages. This was done in order to give equal weight to the two frequency measures that were then combined to create each of the route learning strategy scores (distance references plus cardinal directions for Euclidean strategy use and landmark references plus of relative directions for landmark strategy use).

*Object Location Memory:* Silverman and Eals' (1992) group test was used. Respondents were instructed to examine a pictorial array of 27 objects for one minute and were subsequently presented with another array containing the same objects with positions switched between 7 randomly selected pairs. They were allowed one minute to circle the objects that were in the same place and put a cross through the objects that had been moved, with the measure of location memory represented by the number of correct responses minus the number of incorrect responses. Thus, the range of possible scores was 1 to 14.

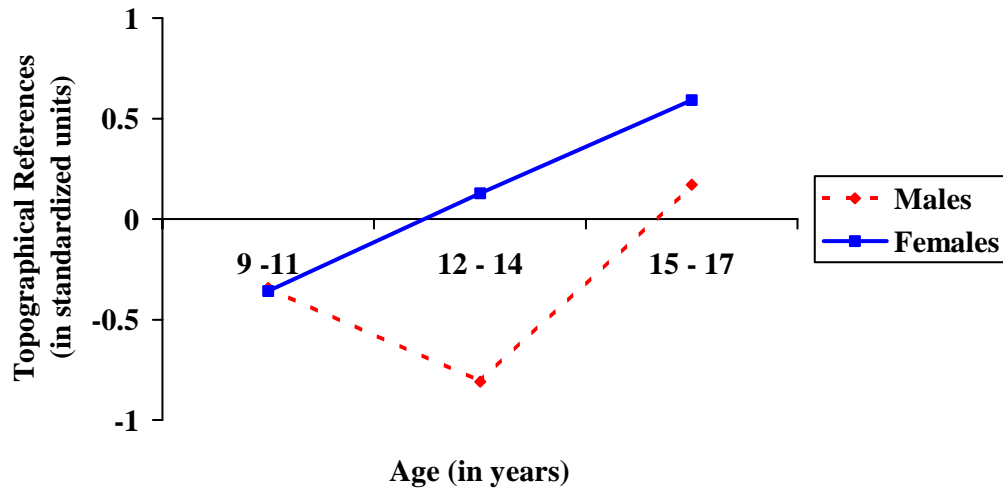
*Euclidean abilities:* The version by Akiyama et al. (1985) of the original water line task by Piaget and Inhelder (1967) was used. This consisted of a drawing containing 12 identical bottles, six suspended over horizontal stands and six suspended over stands tilted at 45 degrees. For each set of stands, one bottle was upright and the other five were tilted at degrees ranging from 45 to 180 degrees. Respondents were instructed to draw a line through each bottle to indicate how it would look if it was half full of water, and responses were considered correct if the water line was within 7 degrees of a horizontal line. The number of correct responses comprised the score, with a possible range of 0 to 12.

## **Results**

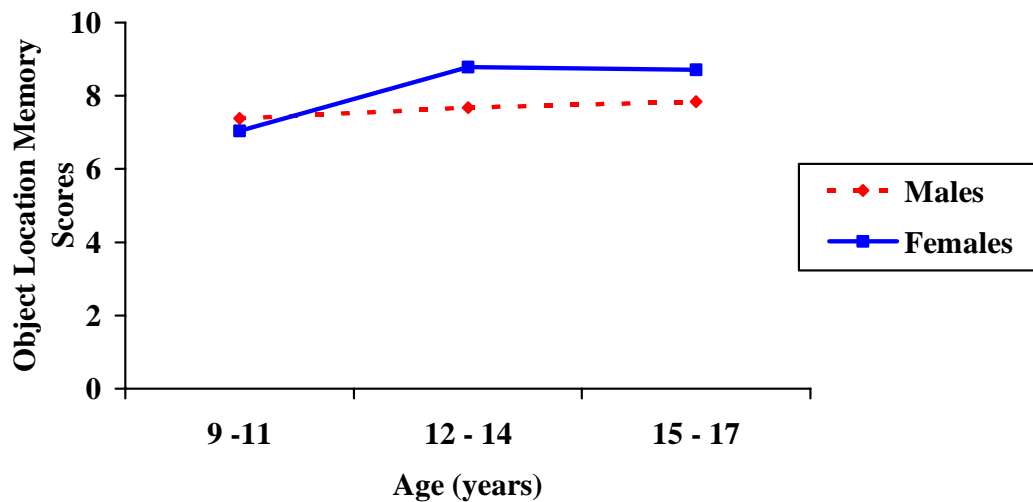
Figures 1 and 2 show, respectively, mean scores for topographical strategy use

and object location memory. Figures 3 and 4 show, respectively, mean scores for Euclidean strategy use and the water line task. All distributions are presented by sex and age. Results for individual ANOVAs are presented in Table 1.

**Figure 1:** Mean topographical strategy use (landmark references and relative directions), in z scores, by sex and age.



**Figure 2:** Mean object location memory scores by sex and age.



**Table 1:** Analysis of Variance (ANOVA) and Simple Effects for Topographical and Euclidean Navigational Strategy Use, Object Location Memory, and Water Line Performance, by Age and Sex.

<b>ANOVA</b>				
Source (df)	Topographical Strategy <i>F</i>	Object Location <i>F</i>	Euclidean Strategy <i>F</i>	Water Line <i>F</i>
Sex (1, 575)	13.59*	4.11*	22.20*	15.21*
Age (2, 575)	17.94*	5.60*	6.39*	56.60*
Age x Sex (2, 575)	4.78*	2.34	1.07	2.07

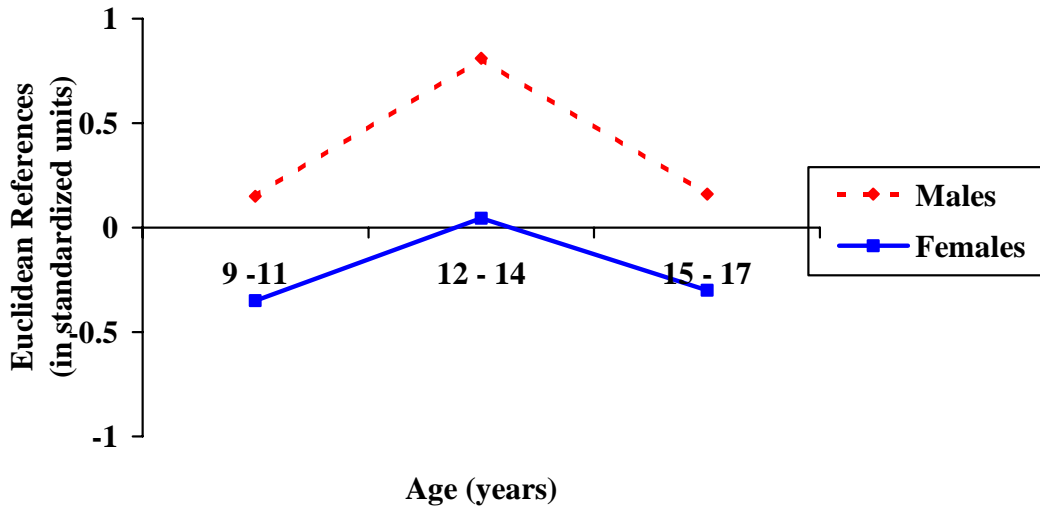
<b>SIMPLE EFFECTS FOR SEX BY AGE</b>				
Age (df)	Topographical Strategy <i>t</i>	Object Location <i>t</i>	Euclidean Strategy <i>t</i>	Water Line <i>t</i>
9 - 11 (131)	.08	.56	2.02*	4.02*
12 - 14 (210)	5.18*	2.43*	3.53*	.79
15 - 17 (234)	1.96*	2.41*	2.79*	2.40*

\* $p < .05$

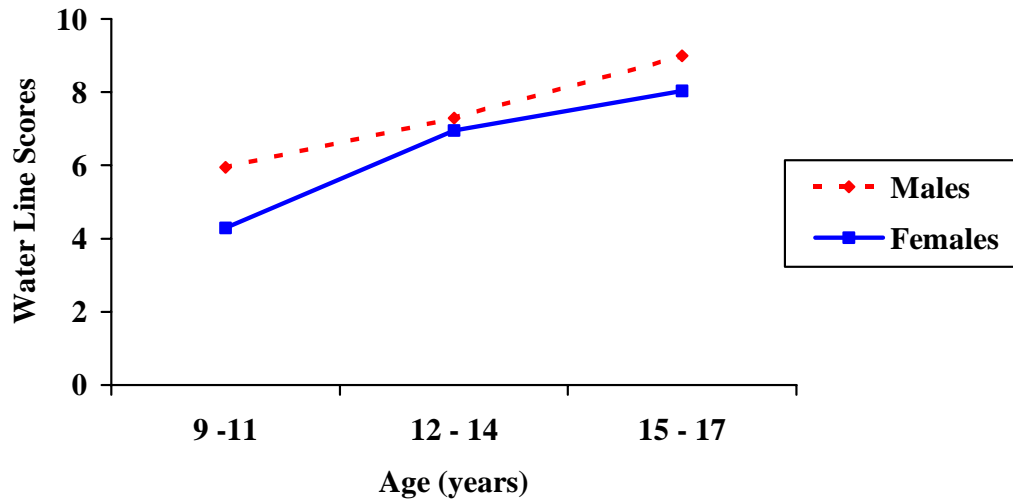
As predicted and depicted in Figures 1 and 2, greater topographical strategy use and higher object location recall scores by females, relative to males, both emerged during the same age interval, which was 12-14 years. Table 1 shows that for topographical strategy use, interaction effects for sex by age were significant. Simple effects showed significant sex differences in both the 12-14 and 15-17 age ranges, while sex differences for the 9-11 group were not significant. For object location recall, the sex by age interaction term narrowly eluded significance, but the pattern of simple effects was the same as for topographical strategy use. There were significant differences favoring females for both the 12-14 and 15-17 year groups, and no differences for the 9-11 group. Thus, following Wilcox's (1987) reasoning, the simple effects analyses were considered valid indicators of the significance of the trend, in this case.

As shown in Figures 3 and 4, the predicted complementary trend for the emergence of sex differences in Euclidean strategy use and Euclidean abilities was not directly supported, though strongly implied.

**Figure 3:** Mean Euclidean strategy use (distance references and cardinal directions), in z scores, by sex and age.



**Figure 4:** Mean water line scores by sex and age.



Following Table 1, there was a significant main effect of sex favoring males for Euclidean strategy use, and the simple effects analyses showed that this difference

was maintained for all three age groups. The same trend and main effect of sex was observed for the water line test, suggesting that the male advantage between sexes on both measures began at or prior to the earliest age interval of 9-11. This pattern was consistent with predictions, with the exception that simple effects for the water line test were significant for the 9-11 and the 15-17 age groups, but not for the 12-14 year olds.

The predicted patterns of correlations across age groups were also found. Pearson  $r$ s for water line scores and Euclidean strategy were positive and significant for males ( $r = .22$ ,  $N=273$ ,  $p < .001$ ), but not for females ( $r = .06$ ,  $N=308$ , ns), while correlation coefficients for object location recall scores and topographical strategy were positive and significant for females ( $r = .28$ ,  $N=308$ ,  $p < .001$ ), but not for males ( $r = .05$ ,  $N=273$ , ns).

## **Discussion**

The dual mechanism theory underlying the present hypotheses was supported by the correlational comparisons, and by the developmental data in females. Though the significant correlations, in themselves, did not suggest a large effect, the patterns for both males and females conformed precisely to predictions. For the developmental data, the observation that the female advantage in object location recall emerged during the 12-14 age range is also consistent with Silverman and Eals' (1992) prior findings.

The developmental data for males suggested that their increases in both Euclidean abilities and the use of Euclidean navigational strategies began at or earlier than the age interval of 9-11, which was also compatible with the hypothesis that these would emerge at about the same time. As well, it is consistent with Linn and Petersen's (1985) observation that the male advantage in water line test performance occurs in children as young as 8 years. The flaw in the present findings, however, was the closing of the gap between males' and females' water line scores in the 12-14 age group. There is no apparent explanation for this anomaly, particularly in view of the reappearance of the sex difference in the 15-17 group, and it may simply be that the 12-14 year olds were an atypical sub-sample in this regard.

The present study supports the general concept that prehistoric sex role differences are manifest in contemporary, sex-specific, perceptual and cognitive modes. Silverman and Phillips (1998) described the female mode as "a more inclusive attentional style," by which they, "spontaneously attend to a wider range of detail in their physical and social environments" (p. 603). In fact, women do have larger visual fields than do men; that is, they can see farther out on the periphery while fixating on a central point (Burg, 1968). They are also better than men at scanning, excelling in various tests of perceptual speed (Kimura, 1999)

The present data may also provide a novel perspective on the issue of whether and how ontogeny recapitulates phylogeny. Extant approaches (see Gould, 1977) begin with ontogenetic sequela in contemporary populations and attempt to

track their phylogenetic parallels. Here we reversed the process, by proposing linkages of specific developmental events in human evolutionary history from which we derived and successfully tested hypotheses about their ontogenetic parallels.

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