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Effects of Gender and Position of Test Stimuli on Undergraduates ' Spatial Task Performance

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Effects of Gender and Position of Test Stimuli on

Undergraduates' Spatial Task Performance

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James Brenton Curley

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Abstract

This study predicted that sex differences in performance can occur where the sense of touch serves as vision, and that the position of the test array may significantly affect performance. Sixty-four college undergraduates (32 males and 32 females), with ages ranging from 18-27 ($M = 20.06$, SD = 1.82) were recruited from the psychology subject pool of Eastern Illinois University for participation. Apparatus consisted of templates with raised line drawings of tilted jars containing water drawn on them. The subjects were blindfolded and instructed to interpret four jar drawings at a time. The task consisted of identifying the jar with the correct water line. All subjects participated in 8 trials. Half were tested on an upright test array, and the rest on an array that was tilted. The data were analyzed using a 2 X 2 X 4 (Gender X Position of Test Array X Angle of Jar) ANOVA. The results indicated that gender was significantly related to performance of the task, and that males performed better than females did, $F\ (1,180) = 8.1$, $p<0.01$, while the position of the test array was not, $F\ (1,180) = .83$, $p>0.37$.

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Introduction

Participation in everyday life continually demonstrates that sex differences exist. There are established sex differences in physical stature, maturation rate, brain hemispheric specialization, and various neurological, psychological, and behavioral disorders (Hoyenga & Hoyenga, 1993; Millar, 1994). Many other sex-differentiated traits exist, some of which are controversial to both the public and academic communities. The notion that males and females differ in their spatial abilities is continuously debated. There are those who feel that sex differences in such abilities are insignificant, and that they occur only when the measures are biased. Others accept the differences in test results as valid, but argue the cause. Some believe the differences are biologically based, while others speculate they are socially constructed.

Halpern (1992) defined the term *spatial abilities* as those abilities that govern how an individual visualizes the way in which an irregular figure appears when it is rotated in space or the ability a person has to discern the relationship among shapes and objects. Halpern suggests that spatial abilities consist of the 4 following factors: 1) *spatial perception*: spatial perception requires the individual to make judgments of the vertical or horizontal while ignoring any distracting information. 2) *mental rotation*: mental rotation is the ability to visualize how an object will appear when it is rotated in space. 3) *spatial visualization*: spatial visualization is the complex analysis of spatial information. 4) *spatiotemporal ability*:

spatiotemporal abilities consist of judging and responding to moving visual displays.

The evidence supporting the finding that men and women differ in spatial abilities, especially those abilities that involve mental rotation, can be found in several areas of research. Shape rotation, route and maze learning studies, for example, generally produce evidence that is concurrent with the above stated theory.

Coltheart, Hull, and Slater (1975), for example, examined sex differences in both verbal and spatial task performance. The study employed 2 conditions; the first condition consisted of subjects being asked to mentally search the English alphabet and tally the number of letters that, when pronounced, produce the sound "ee". The second condition involved subjects mentally searching the alphabet and tallying the number of letters that contain curves when appearing as capital letters. The tasks were described as mental because both writing and speaking were not allowed during the testing conditions. The results indicated that females performed better than males in the first (sound) condition, while males scored better in the second (shape). Many other researchers have conducted similar studies that examine sex differences in shape rotation and have found that males tend to outperform females.

Learning a new route is theorized to be a sex-related trait. Many have suggested that males were under greater selection pressures to evolve the skills necessary to successfully navigate. The act of navigation requires the spatial skill of recognizing objects from different angles of observation; this exercise requires mental shape rotation (Kimura, 1999). Research has consistently demonstrated that males tend to outperform females when the task involves learning a route (Beatty & Troster, 1987; Kimura, 1999). One particular experiment (Galea & Kimura, 1993) involved male and female subjects being tested on how many trials it took them to learn a new route. They each observed a researcher tracing an imaginary line through a tabletop map; that line representing the route. Once the researcher had finished tracing the route, the subjects were asked to replicate it. Their errors were counted and corrected by the researcher as they traced. The trial was repeated until each subject traced the route without error. The results indicated that males learned the route in fewer trials than females (Galea & Kimura, 1993).

There appears to be a positive relation between one's ability to mental rotate objects and successfully navigating through a maze. An experiment that studied such a relation (Moffat, Hampson, & Hatzipantelis, 1998) involved correlating performance data from two spatial tasks. The rotation task was the Vandenberg and Kuse Mental Rotations test, in which subjects select 2 shapes out of 4 choices that, if rotated, would be the same as the target shape. The maze task consisted of subjects finding their way through a computer constructed labyrinth. The correlation between scores on rotation and maze navigation tasks was significant (0.60) (Moffat et al., 1998). The finding of males usually outperforming females on mental rotation tasks leads many to speculate that males would perform similarly on maze navigation tasks. This hypothesis has been supported by research (Nyborg, 1983).

Literature Review

Meta-Analyses Supporting Sex Differences in Spatial Performance Tasks Involving Mental Rotation

Several meta-analyses have achieved results opposite to Hyde's (1981), demonstrating that gender is a significant variable in one's performance on spatial tasks, particularly those favoring males (such as mental rotation). Linn and Petersen's (1985) meta-analysis achieved results contrary to those of Hyde's. The authors chose to examine differences in performance between genders on three different spatial tasks: spatial perception (judging spatial relations while presented with distracting information), mental rotation (mentally rotating two or three dimensional objects), and spatial visualization (solving spatial tasks over the course of several stages). The results indicated significant gender differences in performance on the spatial perception and mental rotation tasks. Gender differences in performance on the spatial visualization task were not found to be significant.

Hoyenga and Hoyenga (1993) conducted a meta-analysis on 14 studies involving gender differences on mental rotation tasks: Allen, 1974; Allen & Hogeland, 1978; Clarkson-Smith & Halpern, 1983; Cooper & Shepard, 1984; Corballis, 1986; Just & Carpenter, 1985; Kail, Carter & Pellegrino, 1979; Kyllonen, Lohman & Snow, 1984; McGlone, 1981; Pearson & Fergusen, 1989; Pezaris & Casey, 1991; Tapley & Bryden, 1977; Van Strien & Bouma, 1990; Voyer & Bryden, 1990. The authors suggested that their findings may indicate a sex difference in spatial abilities (Hoyenga & Hoyenga, 1993).

One of the most comprehensive studies concerning gender differences in spatial task performance is Voyer, Voyer, and Bryden's 1995 meta-analysis. The authors conducted a *Psych-Lit* CD-ROM search for the years 1974 to 1993, examined journals that may have contained published studies not found in the *Psych-Lit* CD-ROM search, and even analyzed all of the studies initially reviewed by both Linn and Petersen (1985) and Maccoby and Jacklin (1974). The authors measured effect size by utilizing Cohen's *d*, which represents standard differences between the means of groups. The results they obtained were significant. Their analysis of 286 studies revealed a mean weighted *d* of .37 ($z = 2.61$, $p < .01$). The researchers felt that the strength of their findings demonstrates that sex differences in spatial abilities that favor males are significant (Voyer et al., 1995). Both the effect size and large sample led the authors to confidently speculate that they had provided significant evidence supporting the claim that sex differences in performance of spatial tasks favoring males do exist. They concluded their study by suggesting that scientists accept the gender gap in performance as fact, and that future research should attempt to discover its cause.

Possible Causes of Sex Differences in Spatial Abilities Favoring Males

Some researchers have speculated as to the cause of the gender gap in performance. The different perspectives are legion. There are those who believe that it is a socially constructed difference, while others maintain it is strictly biological in nature. A socially constructed sex difference, in this case, a gap in spatial task performance, is theorized to occur when a society, as a whole, either encourages or dissuades an individual to engage in and practice certain behaviors, based on their gender. A biologically based sex difference in performance is said to occur due to physical factors, such as genetics and physiology. Many scientists admit they have no convictions to any one theory, and so they conduct numerous studies, each examining whether or not a suspected cause is significant or not.

Genetic differences.

The role of genetics has been paid an increasing amount of attention in recent years. There is a massive database (Hoyenga & Hoyenga, 1993; Millar, 1994; Annett, 1985) that supports the idea that many differences, including spatial abilities favoring males, are genetically predetermined. Events surrounding recent years such as the cloning of animals and mapping the human gene provided scientists with information concerning the role of genetics in human development.

A major assumption that this theory espouses concerns chromosomal differences between the genders. Males have both an X and a Y chromosome, while females possess two X chromosomes, leading some (Harris, 1981; Hoyenga & Hoyenga, 1993; Millar, 1994) to believe that males may be more varied in their cognitive processes. Harris (1981) suggested that the X chromosome of males contains a recessive gene that is responsible for males' superior spatial ability over females. The evidence to support this theory has been mixed. Although many studies achieved results consistent with Harris' (Hartlage, 1970; Springer & Sealman, 1978; Stafford, 1961), there are also those that did not (Boles, 1980; Guttman, 1974).

Differences in the structure of the brain.

An enduring theory as to the cause of sex differences in spatial abilities concerns hemisphere lateralization and specialization of the brain. This view asserts that hemispheric lateralization is more prevalent among males than females, and this in turn leads to males being slightly better at many spatial tasks, especially those involving mental rotation. Many correlational studies have found hand preference to be significantly related to spatial ability (Bryden, 1982; Harris, 1981; Kimura, 1992; Sherman, 1971). It is theorized that many more females are left hemisphere dominant, which causes right- handedness- hence the development of verbal proficiency. The left hemisphere of the brain is associated with verbal specialization, while the right hemisphere seems to involve nonverbal tasks.

Conversely, males are reportedly more varied in their hemispheric lateralization, (Bryden, 1982; Harris, 1981; Kimura, 1992; Sherman, 1971) and have a significantly higher incidence of left-handedness (Annett, 1985) than females. Thus, they develop more right hemisphere specialization, which may cause superior spatial abilities.

Differences in hormones.

Hormones are thought to play an important role in the development of spatial abilities.The hormones testosterone (T) and Estrogen (E) may significantly affect male and female development of spatial abilities. With some cases, the relationship appears to be curvilinear. The results of these studies indicated that females with high levels of T have generally higher spatial task performance while males with high T achieve lower performance (Gouchie & Kimura, 1991). However, many hypothesize that the relationship is not clear (Hoyenga & Hoyenga, 1993). Some have proposed that the higher level of testosterone in males significantly delays the development of the left hemisphere of the brain, which then enables greater development of the right hemisphere (Galaburda, Corsiglia, Rosen, & Sherman, 1987). As mentioned previously, greater development of the brain's right hemisphere has been associated with better spatial abilities (Annett, 1985).

Differences in social learning and experience.

The social learning and experience paradigm has been popular due to its appeal to those who advocate equality in all settings, particularly education. It proposes that all sex differences in spatial abilities, including those favoring males, are socially constructed. This is accomplished through socialization of males to engage in and practice at tasks that are stereotypically defined as masculine. Conversely, females are thought to be socialized to refrain from such tasks, and may instead be encouraged to engage in activities that are stereotypically feminine.

An influential study was conducted in 1971 by Sherman that concerned the nature of the gender gap in performance of spatial tasks. Sherman asserted that the nature of the tasks themselves, not overall differences in analytical reasoning, were responsible for females' inferior spatial performance on tasks favoring males (Sherman, 1971). She further proposed that spatial training and practice are directly responsible for the gap in performance.

Robert conducted several studies examining this perspective as a possible cause of sex differences in spatial abilities favoring males (Berthiaume, Robert, St-Onge, & Pelletier, 1993; Robert & Chaperon, 1989; Robert & Ohlman, 1994; Robert &

Harel, 1996). In 1989, she explored the significance of cognitive and exemplary modeling of horizontality representation on spatial performance tasks- namely Piagetian water level tasks. She argued that although females are generally outperformed by males on tasks that involve mental rotation, and are underrepresented in the mathematical, physical sciences, engineering, and architectural professions, "..a direct causal relationship between the two phenomena has not been established yet" (Robert & Chaperon, 1989, p. 454). The results of Robert and her colleagues' 1989 experiment revealed that exposure to a model improved the performance of female subjects that had earlier failed at horizontal water line problems.

Robert and her colleagues (1996) continued to investigate the significance of social learning and experience by conducting a descriptive study with a large sample in 1996. Robert, along with her colleague Harel, examined the performance of males against females by analyzing test scores of males and females representing 18 different academic majors at the University of Montreal. These 18 academic disciplines were divided into the following three categories: Natural and Applied Sciences (Physics, Engineering, Architecture, Computer Science, Biology, & Pharmacy), Social Sciences (Physical Education, Psychology, Sociology, Anthropology, Geography, & Management Science), and Humanities and the Arts (Law, Philosophy, French, History, Art History, & Music). The test problems consisted of 8 variations of the Piagetian water level task, a measure that males generally perform better on (Voyer & Bryden, 1990). The study's goal was to gather performance data on young adults enrolled in science programs. Stating that most performance data is typically gathered from psychology students, the authors suggested that the resulting data were biased. They reasoned that females enrolled in science programs might have had the training needed to perform at a level equal to that of most males. The results Robert and Harel obtained indicated that one's academic training is not significantly related to their spatial abilities (Robert & Harel, 1996):

Regardless of their academic specializations, women produced less accurate water and plumb lines in tipped stimuli and were less adept at detecting faulty representations. Such robustness in women's deficient achievement is particularly disturbing in that failure to support the expectation that more formal science education would reduce the impact of gender brings to light the unyielding nature of the gender gap (Robert & Harel, 1996, p. 301-302).

It is interesting to note that the researcher's predictions weren't realized in their study. In fact, the results did more to disprove their theoretical assumption, being that social experience and training significantly affect one's ability to solve physics problems.

Differences in response measures.

The response measure may be the most significant variable affecting one's spatial task performance (Linn & Petersen, 1985). There are many researchers who maintain that there is no one cause for the gender gap in performance. Rather, many internal (differences in brain structure, hormones, and genetics) and external (social training and experience) factors combine to give males a slight edge in certain tasks. Different response measures are said to either maximize or minimize sex differences in performance.

Traditional spatial testing usually consists of visual tasks, which seem to favor males (Heller, Calcaterra, Green & Barnette, 1999). Examples include the Piagetian water level task and also rod and frame (RFT) tasks. While both sexes perform better at visual spatial tasks, males may outperform females due to using their bodies as gravitational references in their environment (Heller et al., 1999; Robert & Ohlman, 1994). By doing so, they employ a grid system that is based on longitude and latitude. It is theorized to be more efficient than females' reference system, which may rely mostly on visual cues. Experiments utilizing haptics as the primary response measure have successfully demonstrated that rendering test subjects sightless significantly minimizes sex differences in performance (Heller et al., 1999; Berthiaume et al., 1993).

Examining Causation of Sex Differences in Spatial Abilities By Analyzing Results Obtained Through Haptic Measures

Berthiaume et al. (1993) provided the following description of the science of haptics:

Indeed, the haptic perceptual system incorporates both cutaneous and kinesthetic inputs that are derived through manual exploration and from which knowledge is extracted about objects, their properties, and spatial layout (Berthiaume et al., 1993, p. 57).

Simply defined, haptics is the science of touch. Through the sense of touch, one can derive knowledge concerning objects and their properties. A spatial task may be administered haptically by a) rendering the subject temporarily sightless, and b) presenting test stimuli that are interpretable by the sense of touch. Examples of haptic response measures include the rod and frame task (RFT) and variations of the Piagetian water level task. The rod and frame task is a spatial task that measures one's ability to determine both verticality and horizontality. When the task is performed, a subject will be seated in a dark room, observing a glowing rectangle that possesses neither true horizontal or vertical lines. By observing a glowing rod located in the rectangle's center, the subject determines whether the rod is either truly vertical or horizontal (Hoyenga & Hoyenga, 1993). The Piagetian water level task is typically a pencil and paper measure. A subject will observe a drawing or series of drawings consisting of a vessel, such as a rectangular jar, or a graduated flask. The vessel will be tilted at an angle, and the subject is asked to draw in the water line. Often, several choices are offered, the water line being already drawn in. In this case, the subject is asked to identify the correct choice. The correct answer to the Piagetian water level task is to identify the water line as being horizontal (Robert & Harel, 1996).

The results of many studies comparing spatial task performance between genders have found that minimal sex differences occur when the response is measured haptically (Berthiaume et al., 1993; Heller et al., 1999).

Methodology

Statement of Problem

Research has demonstrated that when tested on the performance of certain spatial tasks, such as those involving mentally rotating objects, males generally outperform females (Hoyenga & Hoyenga, 1993; Linn & Petersen, 1985; Voyer et al., 1995). Based upon such a large body of evidence, researchers can now say with considerable confidence that gender differences in spatial abilities do exist. The problem that twenty-first-century researchers are currently facing is determining the causes of these differences.

The Purpose of This Study

The purpose of this experiment is to contribute to the body of research that aims to determine the cause of sex differences in spatial task performance. It will serve as a logical, next step to studies previously conducted by researchers such as Robert (Berthiaume et al., 1993) and Heller (Heller et al., 1999). This experiment was consistent with their methodology, which is to vary the traditional response measures (such as the Piagetian water level task), in order to either minimize or maximize gender differences in performance. It is theorized that the cause of the gender gap in performance may eventually be discovered through the process of elimination.

Predictions

The term *field dependence* refers to the degree to which individuals are influenced by visual information while processing spatial information. Based on data from performance tasks, such as the RFT, females are reportedly more field dependent than males (Halpern, 1992).

Significant sex differences were predicted to occur in the conditions during which the test array was tilted. Males would perform better at these tasks than females because they use both gravitational and visual references when solving tasks involving mental rotation. This strategy was thought to aid them in their performance. By using their bodies as a reference point, males would have been able to mentally rotate the test array from the tilted angle (either 30° or -30°) to the angle of 0°, which was perpendicular to the test taker's body. This mental rotation would improve males' performance on this task. Females are generally more field dependent than males are, mostly relying on visual references when performing mental rotations. Thus, they make less use of gravitational cues than males. This was predicted to give females a disadvantage in these types of tasks because visual information would not be available. Subjects that were most likely to correctly solve these tasks would have to mentally rotate the test stimuli from its angle of tilt to a position that was perpendicular to the test taker's body. Studies have consistently demonstrated that males generally outperform females on mental rotation tasks (Hoyenga & Hoyenga, 1993; Maccoby & Jacklin, 1974; Voyer et al., 1995). Conversely, sex differences in conditions during which the test stimuli were not tilted was predicted to be insignificant. Studies have demonstrated that performance in conditions during which the test array is not tilted indicated minimal gender differences (Berthiaume et al., 1993; Heller et al., 1999).

Method

Participants

Sixty-four college undergraduate students (32 males and 32 females), with ages ranging from 18 to 27 ($\underline{M}$ = 20.06, SD = 1.82) were recruited from the psychology subject pool of Eastern Illinois University for participation in this study.

Stimuli and apparatus

The test site was located in a small room that was isolated against any noise or other intrusions that would have disrupted the testing process. A specially constructed set of cardboard templates comprised the test array (see Fig 1). Each template had a haptic drawing on its surface depicting rectangular jars tilted at various angles (30°, 60°, -30°, -60°). The drawings were produced by subjects using a Swedish raised-line drawing kit, which is typically used by the blind for making pictures. A tangible, visible line is produced on the paper when a pen is drawn across its surface. Each template was layered with the Swedish raised-line paper. A set of safety goggles, painted black on the inside, provided a sanitary and effective means for rendering subjects sightless.

Design and procedure

This experiment's design employed a 2 X 2 X 4 (Gender X Position of Array X Angle of Jar) mixed factorial ANOVA. The 2 general positions of the test array were tilted and upright. The upright array was straight ahead of the participant, at an angle of 0°. The tilted array was tilted with respect to the straight ahead, at angles of 30° and -30°. There were 16 males and 16 females who participated in the tilted array condition, while 16 males and 16 females participated in the upright array condition. Every subject participated in 8 trials, with 4 choices available for each trial. The following controls for angle were implemented to balance the sequences. Half of the subjects who participated in the tilted array condition began the experiment with the 30° test array (see Fig 1c), while the other half began with the -30° test array (see Fig 1b). Half of the subjects participating in the upright array (see Fig 1a) condition began the experiment with 4 trials tilted at a negative angle (see Fig 1a). The other half began the experiment with 4 trials tilted at a positive angle.

This experiment tested both the subject's ability to mentally rotate an object- the test array- and to correctly solve physics problems that are haptic versions of the Piagetian water-level task. Because the test was administered haptically, subjects were blindfolded. The test itself consisted of 8 water-level tasks. The water-level tasks were presented in multiple-choice format, with 4 choices for each problem. Participants in the conditions during which the test array is tilted were required to mentally rotate the array from either 30° or -30° to 0°, a position perpendicular to the participant's body, in order to correctly solve the water level problem.

Testing consisted of one session per subject. The subject reported to the testing room where they were greeted and oriented to the testing environment. They were asked to sit in the chair that directly faces the tester. Once the subject was seated, the tester read the following directions to each participant.

> This is a raised-line drawing kit. It is used by the blind for making pictures. We have made several pictures that you will feel while blindfolded. Please do not remove the goggles once the experiment has begun until you are asked to do so. When you feel the standard picture, I will ask you what it is. If you cannot answer, I will tell you all about it. Once you are familiar with the standard drawing, you will be presented with similar pictures. You will then perform a multiple-choice task, which consists of choosing the correct picture. There is no time limit on these tasks. It is important to try

> to get as many right as you can, so you should take whatever time you need. Please try not to press too hard on the lines, as too much pressure can damage the raised-line drawings.

At this point, the male tester asked the subject to sign a consent form. Next, the tester asked the subject to put the goggles on. The testing session then proceeded to the next phase, which consisted of familiarizing the subject to the standard drawing. To do so, the tester read the following instructions to the subject.

> Here is the first picture. You can feel it with one or both of your hands, which ever is your desire. Can you tell what it is? It is a jar on a tabletop. Feel the line at the bottom. That is the table surface. The line in the middle represents the surface of the water inside the jar. Go ahead and feel it. The water's surface is about half way up, and the jar is half full. Now, feel the top. That is the jar's lid.

Once the subject was oriented to the standard drawing, the tester removed it and presented four drawings. The following instructions were then read to each participant.

> You will now feel four choice pictures. All of the jars will be tilted in the pictures. They are drawn the same way, and each has a line showing the tabletop. The only difference among them will be the line that represents the water's surface. The jars are immobile. Imagine that they've all been super-glued in place, and have been still for about 5 minutes. I want you to feel the pictures and find the one with the water line the way it would be in the real world, as shown in the picture. Feel all of the choices before

tapping the picture that has the correct water line. This experiment will take approximately 20 minutes to complete.

In the experimental condition, the tester inserted the phrase, "Also, the entire picture array will be tilted" directly before the sentence that read, "Imagine that they've all been super-glued in place, and have been still for about 5 minutes".

The tester then removed and replaced the stimuli during testing. The tester remained objective, not giving the participant any feedback regarding their choices. The tester recorded the participant's responses on to an answer sheet. When the participant had made their final choice, the test ended. The participant's answer sheet was then placed inside a specially marked manila envelope. The tester then debriefed the subject, and explained the principle that, excluding moving containers, a water line is always horizontal no matter what surface the water's vessel is resting on. After they were debriefed, the participant was free to leave the testing room.

Results

Table 1 illustrates the mean number of correct judgments overall and by angle of jar for the haptic Piagetian horizontality task. An analysis of variance (ANOVA) was performed on data obtained from male and female subjects on the total number of correct judgments. A 2 X 2 X 4 (Gender X Position of Array X Angle of Jar) ANOVA was employed to analyze the task. The results indicated that the main effect of gender was significant, $\underline{F}$ (1,180) = 8.1, $\underline{p}<0.01$. Male subjects ($\underline{M}$ = 6.19) outperformed female subjects ($\underline{M}$ = 4.63), evidenced by the mean number correct. However the main effect of the tilt condition did not reach significance, $\underline{F}$ (1,180) = .83, $\underline{p}>0.37$.

Discussion

The outcome for this experiment was somewhat different than expected. While gender did indeed significantly affect performance ($\underline{p}<0.01$), the test array's position did not ($\underline{p}>0.37$). This contribution adds to a growing trend that considers one's sex when planning and executing research as well as treatment. Specifically, this experiment demonstrates that it is possible to obtain a significant gender difference in a study utilizing haptic measures. Previous experiments that measured their subjects haptically found that sex was not related to performance on the different versions of the Piagetian horizontality task (Berthiaume et al., 1993; Heller et al., 1999).

Also important was the discovery that the test array's position did not influence performance. Originally, it was thought that tilting the test array would make the task harder for both genders to solve, but especially more so for females. The reasoning behind this prediction was that solving the task haptically forces the subject to engage in an activity that is unfamiliar. Though the sense of vision was removed during the experiment, the subject could feel the raised line drawings and obtain information through the sense of touch. Thus, touch served as a subject's vision. This mode of sensory input, like vision, is succeptible to error. As mentioned earlier, females generally commit more errors when solving tasks that involve mental rotation (Hoyenga & Hoyenga, 1993) and are also more field dependent than males (Halpern, 1992).

In a previous experiment (Heller et al., 1999) it was noted that subjects seemed to use their bodies as gravitational references when haptically solving mental rotation tasks. This behavior involved the subject using their body as a horizontal plane with which they would use the raised drawing as the vertical plane. While planning the present experiment, it was predicted that tilting the array away from a position parallel to the subject's body would negate the strategy of using one's body as a gravitational cue when solving the task, thus making it much harder to solve.

Speculating on why no significance in the tilt condition was attained, it is possible that the haptic nature of the task was sufficient to negate any advantage that the non-tilt condition had over the tilt condition. Although the sense of touch served in the stead of vision, it may have been too unfamiliar and confusing for the subjects. Perhaps prior knowledge of physics was the most significant factor related to performance. Those who knew the horizontality principle before participating in the experiment were more likely to correctly solve the task than those who did not know the task, regardless of the array's position.

After analyzing the performance data with the ANOVA, a Neuman-Kuels post-hoc test was conducted on the effects of jar angle. The main effect of jar angle was found to be significant, $\underline{F}$ (3,180) = 3.07, $\underline{p}<0.05$. Generally, both males and females scored slightly higher when judging figures at positive and negative tilts of 60° than figures at 30° (see table 1 for comparison). The only statistically significant difference between the 4 different jar angles was that between that of the 60° and -30° jars. The author hypothesized that the jars tilted at positive and negative 60° may have been easier for participants to solve because their water levels were closer to the table top than were those of the positive and negative 30° jars (see Fig 1 for comparison). It was observed that most of the participants who were successful at the task concentrated on the relationship between the water level and the tabletop. It follows, then, that the jars with water levels closer to the tabletop may have been slightly easier to solve.

The result of gender being significantly related to performance on haptic variations of the Piagetian horizontality task contradicts those obtained in previous experiments. The main effect of gender reached significance ($p<0.01$) in the present study, which is inconsistent with previous findings (Berthiaume et al., 1993; Heller et al., 1999). The testing procedure for the present study and that of the Heller (Heller et al., 1999) study were identical except for the instructions given to the subject prior to testing. The instructions in that experiment were different, as they did not ask the subject to focus on the framework. Conversely, the present study did ask subjects to focus on the framework (see Design and Procedure, page 18). Telling the subjects to focus on the picture appears to have aided the males in performance, more so than the females. Why was this so? Perhaps it is due to females' succeptibility to field dependence. As mentioned previously, females are argued to be more field dependent than males (Halpern, 1992). Females attempting to solve the task might have been distracted by the jars themselves, not relating their position and the angle of the surface it was resting on. Males, on the other hand, could have solved the task with greater accuracy by concentrating on the water line and the tabletop. There were many subjects that scored an eight out of eight correct by simply attempting to locate the water-line which was parallel to the tabletop, completely avoiding interpreting the jar's outline.

Unlike the present study, the testing procedure in the Berthiaume (Berthiaume et al., 1993) experiment focused the task away from the framework. The researchers theorized that the subjects would employ a body-centered functioning, rather than a display-centered functioning when they solved a haptic RFT (rod and frame task). This, they concluded, may have contributed to the lack of significance in performance between genders in their study. An alternative explanation is that the task's design makes obtaining a gender difference difficult, if not impossible. First, each subject only participated in four trials. Three out of four correct answers was deemed successful; 61% of females and 60% of males achieved three out of four correct. Four trials for such a task does not allow for much variability, particularly for one that is extremely difficult. The task involved setting a haptic rod and frame to the horizontal, and the subjects could not feel the edges of the apparatus while setting the rod to the correct position. This appears awkward and may have confused most of the participants. Thus, the design of the experiment and the results obtained from it are questionable.

Conclusions

In conclusion, this experiment contributes two important findings to the field of gender differences in spatial task performance. The first is that sex differences can exist in the performance data obtained through haptic versions of the Piagetian horizontality task. The second is that the position of the test array may not be significantly related to performance on that task.

The results of this experiment seem to indicate that some sort of prior knowledge, of the properties of water, perhaps, was the most significant variable in determining a subject's success at the task. Those who scored the highest almost always ignored the jar's sides and concentrated exclusively on the water line and tabletop when judging the figures. A follow up to this study should involve a larger, more diverse sample. An example would contain a wider age range, and different levels of socioeconomic status. Also, more information concerning the participants may be useful in determining the cause of sex differences in spatial task performance. Testing the participant's knowledge of physics, or, specific knowledge of the properties of water, for example, prior to the testing could be a useful method for investigating this. Documenting how much attention the participants pay to the position of the water level relative to the tabletop is also worth examining, as that type of strategy might be correlated with an above average knowledge of physics. The tester of this experiment documented solving strategies as an afterthought to the experiment's design, in order to assist in the interpretation of the results. Consequently, not every subject's solving strategy was recorded. It would be more effective to incorporate this into a future design, in order to ensure standardization and reliability.

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Appendix

Table 1

Mean Number Correct (With Standard Deviation in Parentheses) in Piagetian Horizontality Task

	Angle of Jar				
	-60	-30	30	60	Overall
Tilted Array					
Male	1.6 (0.7)	1.2 (0.7)	1.5 (0.8)	1.6 (0.7)	5.8 (2.3)
Female	1.1 (1.0)	1.1 (1.0)	1.3 (0.8)	1.2 (0.8)	4.8 (2.6)
Non-Tilted Array					
Male	1.8 (0.4)	1.5 (0.7)	1.5 (0.7)	1.7 (0.4)	6.6 (1.7)
Female	1.2 (0.9)	0.9 (0.8)	0.9 (0.9)	1.5 (0.8)	4.5 (2.1)
Total					
Male	1.6 (0.6)	1.3 (0.7)	1.5 (0.8)	1.6 (0.6)	6.2 (2.0)
Female	1.1 (0.9)	1.0 (0.9)	1.1 (0.9)	1.3 (0.8)	4.6 (2.3)
Tilt	1.3 (0.9)	1.1 (0.8)	1.4 (0.8)	1.4 (0.8)	5.3 (2.5)
No Tilt	1.5 (0.8)	1.2 (0.8)	1.2 (0.9)	1.6 (0.6)	5.5 (2.1)

Figure Captions

Figure 1a. Representation of test array at 0° tilt, with jars at -60° tilt.

Figure 1b. Representation of test array at -30° tilt, with jars at -60° tilt.

Figure 1c. Representation of test array at 30° tilt, with jars at 30° tilt.

Figure 1