SEX DIFFERENCES IN OBJECT LOCATION MEMORY:
FIXED VERSUS MOVING THROUGH SPACE

by

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ABSTRACT

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Previous studies suggest that females possess superior object location memory than males. The present study investigated object location memory using both static and dynamic tasks. Additionally, the correlation between object location memory and other variables such as spatial self-rating items, MRT, and 2D:4D was examined. Participants were 136 (70 female and 66 male) undergraduates. Results indicated no significant sex differences in the dynamic task, and only one significant main effect for sex in the static task. As predicted, males rated their sense of direction (SofD), and one-trial directional memory (OTDM) significantly superior to females. Navigation preference also showed significant sex differences. Left and mean 2D:4D measures showed significant sex differences. Males left and mean 2D:4D correlated significantly with correctly located objects in both the dynamic and static tasks. Furthermore, we observed significant correlations between males' self-ratings in SofD, OTDM and the number of correctly located objects in the dynamic task.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS ii

ABSTRACT iii

LIST OF TABLES viii

Chapter

1. INTRODUCTION 1
    - Theoretical background 1
        - Environmental theory 2
        - Biological theory 3
        - Evolutionary theory 4
    - Hunter-gatherer hypothesis 5
        - The hunter 6
        - The gatherer 7
    - Purpose of the present study 8
        - Object location memory 10
        - Mental rotation test 10
        - Spatial self-rating 11
        - 2D:4D 11
        - Hypotheses 12
2. METHODS 14

Participants 14

Materials 14

Design 15

Spatial measures 15

Dynamic task 15

Static task 16

Mental rotation test 17

Spatial self-rating 18

2D:4D 18

Digit ratio 18

Procedure 18

3. RESULTS 20

Object location memory 20

MRT and spatial self-rating 21

Correlation matrixes 23

2D:4D 24

4. DISCUSSION 27

Review of results 27

Interpretation of results 28

Limitations of the current study 30

Conclusions 31

Appendix

A. STATIC TEST OBJECTS 34

B. DYNAMIC TEST OBJECTS 39

C. SPATIAL SELF-RATING 43

D. DYNAMIC SPATIAL MEMORY TASK 45

E. STATIC SPATIAL MEMORY TASK 47

F. DEBRIEFING STATEMENT 49

REFERENCES 51

BIOGRAPHICAL INFORMATION 59

LIST OF TABLES

Table Page

3.1 Task means 22

3.2 Spatial measures T-tests 23

3.3 Correlation Matrix for males 24

3.4 Correlation Matrix for females 25

3.5 2D:4D T-tests 26

3.6 Male 2D:4D correlations 26

3.7 Female 2D:4D correlations 27

CHAPTER 1

INTRODUCTION

Sex differences in certain cognitive abilities are well documented. For example, research shows that females generally perform at higher levels than males on tasks involving verbal fluency, reading comprehension, and facial emotion processing (Halpern, 1992; McClure, 2000; Notman & Nadelson, 1990). On the on the other hand, males outperform females on visual-spatial tasks (Wiess, et al., 2003) and tests of mathematical achievement (Halpern & Lamay, 2000). A more generalized research finding demonstrated gender-based *variance* differences in cognitive performance, with females showing less variability in IQ scores than males (Fisher, 1998).

Theoretical background

Few findings have been as reliable or robust as the sex differences in spatial ability. Traditionally it was believed that males possessed overall superior spatial ability. However, recent research has shown some spatial tasks tend to favor males, whereas others favor females. Males tend to outperform females on spatial tests such as mental rotations (Levy & Heller, 1992; Silverman & Eals, 1992; Vandenberg & Kuse, 1978 Voyer, Voyer, & Bryden, 1995) and space relations that require manipulations and transformations of figures and forms (Bennett, Seashore, & Wesman, 1947). Females have been shown to possess superior object recall (Kimura, 1999), and appear to be better at the encoding and retrieval of object locations from within complex arrays

(Silverman & Eals, 1992), and on other similar object location memory tasks (McBurney, Gaulin, Devineni, & Adams, 1997). Many theories have been proposed to account for the pervasiveness of sex differences in spatial abilities.

Environmental theory

If adults perform significantly better than children on spatial tasks it could be argued that experience plays a key role in spatial memory. Consequently, any observed sex differences in spatial ability could be attributed to learning, and not inherited. This argument is not very convincing, as young children are not yet able to cognitively perform the same complex spatial tasks as adults. For example, Hargreaves and Colley, (1987) found inconclusive results on spatial studies conducted on young children, and postulated that significant results depended on the complexity of the task, rather than the aptitude of the child. It then becomes very questionable if the same spatial ability is actually being tested.

Matthews (1986) found that young boys possess greater awareness of space by being able to recall far-off places better than girls of the same age. Matthews hypothesized that socialization and gender role expectations play a significant role in how young boys and girls develop different spatial skills. A meta-analysis by Signorella and Jamison (1986) found that individuals whose self-descriptions include many stereotypical masculine traits perform better on spatial tasks. However, contrary evidence suggests that sex differences in spatial ability appears to manifest very early in childhood. A study by Levine, Huttenlocher, Taylor, and Langrock (1999) found a significant male advantage on a spatial transformation task by four and half years of age. Other research found a male advantage in constructions of 3-D models (Siegel & Schadler, 1977) and interpretation of space (Uttal, Gregg, & Chamberlain, 1999) in kindergarten-aged children. These findings suggest that the observed sex differences in spatial ability are not simply due to differential experience or socialization as suggested (Baenninger & Newcombe, 1989), but instead reflect an evolved, internal gender-differentiated mechanism.

Biological theory

There is no arguing that males and females are biologically different. Indeed, modern neuroscience has revealed that these differences extend to the finer functioning mechanisms of the brain (Kimura, 1992). For example, the left hemisphere has dominance on language-oriented tasks, whereas the right hemisphere on spatially oriented tasks. Research indicates that males tend to use the right side of their brain more than females when performing mental rotation and other spatial tasks (Hamilton, 1995; Levy, 1971). This suggests a sex difference in hemispheric asymmetry.

The idea that the sex hormones estrogen and androgen are the cause of the observed sex differences in spatial ability and memory has been proposed. Kimura (1992) found that females with high levels of testosterone perform better on certain spatial tasks than females with low levels of testosterone. On the other hand, increased levels of testosterone did not effect male performance significantly. Alternately, Choi and Silverman (1996) proposed that estrogen in high levels would have the opposite effect. A study conducted by Silverman and Phillips (1996) found significantly higher mental rotation scores in females who were in their menstrual period phase, during which time estrogen levels are at their lowest. Other similar hypotheses such as rate of maturation (Sanders & Soares, 1986; Waber, 1976), and sex hormones (Neave, Menaged, & Weightman, 1999) have been proposed. Although many of these biological explanations answer proximate questions, taking an evolutionary perspective leads to speculation about the ultimate function of sexually selected spatial skills.

Evolutionary theory

Strong evidence exists that an evolutionary explanation is well-suited to explain sex differences in spatial ability. Sex differences in spatial ability are not limited to humans; a male superiority in spatial learning has been established in other mammalian species such as, deer mice (Kavaliers et al., 1996), rats (Bucci, Chiba, & Gallagher, 1995), and rhesus monkeys (Lacreuse et al., 1999).

Gaulin and Fitzgerald (1986, 1989, 1990) studied the mating systems of three species of polygynous meadow (*Microtus pennsylvanicus*) and pine voles (*Microtus pinetorum*). The male meadow voles' reproductive strategy is one in which they defend and hunt large home ranges; males defend large home ranges that encompass the territories of several females. This has resulted in selective pressure for superior spatial ability, and predictably Gaulin and Fitzgerald found that male meadow voles possess greater spatial ability than the female voles. Conversely, pine voles which have smaller home ranges did not perform as well as meadow voles, and needed twice the training to achieve comparable results. The observation of these sex differences across a variety of species leads to the suggestion that the sex differences in spatial ability in humans and nonhumans may share a common evolutionary basis related to ranging and hunting in the environment.

There is no “one” universally accepted evolutionary theory to account for the apparent sex differences in spatial ability. In fact, a number of conceptually distinct evolutionary hypotheses such as female choice (Sherry & Hampton, 1997), male warfare (Geary, 1995; Sherry & Hampton, 1997), and range size (Gray & Buffery, 1971; Gaulin, 1995) have been proposed. However, it should be noted that these different evolutionary theories should not be viewed as mutually exclusive, because spatial ability is not a unitary ability and is likely to integrate several different cognitive abilities (Linn & Petersen, 1985).

Hunter-gatherer hypothesis

The hypotheses of the current study were based on Silverman and Eals’ (1992) hunter-gatherer hypothesis, one of the proposed evolution based hypotheses explaining sex differences in spatial abilities. According to this theory, the critical element for the spatial dimorphism in humans was the sexual division of labor between hunting and gathering in early man. Data from archaeological studies looking into the history of prehistoric man strongly suggest that, across evolutionary time, males mostly hunted whereas females predominately foraged (Tooby & De Vore, 1987). In fact, this division of labor can still be observed today in the primitive tribes of South America and on the African continent (MacDonald & Hewlett, 1999).

Moving across vast distances to track and kill prey requires different kinds of spatial skills than does foraging for edible and useful items in plant-based environments. The cognitive mechanisms of modern man appear to emulate these evolved differences, in that the varied spatial measures showing male and female biases imitate attributes that would enable successful hunting or gathering.

The hunter

A large part of successful hunting involves wayfinding, goal-directed navigation in which the hunter must adopt a strategy to find a target location (Gerber & Kwan, 1994). If one is to track prey over vast terrain, it is imperative to develop an effective spatial orientation strategy that will enable one to return home after a successful hunt. Therefore, for males, attributes such as skill in navigation, the ability to orient oneself in relation to objects or places, and the capacity to estimate distances accurately, are all necessary skills for the successful hunting of prey.

Human males do report the use of an orientation strategy when navigating, which involves the utilization of a Euclidean representation of space (cardinal directions, and exact distances). Sex differences in navigation have been examined using paper-and-pencil tasks (Dabbs, et al., 1998), virtual environments (Moffat, Hampson, & Hatipantelis, 1998), and natural environments (Silverman, et al., 2000; Malinowski & Gillespie, 2001). In all instances, males performed better than females, completing the tasks more quickly or with fewer errors. The underlying evolutionary implication here is that superior hunters were more successful in passing on their genes than inferior hunters. An alternative mating strategy in which some males stayed with the females to help with foraging has been proposed. Evidence for this theory is limited, and should be further investigated.

The gatherer

On the other hand, it seems reasonable to speculate that spatial specializations associated with foraging should have also evolved concurrently in females. The female foraging hypothesis postulates increased recognition and recall of spatial configurations of objects. In other words, the capacity to quickly remember the content of objects arrays and their location in relation to other similar objects. Females perform significantly better than males in both a pencil-and-paper format, naturalistic settings, and in three dimensions on tasks for object location memory (Eals & Silverman, 1994; Silverman & Eals, 1992). These findings have been elaborated in research by McBurney, Gaulin, Devineni, and Adams (1997), who found that females performed significantly better than males on a memory task designed to emulate the cognitive demands of foraging[1].

A further expansion of the Silverman and Eals (1992) hunter-gatherer hypothesis is that foraging success in females should be enhanced by peripheral perception and therefore resulting in superior incidental memory for objects and their locations. Their rationale for this hypothesis is that, for successful gathering to occur, it would be of great advantage to absorb information non-purposefully while walking around and performing other routine daily tasks. The literature appears to support this hypothesis: the female advantage in object location memory tasks is most pronounced under incidental test conditions (Eals & Silverman, 1994; Silverman & Eals 1992).

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[1] The memory game “Uno” was used as the spatial memory task.

Purpose of the present study

The current study follows the lead of Silverman and Eals (1992) in recognizing the potential importance in our ancestral past of hunting and foraging tactics in the evolution of sex-specific spatial abilities. Although, the evidence for sex differences in certain spatial tasks is well-documented, there have been inconsistent findings (Jones, Braithwaite, & Healy, 2003). Although the female advantage has been demonstrated for object location tasks, the majority of this research has been conducted under static (seated or immobile with all to-be-remembered items in view from that fixed perspective) conditions. To the best of our knowledge, the closest attempts at a dynamic object location memory task are studies by Tottenham et al. (2003) and Iachini et al. (2005).

Tottenham and colleagues devised a computerized 3-D version of the game Concentration to create a dynamic task of object location memory. In their study, the dynamic task was created by giving an illusion of depth perception while selecting test items during the course of completing the concentration game. Females outperformed males in object location memory regardless of the nature of the presentation environment (2-D or 3-D).

A recent study by Iachini et al. (2005) created an object location task in which participants were able to freely explore numerous objects in a cylindrical room. All participants were directed to try and remember objects and their specific locations, and were allowed to take as much time as needed to complete memorization. The study showed no sex differences in object recognition, or in estimating the absolute distance of objects. Although the study created a dynamic task in which to examine object location memory, it was still limited by the fact that the area of movement was relatively small (a diameter of 3.5 meters). Furthermore, the study tested all participants in under directed condition.

The present study sought to further extend the study of object location memory by using a dynamic task beyond the use of computerized 3-D programs, and a confined setting which, while helpful, may not capture the true nature of actually moving through space in a natural environment. Unpublished initial research by Velarde and Mellgren (2003) found no significant differences between males and females in a directed dynamic object location memory task (participants were asked to remember the location of items after navigating several hallways of an academic building), and in an expanded study, males in fact outperformed females[2] (Velarde & Mellgren, 2004). However, we suspect that the results were significantly affected by the task order in the study, because participants completed two different spatial memory tasks upon completion of navigating the hallways. In addition, the two previous studies only tested participants under directed conditions.

The present study also sought to investigate the relationship between performance on a mental rotation test, perceived spatial ability, 2D:4D ratio, and object location performance in both dynamic and static tasks. Previous research has found a correlation between navigation performance and mental rotation scores (Silverman, et

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[2] The male advantage was not statistically significant.

al., 2000). I wish to explore other correlates (like MRT) that might explain or account for the variance in the observed sex differences in object location memory.

Object location memory

Silverman and Eals found that females possessed superior object location memory for both common (1992) and uncommon objects (1994). Object location memory is typically studied by asking participants to learn presented objects and afterwards to reproduce from memory the original locations of the objects, or to determine if objects have changed positions. In the current study, all objects are presented indirectly (participants are not told which objects will be tested), and all objects are presented as clear color images, and locations marked with an "X" on a depicted route map or photographic view a room. Participants are evaluated on the number of object correctly located, errors (objects incorrectly located), and objects indicated as "no recollection". An exact measure will also be used in the present study such that the distance between where the participant locates the object and the exact location of the object will be measured (absolute difference).

Mental rotation test

The mental rotation test (MRT) has demonstrated one of the largest and most consistent sex differences favoring males (Casey, 1996; Kimura, 1999; Stumpf, 1998). Because MRT yields sizeable and replicable sex differences (Peters, et al. 1995; Voyer, et al. 1995), it was included so that I could test to see if any relationships exist between MRT, object location memory, spatial self-ratings, and 2D:4D ratio.

Spatial self-rating

Because males report the use of cardinal directions more than females (Lawton, 1994; Ward, Newcombe, & Overton, 1986), I expected their perceived sense of direction and one trial directional memory ratings to be higher. Females are expected to rate their item location ability (e.g. find small things around the house) higher than males. In addition, because females are more likely to report the use of landmarks while navigating, I expected females to prefer landmark-based directions, and males to choose map -based directions. Spatial self-ratings were used to explore the possibility of a connection between perceived spatial ability and actual object location memory performance.

2D:4D

Much recent research has focused on the lengths of the second and fourth fingers (2D: 4D ratio), with several variables such as sexual orientation, spatial ability, and physical aggression claimed to be related to this ratio (Bailey & Hurd, 2005; Putz, et al., 2004). The role of sex hormones in the development of digit lengths has been well established; for example, Manning et al. (1998) showed that 2D:4D ratio correlated negatively with testosterone levels in adult men. We therefore wish to investigate whether lower 2D:4D ratio (indicating higher prenatal testosterone) in either males or females correlates with object location memory performance.

Hypotheses

The present research investigated if females would perform significantly better than males in their object location memory when the objects are presented in a dynamic (walking through space) task. A strong test of Silverman and Eals' evolutionary hypothesis requires that the predicted gender difference in location memory should also apply in this case. We suspect that females will perform significantly better than males on the dynamic object location task. Furthermore, the differences between males and females should be most pronounced when objects are presented in the incidental condition.

Based on Silverman and Eals (1992) findings, I hypothesized that females would perform significantly better than males on object location memory in a static (seated in a room) task. I further predicted that the difference between males and females in the directed condition would be smaller than in the incidental condition. Overall, participants should locate significantly more objects correctly in the static task, than in the dynamic task.

Other hypotheses tested were based on previous findings and included the following: (a) males should perform significantly better than females on the mental rotation task; (b) males should have significantly faster judgment reaction times to the geometric shapes in the mental rotation task than females; (c) males would rate themselves higher than females their sense of direction and one-trial directional memory ability; (d) females would rate themselves higher on object location memory, and (e) in reports of navigational preference, males should prefer maps, whereas females should prefer landmark based directions. I also sought to investigate if a correlation(s) exist between MRT, spatial self-ratings, and object location memory performance.

Finally, the current study explored the correlation between 2D:4D and object location memory. If a low 2D:4D ratio is an accurate indicator of prenatal testosterone levels, as has been suggested, I expect to find a negative correlation between 2D:4D ratio and the spatial measures used in this study.

CHAPTER 2

METHODS

Participants

The participants were 136 undergraduates (66 men and 70 women) who were enrolled in introductory psychology classes (*M* = 21 yrs; *SD* = 5.8) at the University of Texas at Arlington. The majority of participants were Caucasian (37.5%) with 16.18% Asian, 14.71 % Black or African American, 11.13% Hispanic, and 4.41% who labeled their race as multi-racial or other. No racial data were available for 15.44% of the research participants. Participation was voluntary and provided one means by which participants could fulfill a course requirement. Of the 136 original participants, the data from two were deleted from the study because of issues at the time of the experiment[3].

Materials

Test objects for both the dynamic and the static object location tasks were presented in two identical binders containing 8.5 x 11 inch color pictures of the test objects[4]. The picture objects used in the dynamic task (lion, blue question mark inside blue circle, tree, light bulb, abstract man, corn with eyes, orange, apple on a book, horn of fruit, knife and cutting board) were obtained from Microsoft® Word's clipart.

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[3] Other participants had portions of data dropped due computer issues or test objects.

[4] See Appendix A and B.

A flatbed scanner was used to produce scanned images of the hand. The GNU Image Manipulation program (v.2.2.6) was used to derive 2D:4D ratios. This program has been successfully used in a previous study by Bailey and Hurd (2005).

A computerized version of the MRT test was obtained from Dr. John C Hay's online psychology lab, and can be found at (http://pantherfile.uwm.edu/johnchay/index.htm?uniq=1n12ul). Upon completion of the MRT an excel file was automatically saved in the hard drive. A single desktop PC was used to administer the MRT to participants.

Design

The design of the experiment was a 2 (sex) x 2 (directed or incidental) x 2 (dynamic-to-static, static-to-dynamic) between-subjects design. The participants were randomly assigned to the four experimental

Spatial measures

Dynamic task. After walking through a series of hallways in a primarily office area of an academic building, the participants were given a folder containing 15 pictures of objects encountered during navigation of the hallways. Care was taken by the experimenter to walk at a normal steady pace. Participants were asked to mark the correct locations of the pictured objects on a simple (the only markings on the map were the start and end locations, and elevators) accurate map[5]. Each object in the test folder was marked with a unique letter; to locate the item, the participants were instructed to mark an "x" and next to the "x" place the letter of the corresponding object. To

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[5] See Appendix D

discourage outright guessing, participants were advised to only mark objects on the map that they were *fairly certain* they remembered the location of. All objects the participants were not able to locate on the map were noted by the participant in a box labeled “No recollection”. The important distinction here is that it is not if the participant can merely recall seeing the object itself, but rather if they can remember the objects’ location. Two previously used methods (Velarde & Mellgren, 2003; Velarde & Mellgren 2004) were used to evaluate the number of correctly located objects on the map. First a proximate measure was used; objects are counted correctly located if the object is placed in the correct general area (e.g. fire extinguisher located in the first hallway, regardless of position in that hallway). Other proximate measures used to evaluate the object location performance are errors (e.g. object located in the wrong hallway) and objects designated as no recollection. Second an exact measure was taken, in which the located objects’ deviation from the exact location was measured in centimeters. There was no time limit, and participants were encouraged to take as much time as was needed to complete the task successfully.

Static task. Participants spent one minute and thirty seconds[6] alone in a typical academic office containing innocuous items such as desk, bookshelf, etc. After this time period, the participant was removed from the office and tested in another nearby room. Participants were given a folder containing 15 pictures of objects that appeared in the previous office, and were asked to correctly locate the objects on a sheet containing a view of the office with all items removed except the desks and

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[6] Time was purposely made approximately the same as the length of the walk in the dynamic task.

bookshelves[7]. Once again, each object in the test folder was marked with a unique letter; however, this time to locate the object participants were told to simply mark the letter of the corresponding object directly onto the sheet. A total of 15 digital pictures of the various objects present in the previously viewed office were presented to the participants. Once again to discourage outright guessing, participants were advised to only mark objects on the sheet that they were *fairly certain* they remembered the location of. Participants were asked to mark all objects they were unable to locate (i.e. "no recollection") on the right margin of the data sheet. Two different methods which are analogous to the proximate and exact measures detailed in the dynamic location task were used to assess performance. Parallel to the dynamic task no time constraints were placed on the participants when they completed their task.

Mental rotation test. The MRT was obtained from an online psychology laboratory. This computerized three-dimensional task consisted of one practice trial and 30 test trials presented in a randomized order. In the test portion, 30 pairs of three-dimensional shapes were presented, and the participant indicated whether the two shapes in each pair were congruent or incongruent. Geometric shapes were presented at 15 different angles of rotation ranging from 0º to 280º, with half being congruent and half incongruent. Participants responded on a standard PC keyboard by pressing the "E" key to indicate congruent, and the "Q" key for incongruent. The maximum score was 30, and the minimum possible score was 0. The time (in seconds) it took the participant to register a decision was also recorded.

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[7] See Appendix E

Spatial self-rating. Participants were asked to rate themselves on four types of spatial ability[8]. Appropriate responses were made using a five-point Likert-type scale (1 = very poor, 5 = excellent).

2D:4D

Digit ratio. A flatbed scanner was used to scan both of the participants' hands. Participant's index (2D) and ring (4D) fingers were measured from the obtained scans using the GNU Image Manipulation Program (GIMP). The total length of each digit was measured in pixel units, from the middle of the basal crease to the tip of the finger. Ratios were calculated by dividing the length of the second digit by the length of the fourth digit. A single experimenter performed all 2D:4D measurements. Twenty percent of digit lengths were re-measured using GIMP to assess intra-measure reliability. Correlations between repeated measurements ranged from r = .854 to .906.

Procedure

Participants were instructed to arrive at room 502 on the fifth floor of the Life Sciences building at the University of Texas at Arlington and wait outside until greeted by the experimenter. All participants were tested individually, and by the same experimenter. Before beginning, the participants were asked to read and sign a statement of informed consent; and all of their bags, purses and pagers were stowed away. Upon completion of the informed, the consent participants filled out the spatial self-rating form. At this juncture, participants were randomly assigned to one of the four groups (dynamic or static task first; directed or incidental condition). Because all

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[8] See Appendix C

participants performed both the dynamic and static tasks, if the static task was performed first, it was then followed by the dynamic task, or vice versa.

Participants in the dynamic task were given the following verbal directions before they were walked to the test location; directed condition, “I am going to take you to another room for this experiment. As we walk to that room I want you to notice the things you see along the way. I will be asking you about these things and where you saw them. Please walk at my pace and stay slightly behind me without talking”; and incidental condition, “I am going to take you to another room so we can begin the experiment, please walk at my pace and stay slightly behind me without talking.”

Participants in the static task were seated in such a way that they had a clear, unobstructed view of an actual typical school office containing a variety of school-related items (bookshelves containing books, computer, etc.). These participants were given the following verbal directions; directed condition; “Shortly I am going to be asking you about certain items in this office, please observe the room and try to remember as many items as you can and where they are located. I will be back in a couple of minutes”; and incidental condition; “I am going to get the other room set up for the actual experiment, please wait here, I will be back in a couple of minutes.”

Following the completion of both the dynamic and the static tasks, the participants had both hands scanned and followed by administration of the MRT. The participants were then debriefed, and thanked for their participation.

CHAPTER 3

RESULTS

Object location memory

A 2 (sex) x 2 (directed or incidental) x 2 (dynamic-to-static, static-to-dynamic) between-subjects ANOVA found no significant main effects for sex in the dynamic task for the number of objects correctly located, F (1, 118) = .53, p = .467, for the total number of errors, F (1, 118) = 1.32, p = .253, or for the recollection of objects, F (1, 118) = .03, p = .874. The results for the static task also revealed no significant sex difference for the number of objects correctly located F (1, 124) = .28, p = .59, or the total number of errors F (1, 124) = 3.25, p = .073. However, the number of objects participants reported as "no recollection" did reveal a significant main effect for sex. Men (M=6.12, SD=3.16) reported significantly more objects as "not recalled" than women (M=5.22, SD=2.74) on the object location memory task, F (1, 124) = 3.78, p < .05. There were no significant sex differences in the dynamic or static tasks for the exact measure of object location memory. Static task participants located objects significantly more accurately in the directed condition (M=1.37, SD=1.68) than in the incidental condition (M=2.95, SD=2.19) and this difference was highly significant F (1, 123) = 14.32, p < .0002.

Table 3.1 shows mean totals and *F* values by task condition for the three measures of performance. As expected, the participants located more objects correctly, made fewer errors, and recalled more objects in the directed condition. Only the measure of total number of errors in the dynamic task did not reach significance.

Table 3.1 Task Means

	Correct	Errors	No Recall
Dynamic Task			
Directed	5.36	2.31	7.31
Incidental	3.98	1.96	9.04
F (1, 118)	12.56*	3.96	10.31*
Static Task			
Directed	9.66	1.13	4.19
Incidental	5.5	2.36	7.13
F (1, 124)	72.88*	14.62*	46.79

Note. * *p* < .001.

These data indicate that condition (directed vs. incidental) had a much bigger effect on performance for the static task. In fact, regardless of condition, the participants located significantly more objects correctly in the static task. There were no significant main effects for task order in the dynamic task, however, in the static task both objects correctly located F (1, 124) = 5.27, p=.01, and recollection of objects F (1, 124) = 4.40, p=.03 task order reached significance. Participants in the incidental condition who completed the static task after the dynamic task were more aware of the condition, and performed better. No significant interactions between sex and task condition or sex and task order were observed.

MRT and spatial self-rating

Independent samples t-tests were conducted on the MRT and spatial self-rating data, for males and females. Results are shown in table 3.2, and descriptive statistics are also provided. As the data in table 3.2 indicates, the men not only performed significantly better women on the MRT, but also had significantly faster reaction times.

Table 3.2 Spatial measures T-tests

	Mean	S.D	N	Mean	S.D	N	*t*	*P*
MRT	26.217	4.716	60	24.300	4.702	63	-2.25	.02
MRT – React	5.285	1.968	60	6.629	2.704	63	3.16	.02
Sense of Direction	3.318	1.165	66	2.685	1.090	70	-3.26	<.001
Item location	3.484	.964	66	3.542	.810	70	.38	.70
OTDM	3.803	.931	66	3.428	.860	70	-2.44	.01
Navigation preference	1.409	.495	66	1.728	.447	70	3.95	<.001

The MRT mean indicates number of three-dimensional objects paired correctly, and reaction time is the length of time (in seconds) it took to make the decision. The men rated their sense of direction significantly higher than the women on the spatial self-rating. Then men also rated their one-trial directional memory (OTDM) significantly better than women. OTDM was simply the question “ability to find my way back to a place I have only been to one time before”. In navigation preference, significantly more women chose landmark based directions, whereas men preferred a map. Sense of direction, item location, and OTDM self-rating questions were assessed using a 5-point likert scale, with one being poor and five being an excellent self-rating. Navigation preference was evaluated using a “1” indicating map preference, and “2” indicating landmark-based directions preference.

Correlation matrixes

A Pearson Product Moment correlation matrix was generated for spatial self-ratings, MRT, and the number of correctly located objects performance measure for the static (SC) and dynamic (DC) tasks. For men (see Table 3.3), a high self-rating in sense of direction correlated significantly with the number of correctly located objects on the dynamic task (r=.254, p<.05) and with mental rotation test aptitude (r=.275, p<.05). OTDM was another self-rating item that correlated strongly not only with the sense of direction item (r=.469, p<.01), but also with memory in the dynamic task (r=.322, p<.01). It is also interesting to note that there was a highly significant correlation between performance on the dynamic and static tasks (r=.373, p<.01), a correlation that was not found for the female participants.

Table 3.3 Correlation matrix for males

	SofD	Item	OTDM	SC	DC	MRT
SofD	1.00	.024	.496**	-.027	.254*	.275*
Item		1.00	.124	.095	.025	-.064
OTDM			1.00	.133	.322**	.236
SC				1.00	.373**	.014
DC					1.00	.174
MRT						1.00

Note. ** $p < .01$; * $p < .05$.

In fact, there were no significant correlations at all for the women (Table 3.4), However, higher ratings of item location memory and static task performance (r=.171, p>.05) did show a trend in the expected direction.

Table 3.4 Correlation matrix for females

	SofD	Item	OTDM	SC	DC	MRT
SofD	1.00	-.033	.206	.026	.065	-.016
Item		1.00	-.005	.171	-.025	.175
OTDM			1.00	.117	-.138	-.021
SC				1.00	.208	.179
DC					1.00	-.030
MRT						1.00

Note. ** $p < .01$; * $p < .05$.

2D:4D

Table 3.5 presents sex differences in 2D:4D ratios for all participants, I did not find stronger sexual dimorphism in digit ratio on the right hand (as past studies have), and in fact instead found the largest significant difference between males (M=.984, SD=.040) and females (M=1.00, SD=.036) in the left-hand ratio $t(131) = 2.34$, $p <.02$. In addition, I found a significant sex difference with mean 2D:4D. No significant sex difference for directional asymmetry (DA) in 2D:4D ratio was observed in this sample. DA is simply left hand 2D:4D minus right hand 2D:4D.

Table 3.5 2D:4D T-tests

	Male			Female					
	Mean	S.D	*N*	Mean	S.D	*N*	d.f	*t*	*P*
RH	.972	.039	63	.982	.037	70	131	1.44	.152
LH	.984	.040	63	1.000	.036	70	131	2.34	.021
Mean	.978	.035	62	.991	.032	70	130	2.12	.035
DA	.013	.036	62	.018	.032	70	130	.75	.453

Pearson correlations were calculated analyzing the relationship between 2D:4D ratios, MRT, spatial self-ratings and the proximate performance measures on the static and dynamic tasks. Correlations for the men are shown in Table 3.6 and for the women in 3.7. Only the participants in the directed condition groups were included in these correlations, because the data in the incidental conditions revealed very restricted ranges. If examining all participants regardless of condition, no significant correlations were observed for either sex.

Table 3.6 Male 2D:4D correlations

		Right			Left			Mean	
	N	*r*	*P*	N	*r*	*P*	N	*r*	*P*
MRT	59	.013	.917	58	.101	.447	58	.104	.437
SofD	63	.070	.580	63	-.031	.805	62	-.029	.819
Item locate	63	.164	.197	63	.071	.580	62	.073	.568
OTDM	63	.036	.773	63	.035	.780	62	.035	.783
Static Corr	31	.335	.065	31	**.398**	**.026**	30	**.413**	**.023**
Static Error	31	-.067	.718	31	.187	.313	30	.055	.770
SNR	31	-.308	.091	31	**-.517**	**.009**	30	**-.459**	**.010**
Dyna Corr	30	.236	.208	30	**.388**	**.033**	29	**.362**	**.053**
Dyna Error	30	.103	.587	30	**.468**	**.009**	29	.296	.118
DNR	30	-.216	.250	30	**-.511**	**.003**	29	-406	.080

The men's data revealed no significant correlations between 2D:4D and spatial self-ratings, however significant correlations with static and dynamic task measures on the left and mean 2D:4D were observed. Males had significant positive correlations with left 2D:4D and the number of correctly located objects in both the static (r=.398, p<.02) and the dynamic (r=.388, p<.03) tasks. The same trend of significant positive correlations were observed in mean 2D:4D and the static (r=.413, p<.02), the dynamic (r=.362, p<.05) tasks for males. Logically, a significant negative correlation was observed between left 2D:4D and object location no recollection for static (r=-.517, p<.009) and dynamic (r=-.511, p<.003) tasks.

Female 2D:4D did not correlate significantly with any of the spatial measures, including MRT or spatial self-ratings. An anomaly appears in the data because although there is a significant positive correlation between male left 2D:4D and number of objects correctly located in the dynamic task, there is also an observed significant positive correlation for errors (*r*=.468, *p*<.009).

Table 3.7 Female 2D:4D correlations

		Right			Left			Mean	
	N	*r*	*P*	N	*r*	*P*	N	*r*	*P*
MRT	63	-.037	.770	63	.020	.870	63	-.008	.946
SofD	70	.079	.514	70	.141	.242	70	.122	.310
Item locate	70	-.064	.593	70	.075	.536	70	.007	.949
OTDM	70	-.129	.283	70	.003	.978	70	-.071	.556
Static Corr	34	-.002	.989	34	-.068	.702	34	-.041	.817
Static Error	34	.237	.175	34	.154	.384	34	.216	.219
SNR	34	-.191	.277	34	-.034	.845	34	-.121	.492
Dyna Corr	32	-.032	.861	32	-.046	.802	32	-.044	.809
Dyna Error	32	-.125	.493	32	-.077	.673	32	-.109	.552
DNR	32	.106	.563	32	.084	.645	32	.104	.570

CHAPTER 4

DISCUSSION

The purpose of this study was to test for possible sex differences in object location memory. Although object location memory and recall have been examined by past research, I sought to examine object location under both static and dynamic conditions. In addition, I explored the relationship between object location memory, MRT, 2D:4D and also whether self-ratings of spatial ability bore any relationship with object location ability.

Review of results

There were no significant differences between males and females in the dynamic object location task in either the directed or the incidental conditions. In the static task, only the number of objects indicated, as “no recall” was significant, with males reporting more objects in this category than females. Regardless of sex, participants located more items correctly, made fewer errors, and reported fewer objects as “no recollection” in the directed condition trials. Moreover, when participants completed the static task, they did better than when they completed the dynamic task on all three measures of object location memory.

As expected, the men performed significantly better than the women on the MRT, and had significantly faster reaction times. On the spatial self-rating questions, male had significantly higher average scores on the sense of direction, and OTDM rating questions. Unexpectedly females did not have significantly higher average scores on the item location memory question than males. Correlation matrixes for the MRT and self-rating data revealed interesting results. Males' perceived sense of direction was positively correlated with MRT and object location performance[9] in the dynamic task. OTDM also showed a high positive correlation with object location performance in men. Interestingly, men who performed well in the dynamic task also tended to do well on the static task. The female data showed no significant correlations, and unlike males, self-ratings had absolutely no correlations with object location in either dynamic or static task. There was a non-significant trend between female item location ratings and static task performance. Women had significantly higher mean and left 2D:4D ratios than men. This is consistent with past research findings indicating that men posses lower 2D:4D (Manning et al. 1998). However, female 2D:4D did not correlate significantly with any spatial measure. Male left and mean 2D:4D did correlate significantly with the dynamic and static task measures. Unlike previous research (e.g. Benderlioglu & Nelson, 2004), I found no significant sex differences in directional asymmetry.

Interpretation of results

There were no significant differences between men and women in the static task for the number of objects correctly located and for errors, although women had less trouble recalling object location than the men. The dynamic task exhibited no significant differences between males and females. A potential hypothesis to explain

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[9] Performance is defined as the number of objects correctly located.

this result is that because the dynamic task involves both spatial orientation and location memory skills the difference in performance between men and women was attenuated relative to the static task. This explanation seems plausible because men's self-ratings of sense of direction, a measure that correlates highly with MRT performance (r=.275 p<.05), was highly related to dynamic task performance (r=.254, p<.05).

The present study used an object location task that was different from earlier object location tests by using only pictures of the test objects, and locations were marked on actual depictions of traveled hallways or visited office. This method allowed for exact and proximate measures of object location memory to be obtained. Although the study found no significant sex differences for the exact measure of object location, the results may not be as contrary to expectations as it first appears. Because the task focuses on exact measurements, the task may in fact favor males, because past studies have demonstrated a significant male advantage in estimating exact distances (Dabs et al., 1998).

The most interesting results of the present study were the correlations between spatial self-ratings and object location performance. More specifically, there were significant inter correlations of the men's sense of direction, OTDM and the dynamic task. It appears that the men who were able to better mentally visualize and rotate prior environments were also better able perform the dynamic task in the study. Actually, a study by Ecuyer-Dab and Robert (2004) found that navigation ability is associated with a broad set of spatial abilities, including location memory.

That a correlation between static and dynamic task performance obtained only for men but not for women, was an unexpected finding. A possible explanation for the observed correlation is that the motivated male research participant was more attentive and conscientious while performing both tasks, than would the unmotivated male participant. There were no significant correlations between female spatial self-ratings and dynamic and static tasks.

As expected the men had significantly lower left and mean 2D:4D than the women, and their object location performance on static and dynamic tasks correlated positively with this ratio. The implication here is that males with more feminine typical (higher) 2D:4D ratios also performed better at the spatial tasks predicted to be female-superior tasks. The data from the study does not support the idea that increased levels of testosterone are associated with better spatial ability.

Limitations of the current study

Most social science research is conducted at higher education institutions; participants available to experimenters are limited to a somewhat restrictive population. The majority of participants in the current study were freshman; the median and mode age was 19 years old. Although age in itself is not a problem, participant attention and motivation is a possible confounding factor. Although participant apathy was not always overt, numerous instances of repeatedly asking answered questions, and incorrectly filled data sheets were observed.

Because the study endeavored to create a naturalistic (everyday) environment, in the dynamic task the participants were walked down several hallways of the Life

Sciences building. Although most test trials were conducted in mid to late afternoons to insure that the hallways were clear, ultimately the amount of traffic, and noise in the hallways could not be always controlled.

Furthermore, a possibility exists that the dynamic task as designed was too difficult, limiting the range of scores to an extent that prevented the detection of significant effects. For example, in directed conditions the mean number of objects located correctly was 5.3 objects or roughly 35% of total objects. The number of correctly located objects drops even further to 3.9 located objects or 26% under incidental conditions, creating a possible floor effect. While walking down the hallway, exposure to a single test object may last only mere seconds in some instances, creating a very difficult test situation.

Conclusions

In conclusion, the present study failed to find evidence for sex differences in object location memory in dynamic or static tasks. Of the eight total measures used to evaluate both the static and the dynamic tasks, only one showed a significant main effect for sex. The results from the MRT and spatial self-ratings were consistent with past research highlighting male superiority in MRT and perceived sense of directional ability. The finding that females prefer landmark-based directions for navigation was also reaffirmed. Partially reaffirming previous 2D:4D research, women and men had significantly different left and mean finger length ratios; there was no observed difference for the right hand. Females had significantly higher left and mean 2D:4D ratios than males.

Nevertheless, the present study cannot provide a definite answer to the question of whether 2D:4D ratio is related to sex differences in object location memory. A positive correlation was found for male left and mean 2D:4D and three object location measures. A prediction based on the 2D:4D literature would hypothesize a negative correlation between MRT and 2D:4D; however, the present data suggests no such correlation.

Because testing evolutionary theories under naturalistic conditions applies treatments to naturally occurring groups (like men and women), this type of research, often referred to as *quasi-experimental* it is important for the researcher to establish that the differences between groups do not differ on incidental characteristics that may affect performance (Keppel & Wickens, 2004). It is therefore important to collect as much ancillary background data as possible on all participants. For example, a recent study by Levine et al. (2005) found that even socioeconomic status modified sex differences on a mental transformation task.

Future research should continue to concentrate on examining sex differences in spatial ability in real-world settings. The present study endeavored to create a naturalistic setting in which to test for object location memory. In retrospect, it appears that the dynamic task utilized was too difficult, creating a highly restricted range. Contributing to this problem was the salience of the objects used in the study. In the static task the majority of the objects were salient; however in the dynamic task the majority of the objects were not very prominent.

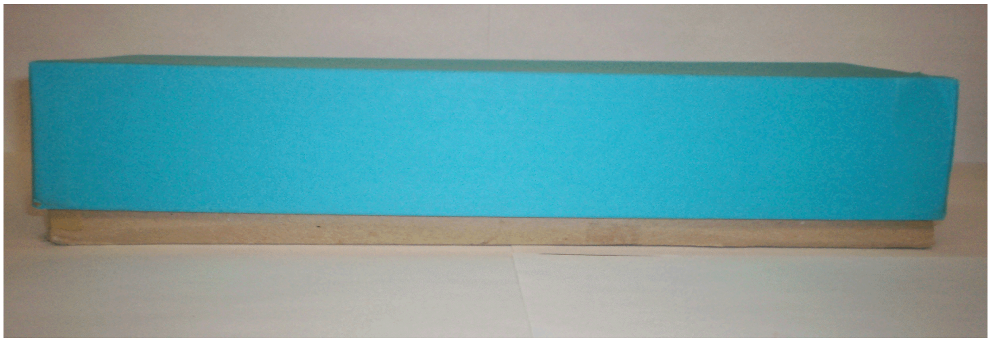
Although 2D:4D is reported to be a marker for prenatal androgen exposure (Manning, 2002), any additional measure of testosterone, such as saliva, should be used to attain a more accurate measure of circulating testosterone levels.

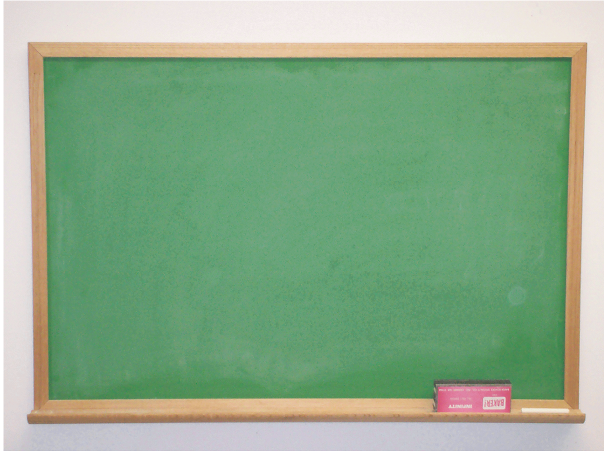
In light of the important role that spatial skills play in everyday tasks and certain specialized tasks, there is a real impetus to identify the replicable differences in spatial ability that exist between males and females.

APPENDIX A

STATIC TEST OBJECTS


ArtBin
MADE IN U.S.A
MODEL 8399





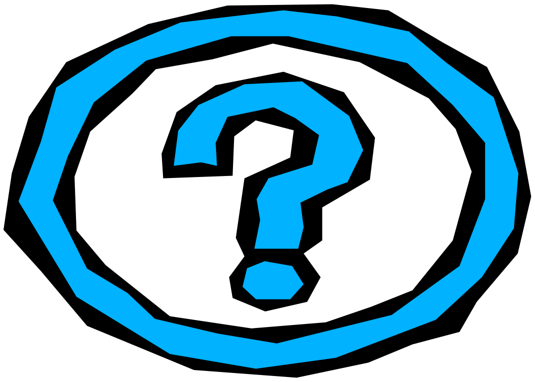

KU

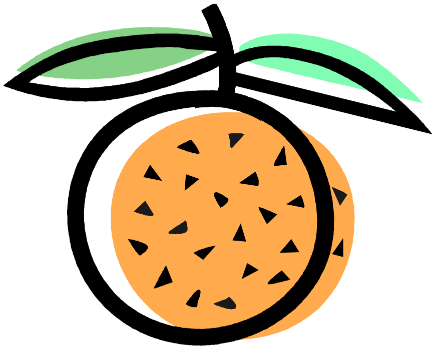

FUNAI
Microwave oven

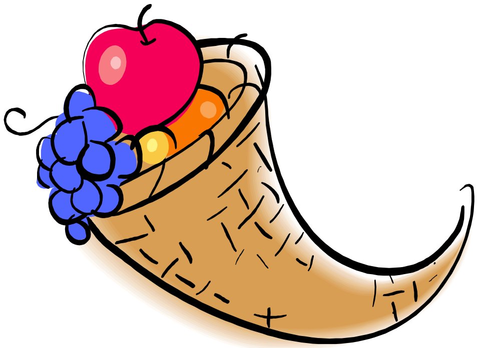

HIGH CLASS CAT

APPENDIX B

DYNAMIC TEST OBJECTS








Cordley
SIERRA CLUB


593


GARAVENTA
ACCESSIBILITY


UTA

APPENDIX C

SPATIAL SELF-RATING

Experiment #98

S# _____ Age _____ Handedness _____

Major _____ **Current Occupation _____**

Self Report
(*Rate yourself*)

1- very poor, 2- poor, 3- average, 4- above average, 5- excellent

Sense of direction: Knowing which direction is North, East, etc. when I am in an unfamiliar place.

1 2 3 4 5

Ability to find misplaced items in your house or apartment (e.g. keys, remote control).

1 2 3 4 5

Ability to find my way back to a place I have only been to one time before.

1 2 3 4 5

If going to a new place would you rather have (circle one):

1 A map (mapsco)

2 Instructions based on landmarks (turn left at the church, go past the golf course etc.)

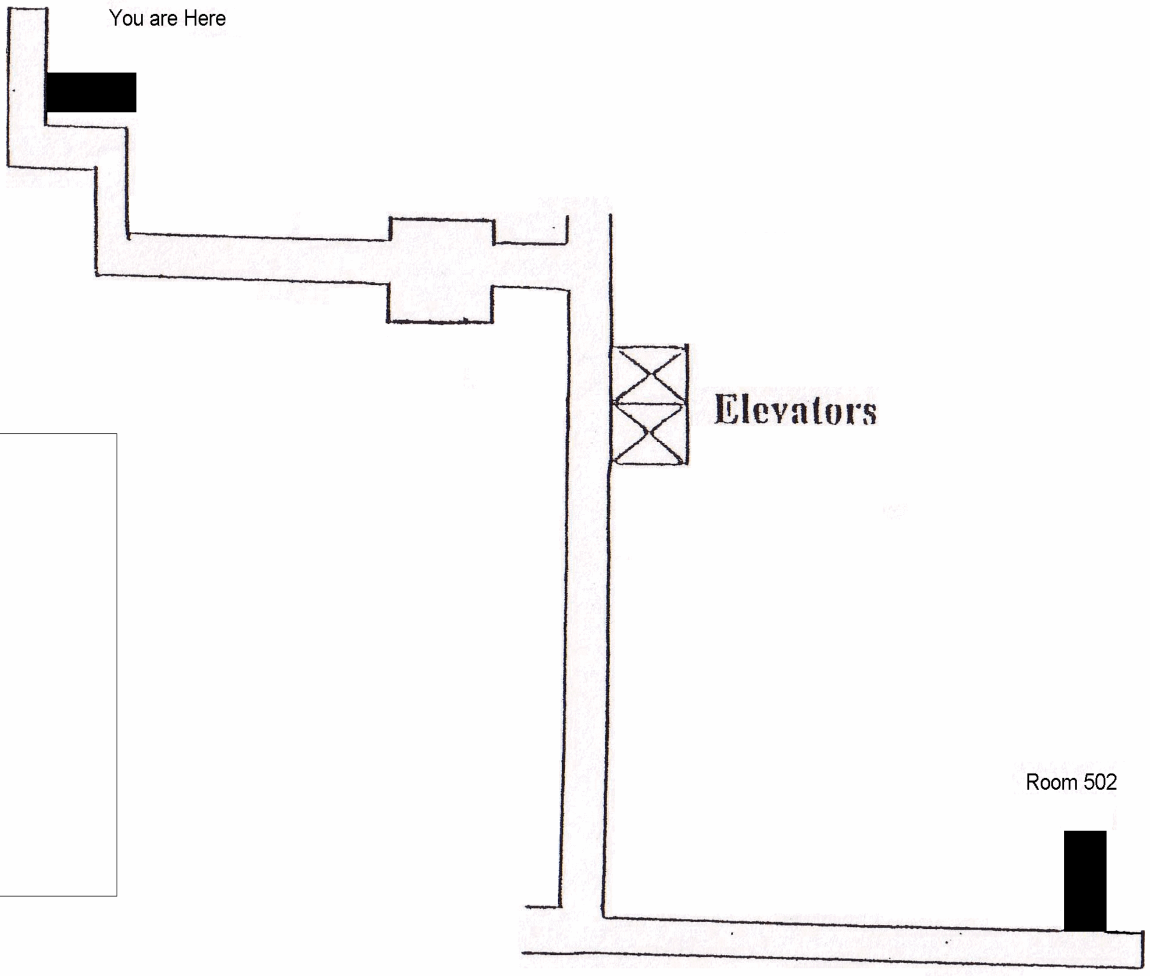
APPENDIX D

DYNAMIC SPATIAL MEMORY TASK

Subject #

C 1 2 3 4

Block #



No Recollection

APPENDIX E

STATIC SPATIAL MEMORY TASK

APPENDIX F

DEBRIEFING STATEMENT

We are studying how well things that are experienced in the environment can be remembered. Therefore, we walked you down several hallways, and asked you to locate as many items as you could remember on a map of the just traveled path. You also did the same task remembering the location of items after sitting in a graduate office. We will be testing a hypothesis based on our evolutionary history of human beings. In ancient times people would have lived a "hunter-gatherer" existence. We suspect that there would have been a division of labor among men and women in those times such that men would have been primarily responsible for hunting and women primarily responsible for gathering. Being a hunter requires moving across large amounts of land in pursuit of prey, and keeping track of where you are relative to the current home. Males who were good at such spatial cognition would have been successful, and those who weren't good at it would have been less successful. On the other hand, females who could remember where food was available for harvesting would have been more successful gatherers than those who had a poor memory for where could be found. So translating these ideas into the experiment you just participated in, we expect the female subjects to do better in the static spatial task (remember location of items in the office) and remembering items encountered in the hallway. We also scanned your hands and had you complete the computerized mental rotation test, both will be used as additional measures to help us determine what other factors may or may not contribute to object location memory performance.

One comment we often hear when we describe these differences between male and female spatial abilities is that, "When guys get lost they won't stop and ask for instructions. They always think they know where they are and how to find the place they are looking for." You may feel this way yourself. Does it make sense why this might be so given the argument we made in the above paragraph.

If you have any questions about this study or would like to obtain a copy of the results, you can email us at jvelarde10@yahoo.com. Thanks for your time and participation.

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