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SEX AND HANDEDNESS EFFECTS ON TWO TYPES
OF COGNITIVE ABILITY TASKS

A Thesis
Presented to the
Faculty of
California State University,
San Bernardino

In Partial Fulfillment
of the Requirements for the Degree
Master of Arts
in
Psychology

by
Randall Wayne McCauley
June 1990

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Approved by:


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Abstract

Research has shown that males outperform females on spatial tasks and females outperform males on verbal tasks. These differences may occur because males' and females' brains may be organized differently, and handedness has been shown to be a rough indicator of the underlying organizational pattern of the brain. The current study compared results on two different types of tasks--paper and pencil tasks and reaction time tasks--for verbal and spatial abilities. A paper and pencil test of mathematical ability was also used for comparison. As hypothesized, males outperformed females on the paper and pencil spatial abilities test, and females outperformed males on the paper and pencil vocabulary task. Sinistrals outperformed dextrals on the mathematics test, but no significant sex differences were found. A significant sex by degree of rotation affect was found on the spatial reaction time task which involved rotating a three-dimensional object by various degrees. This difference might have occurred because females switched strategies at the larger degrees of rotation. No significant sex, handedness, or sex and handedness interaction was found on the verbal reaction time task.

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To my dear wife, DeShea, I would like to say that without your love, patience, hard work, encouragement, and devotion I would have never completed this thesis. Although I cannot adequately express my feelings in words, I am thankful that I have the rest of my life to show you how much I love you and how grateful I am for all the ways you make my life wonderful.

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Introduction

For many years the nature of human intelligence has baffled and intrigued many scientific investigators. Psychologists have tried various methods of trying to quantify and understand the elusive nature of the human intellect by hypothesizing about its nature and testing their hypotheses by various means. Recently researchers have reconceptualized intelligence as a collection of cognitive abilities or "intelligences," as opposed to a unitary entity (Halpern, 1986).

This approach to conceptualizing intelligence is particularly useful in light of the research on the functioning of the brain. Research on the human brain has shown that the two hemispheres of the brain are asymmetrically organized and that certain cognitive functions are lateralized to one hemisphere or the other. Also, research has shown that there appear to be sex differences in the performance of certain cognitive tasks that are thought to be laterally represented in the brain (Springer & Deutsch, 1981). In a related body of research, handedness has proven to be a fairly accurate measure of how the brain is organized regarding these cognitive tasks (Levy & Nagylaki, 1972).

Therefore, in light of this research, this paper examines the effect of gender and handedness (as a measure

of cerebral laterality of functions) on tasks involving three types of cognitive abilities: verbal ability, spatial ability, and mathematical ability.

Sex Differences in Cognitive Abilities

A review of the literature of cognitive abilities reveals that there is an enormous amount of research in this area, and much of this research contains contradictory findings. This is to be expected considering the multifarious variables that have been examined. McGlone (1980) points out that much of the research on the laterality of cognitive abilities does not take sex differences into consideration. Maccoby and Jacklin (1974), in an attempt to remove some of the obfuscation surrounding this literature, analyzed over 1,600 research articles in the sex differences literature to determine exactly which areas researchers have actually been finding sex differences. This analysis found four areas where sex differences appear to be found fairly consistently. Three of the areas were in the cognitive domain and included verbal ability, spatial ability, and quantitative ability; the fourth area was a personality variable--aggression. Of the three cognitive abilities, they found that men perform better on visual-spatial and quantitative tasks and women perform better on verbal tasks. Each of these cognitive abilities are examined further in the next sections.

Spatial ability. Spatial ability involves the ability to comprehend and manipulate various aspects of two- and three-dimensional objects. One such ability, known as tactile-spatial ability, involves the ability to comprehend the shape of objects by touch. Research in this area has found that spatial ability, for the most part, is lateralized to the right hemisphere and that adult males perform slightly better at this type of task than adult females (Flanery & Balling, 1979). However, no significant differences in the ability to perform this task have been found in children (Flanery & Balling, 1979). These results appear to be in line with other types of spatial tasks, primarily tasks involving visual-spatial ability.

Visual-spatial ability has been defined as the ability to mentally rotate an object in space or the ability to discern the relationship between objects (Halpern, 1986). As this definition implies, visual-spatial ability involves two separate but similar functions. A review of several studies that investigated tasks that involve visual-spatial abilities shows that these tasks can be divided into two factors: a spatial visualization factor and a spatial orientation factor (McGee, 1979). The spatial visualization factor involves the ability to mentally manipulate an object (such as twisting, inverting, or rotating it) while maintaining the relationship between the parts of the

object. The spatial orientation factor involves perceiving an object in space with the observer as the reference point; such tasks as the rod-and-frame test (Whitkin, Lewis, Hertzman, Machover, Meissner, & Wapner, 1954) and the embedded-figures test (French, 1963) are examples of these spatial orientation tasks.

Males generally outperform females on tasks that involve visual-spatial ability (Halpern, 1986). Particularly strong sex differences have been found on tests that involve mentally rotating an object. For example, the Shepard and Metzler (1971) mental rotation task has shown very large sex differences. This task requires the subject to mentally rotate a three-dimensional object in order to bring it into congruence with another three-dimensional object; it is considered a test of the subject's spatial visualization ability. When performing this task, the subject views two objects presented in two viewing circles. These objects, which are either identical or mirror images of each other, are presented to the subject; and the subject then responds as to whether or not the two stimuli are the same or different. One object is rotated in either two- or three-dimensional space at angles from 0 to 180 degrees in 20 degree increments. As mentioned above, the task involves mentally rotating one of the objects to bring it into congruence with the other and analyzing whether it is the

same or a mirror image of the other object. Reaction times as well as accuracy measures are recorded for this task. Shepard and Metzler (1971) found significant differences between the sexes on this task; males were shown to perform this task both quicker and more accurately than females. Males also outperformed females in a similar paper and pencil task using a subset of the same objects (Vandenberg, 1969). Sex differences on this effect are quite robust and are easily replicated (Herman & Bruce, 1983).

While research has found that males outperform females in visual-spatial tasks in general, differences do occur according to the type of task; and differences may occur based on the type of strategy utilized to solve the task. For example, research using both visualization and orientation components has shown that low scoring males and high scoring females may use a verbal strategy to solve spatial visualization tasks; whereas, no verbal mediation effects were found in spatial orientation tasks (Bowers & LaBarba, 1988).

Directly related to this finding, research has shown that sex and handedness interact with reasoning ability measures on spatial ability tasks (Harshman, Hampson, & Berenbaum, 1983). Therefore, part of the reason that males and females perform differently may be due to each sex using different reasoning strategies to solve spatial problems.

However, it is highly probable that sex differences in these abilities are due to a multitude of factors, of which reasoning ability is merely one.

It should be noted that while the literature suggests that males perform better on spatial abilities tests than females, some researchers have failed to find sex differences; and others have questioned the variability in test scores, particularly for males (Halpern, 1986). As an example, Kimura (1969) failed to find sex differences on a spatial task that involved locating the position of a dot presented tachistoscopically on a spatial map depicting all possible dot locations. However, this finding illustrates that different types of tasks are used to measure spatial ability, and that these tasks may not be measuring the same phenomenon.

Verbal ability. Verbal ability covers many different areas including the following: word fluency, grammar, spelling, reading, verbal analogies, vocabulary, and oral comprehension. The majority of studies of these abilities suggest that after age eleven females outperform males in each of the verbal tasks (Halpern, 1986).

Regarding the types of tests utilized to measure verbal ability, one of the instruments most often used to measure verbal abilities is the Wechsler's intelligence scales for adults and children (e.g., McGlone, 1978; Kraft, 1984). The

Wechsler Adult Intelligence Scale (WAIS) is designed with 12 subtests which divide into two groups--verbal and performance. Studies using the WAIS have found that females do better overall on the verbal section of the test--especially in the vocabulary, comprehension, and digit symbol subtests (Matarazzo, 1972). Another rich source of data on linguistic abilities is the standardized tests used for college admission--the American College Tests (ACT) and the Scholastic Aptitude Tests (SAT).

Also, researchers have examined verbal ability by using reaction time tasks as well as vocabulary tests. These types of tests are generally used to examine the rapidity of access to verbal material which include knowledge of written words and letters. One type of verbal reaction time task is the lexical decision task which requires subjects to make a linguistic decision about objects such as words or letters presented to them. Research has shown that females outperform males on these types of tasks as well as the paper and pencil vocabulary tasks (Bradshaw & Nettleton, 1983).

Mathematical ability. Research in the area of mathematical abilities shows that males generally outscore females on standardized tests of mathematical ability (Benbow & Stanley, 1980, 1981). However, like spatial and verbal abilities, mathematical or quantitative ability is

not a unitary concept; and when each of the various components are examined separately, the sex differences in the score are illuminated. For instance, Stone, Beckman, and Stephens (1982) tested students on ten different subsets of mathematical ability. They found that females scored significantly higher than males on tests of mathematical reasoning ability and mathematical sentences. This effect may occur because these types of tasks involve a verbal problem-solving strategy in which females excel. Males, on the other hand, scored significantly higher on tests involving geometry and measurement. This may occur because solving these tasks involve utilizing a spatial strategy.

Research has shown that mathematical ability and spatial ability are correlated, which may be due to the fact that many mathematical topics such as geometry and calculus require a high degree of spatial ability (Halpern, 1986). Maccoby and Jacklin (1974) conclude that the magnitude of sex differences in mathematical ability is not as large as spatial ability differences and may be due to the sex differences in spatial ability.

The next question that needs to be addressed is, if these sex differences are actually occurring, then what is causing these differences. Several hypotheses have been proposed to account for sex differences in cognitive abilities, but most of these hypotheses can be divided into

two groups: psychosocial hypotheses and biological hypotheses (Halpern, 1986).

Socialization Explanations

Many of the hypotheses in the psychosocial group are concerned with sex role stereotypes and the behaviors associated with them. Sex role stereotypes can be defined as widely-held oversimplified conceptions about what males and females are like as well as what they should be like (Halpern, 1986).

Several theories have been developed that attempt to explain the socialization process and the sex-typed behavior that is a result of these processes. These theories fall into four basic categories: psychoanalytic (Freudian), learning, social modeling, and cognitive. Cognitive theory encompasses two different theories, namely cognitive development and gender schema theory. Freudian theorists propose that children acquire sex-typed behavior because of the need to resolve the Oedipus and Electra complexes that are problems during the Freudian phallic stage of development. Children resolve these problems by identifying with the same-sex parent, thereby conforming to gender specific behavior.

Learning theory, social modeling theory, and cognitive development theory all share a common set of premises. The basic premises common to all of these hypotheses is that

boys and girls receive rewards for appropriate behavior and punishments for inappropriate behavior which lead them to exhibit sex appropriate behavior. However, each of these theories differ regarding the initial premise. Learning theory does not have an initial premise because learning theorists hold the position that behavior stems directly from reward or punishment. Social modeling theory states that boys and girls observe male and female behavior and then imitate same sex behavior. Kohlberg's (1966) cognitive development theory states that children first develop a sexual identity and then imitate the same sex model.

The other cognitive theory is the Gender Schema Theory; this theory states that children develop categories based on sex differentiated behaviors. As children observe the behavior of males and females, they interpret and remember this information based on these categories. Eventually children begin to exhibit behavior consistent with the information they have in same sex behavior categories (Bem, 1981).

It is assumed that these behaviors are related to the type of cognitive abilities in which each of the sexes exhibit proficiency. For example, if boys are encouraged to play with visual-spatial type toys and girls are encouraged to engage in verbal activities, then it seems to follow that boys would be better at spatial abilities and girls would be

better at verbal abilities. It comes down to the fact that girls and boys have had more practice at each of the respective skills in which they excel.

Biological Explanations

Regarding the biological hypotheses, it appears that these hypotheses fall into three categories: genetic theories, sex-related brain differences, and sex hormone theories (Halpern, 1986).

Genetic hypotheses. Genetic hypotheses of sex differences in cognitive abilities are concerned with examining whether or not certain abilities can be inherited. One of the major theories in this area is known as the sex-linked recessive gene theory. As the name of the theory implies, this theory states that high spatial ability is a sex-linked recessive trait carried on the X chromosome. Based on this assumption, predictions of the percentage of the population that contain each combination of chromosome and dominant or recessive gene can be made. However, subsequent research has failed to confirm this hypothesis (Bouchard & McGee, 1977).

Hormone hypotheses. Several hypotheses that involve hormones have been posited to explain sex differences in cognitive abilities. These hypotheses have sprung from research on the effects of different hormone levels on the ability to perform certain types of motor tasks that involve

spatial abilities (Halpern, 1986). Basically, the hormone hypotheses can be divided into three categories: maturation rate, androgens available at puberty, and optimal female-male hormone balance.

Proponents of the maturation rate hypotheses present research indicates individuals who mature later are more lateralized for speech, and generally individuals who are more lateralized for speech are better at spatial abilities (Waber, 1976, 1977; Rovet, 1983). Because research has shown that females tend to mature at an earlier rate than males, it is assumed that the earlier maturing females are less lateralized for verbal ability and, therefore, less adept at spatial tasks.

Proponents of the androgen rate at puberty hypothesis state that a minimum amount of male hormones must be present at puberty for optimal spatial ability functioning. Some studies suggest that the amount of testosterone available at puberty may affect the ability to perform mathematical tasks (McGee, 1979). Other proponents of the testosterone hypothesis speculate that neurological development might be altered in favor of spatial abilities by the presence of excess testosterone in the developing fetus (McGee, 1979).

Another group of researchers propose that male and female hormones must be optimally balanced to achieve optimal spatial ability functioning. These researchers have

found that males with less androgens than other males and females with more androgens than other females are more lateralized for verbal ability and, consequently, are better at spatial ability tasks (McKeever, 1986).

Researchers concerned with hormone levels use several ways to measure the androgen level of individuals. Some researchers rate certain physical attributes such as the size of the biceps, the size of the chest (size of breast for women), and the distribution of pubic hair; others actually measure the amount of androgens in the bloodstream; still other researchers utilize androgyny inventories as an estimate of the androgen level (McKeever, 1986). The researchers that utilize androgyny inventories report that androgynous males and females perform better at spatial tasks than those individuals who are less androgynous (McKeever, 1986).

Handedness and cerebral organization. Before a proper explanation of the sex-related lateralization differences hypothesis can be explored, it is first necessary to briefly examine cerebral organization and handedness. This is necessary to lay the structural framework on which the sex-related lateralization differences hypothesis rests.

Medical research on patients with brain damage as far back as the 1800's reported that the two hemispheres of the brain seemed to be responsible for different functions

(Springer & Deutsch, 1981). It has since been determined that this is indeed the case; for the most part, the left hemisphere controls speech functions and the right hemisphere controls spatial functions in dextrals (Springer & Deutsch, 1981).

An enormous amount of information has been published in the last twenty years on the subject of cerebral organization, especially relating the separate functions of the two hemispheres of the brain and sex differences in cognitive tasks. Intimately tied to this research is the use of handedness as an indicator of laterality of certain cognitive abilities.

Some of the research has been conducted to establish that the data on cerebral organization and handedness involves clinical research on patients with cerebral tumors or other types of brain damage. A technique known as the Wada test has been employed to obtain some of the data on hemispheric specialization. This test involves insertion of a small tube into the carotid artery of a patient being prepared for brain surgery. The neurosurgeon then injects into the tube the drug sodium amobarbital, which is chemically similar to the drugs used in sleeping pills. Because the carotid artery only supplies blood to one hemisphere, this procedure anesthetizes only one half of the brain.

With this technique and with electrical stimulation of the cortex, researchers have been able to determine that approximately 95 percent of all right-handed people (dextrals) have speech and language control predominantly in the left hemisphere; whereas, only 60 to 70 percent of left-handed people (sinistrals) have left hemisphere control of speech functions (Springer & Deutsch, 1981). Of the other 30 to 40 percent of sinistrals, approximately 15 to 20 percent have control of their speech functions in the right hemisphere, and the other 15 to 20 percent have bilateral representation of the speech functions (Springer & Deutsch, 1981).

Because most researchers cannot practically employ these techniques to determine in which hemisphere a subjects speech functions lie, handedness has become one of the standard rough indicators of speech laterality. Jerre Levy (1969) has proposed an interesting connection between handedness and sex differences on cognitive tasks. She hypothesizes that males are better at spatial tasks because they are more lateralized for spatial abilities; and since sinistrals are lateralized for speech more like women, dextral males should outperform sinistrals and females on tests of spatial abilities.

Other researchers have also looked at the interaction of familial handedness with sex and handedness on a wide

variety of cognitive tasks. Through these studies, it has been found that familial handedness is a significant factor in indicating laterality and can be used as a predictor of performance on tests of cognitive abilities (McKeever & Van Deventer, 1977).

Even though the above research looks fairly consistent, it should be noted that the cognitive literature regarding sex, handedness, and familial handedness difference in visual-spatial ability and verbal ability is filled with contradictory findings. For instance, McGlone (1980) states that a person can find statistically significant results for almost any hypothesis in the literature. However, it is possible that some of these contradictions may be due to the fact that many different types of tests for cognitive abilities are used and very little research has been conducted to see if these tests are measuring the same construct.

Lateralization hypotheses. Jerre Levy is one of the most influential researchers in the area of cerebral lateralization. Although her theory has evolved over time, the basic premise of her hypothesis is that the sex differences in verbal and visual-spatial ability are related to the way males and females brains are lateralized, which is defined as the extent to which each hemisphere specializes in a certain task. She hypothesizes that when

the two distinct skills of verbal and spatial ability are confined primarily to separate hemispheres of the brain, the patterns of neural connections that underlie these abilities have optimal room for development. Should one ability impinge on the opposite hemisphere, the function of the dominant skill in the "invaded" hemisphere is impaired; should bilateral cross-over of skills occur, both skills are impaired. Also, the bilateral representation of verbal skills is more common than bilateral representation of spatial abilities (Levy, 1976). Hence, a person with bilateral representation of verbal functions should do less well on visual-spatial tasks than a person who is strongly lateralized for visual-spatial skills (and, therefore, has verbal functions more laterally represented in the left hemisphere). Research confirms that women appear to have their language skills more symmetrically represented in the two hemispheres (Kimura, 1983; McGlone, 1980; Springer & Deutsch, 1981). Also, research shows that, as a group, sinistrals are less lateralized than their dextral counterparts.

The Current Study

The purpose of this study is to examine the interaction of the various cognitive abilities that show significant sex differences with the gender of the subjects and their handedness as a measure of their cerebral laterality. This

approach combines some of the factors discussed in the disparate hypotheses examined earlier in an attempt to gain greater understanding of how the differing cerebral organization of males and females affect their performances on cognitive tasks. Also, unlike past studies, several tasks will be used to measure these abilities.

The examination uses the theoretical framework and findings of Jerre Levy's (1972) biological hypothesis of sex differences in cognitive abilities as a model to examine reaction time and paper and pencil tasks for the three measures of cognitive abilities that show consistent sex differences: verbal ability, mathematical ability, and visual-spatial ability (Maccoby & Jacklin, 1974). According to Levy's hypothesis, one should find a distinctive pattern of handedness by sex interactions on tests of verbal and visual-spatial abilities, specifically that dextral males should score higher than females and sinistral males.

Some researchers suggest that sex differences may be task-type dependent; however, these researchers have not compared several tasks that measure the same abilities to see if their findings are consistent across tasks. It is hypothesized that if the effect of sex differences is caused by differences in the cerebral organization of the brains of males and females as opposed to some type of test-taking strategy, then the effects of this organization should be

seen across a variety of tests that measure the same construct.

One of the verbal tasks that was used consists of presenting verbal information to each hemisphere via a divided visual field arrangement. This task involves presenting verbal material in the form of words or non-words to the left or right of a fixation point which is then sent to the contralateral hemisphere. According to the above literature, if there truly are differences in the cerebral organization of the sexes by handedness, handedness can then be used as an indicator of laterality and a predictor of cognitive test scores. In addition, there should also be significant interactions between sex and handedness and the score for each side of presentation on the divide half-field portion of the experiment. It is predicted that dextral males should show significant differences between the scores for each presentation side. Also, since this is a verbal task, females should outperform males on this task.

One of the most commonly used tests for visual-spatial abilities is the Shepard and Metzler Mental Rotation Task (Shepard & Metzler, 1971). This task is a reaction time task that has shown a robust relationship between reaction time and degrees of rotation. Basically, males outperform females on this test, and dextrals outperform sinistrals as well.

In summary, it is hypothesized that if Levy's (1979) hypothesis is correct, males should outperform females on spatial tasks, and females should outperform males on verbal tasks. Also, since handedness is used as an indicator of cerebral organization, there should be significant handedness differences on each of the tasks used in this study. Specifically, sinistrals should perform more like females and dextrals should perform more like males. In addition, the interaction of sex and handedness will also be examined.

One issue that has not been thoroughly addressed in the literature is whether or not each of the tests that purport to measure a particular cognitive ability actually do measure the same ability. Since some of the discrepancies in the literature may be due to the way spatial abilities and verbal abilities are measured, two different types of tasks will be utilized to measure verbal ability and spatial ability: a paper and pencil task and a reaction time task. The relationship between these two types of tasks will be examined.

Method

Subjects

The subjects recruited for this experiment were college undergraduates at a medium-sized state university in California. Due to the location of the university in a metropolitan area and the fact that the campus is primarily a commuter campus, the campus draws undergraduates with a wide variety of backgrounds and abilities. A total of 80 subjects were recruited so that each hand group (left and right) and each sex were equally represented. The age of the subjects ranged from 20 to 47 (\bar{X} =26.83; s.d.=5.93). This age range was chosen for two reasons: 1) some studies have shown that sex differences in cognitive abilities do not manifest themselves until at least the adolescent years (Porac & Coren, 1981); and 2) it is necessary for the subjects to be roughly equivalent regarding reaction times and visual acuity. Because this experiment involved a great deal of visual information processing, subjects had to have good visual acuity. Although no actual test of visual acuity was performed, all subjects that were aware that they had a vision problem were required to wear corrective lenses that corrected their eyesight to 20/20 while participating in the experiment.

Apparatus

An IBM PS/2 Model 30 personal computer was used to present the stimuli for the verbal portion of the experiment. Micro Experimental Lab (MEL) software was used to create the reaction time lexical decision task. This software was chosen for its ability to use the internal real-time clock of the computer to record reaction time with millisecond accuracy. The visual-spatial reaction time task used a Lafayette MAS System II slide projector with a tachistoscopic shutter to present the stimuli. The presentation of the stimuli was controlled by an Apple IIE computer; the computer controlled the slide projector, shutter, and various Colbourne modules that were used for timing and collecting the reaction time data. Also, a Tectronics J-16 digital photometer was used to record light levels of the slide projector and the computer. In addition, an IBM PC XT was used to generate a quasi-random number table.

Measures

Reaction time visual-spatial task. The reaction time visual-spatial task that was chosen for this study was the Shepard and Metzler (1971) mental rotation task that required the subject to mentally rotate a three-dimensional object to bring it into congruence with another three-

dimensional object. Figure 1 is an example of the type of objects used as stimuli. In this task, the subject viewed two stimuli presented in two viewing circles which subtend 10° of visual angle at a luminance level set at 15 mL; this angle is normal for comfortable reading (Schiffman, 1982).

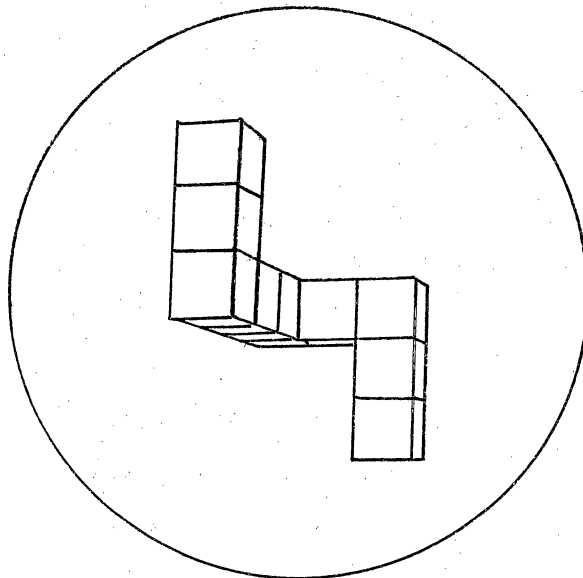


Fig. 1. Example of stimuli used for spatial reaction time task (Shepard & Metzler, 1971).

The stimuli were either identical or mirror images of each other and were rotated in either two- or three-dimensional space at angles of 0, 40, 80, 120, or 160 degrees. Two different objects were used to represent each of the three dimensions of the stimuli: the five degrees of

rotation, the two types of rotation (two- or three-dimensional space), and the two degrees of similarity (same or mirror image). This configuration of elements yielded forty separate stimuli.

The stimuli were presented to the subject on the screen, and the subjects responded as to whether or not the two stimuli were the same or different; a different response was used for the mirror image. Reaction time data and accuracy of response data were recorded for the amount of time it took the subject to make the decision as to whether the two stimuli were the same or different.

The presentation sequence began with a warning tone that was followed by a 500 ms delay. After the delay, the stimulus was presented; and, at the onset of the stimulus presentation, a timer was started. The timer and the stimulus both stopped when the subject pressed a button on the computer keyboard. After the subject responded to the presentation, the timer was reset to 0.0 and the screen returned to blank viewing circles; at this point, the next sequence was ready to begin. The forty stimuli were divided evenly between the two response hands. The hand used to respond with was randomly determined, and the subject switched hands after twenty presentations. Ten practice trials were given at the beginning of the experiment to familiarize the subject with the task.

Reaction time verbal task. The reaction time verbal task selected for this experiment was a lexical decision task similar to the one used by Bradshaw (Bradshaw, Bradley, Gates, & Patterson, 1976). As mentioned before, this type of task shows large sex differences with females scoring higher than males (Bradshaw & Nettleton, 1983). For this task, a four-letter word or non-word was presented to either the left or right visual field. The subject pressed a key on the computer keyboard to respond to whether the stimulus was a word or a non-word. During a typical trial, the subject saw a blank white screen until the experiment began the sequence. The blank screen was replaced by a fixation point that the subject was instructed to look at until the stimulus appeared. After a brief period of time, the stimulus appeared for 180 msec. At that time, the subject made a decision whether the stimulus was a word or a non-word. Reaction times were collected as well as accuracy of the response.

Regarding the stimuli that are used in these types of studies, it appears that high frequency, concrete nouns are used for the words due to the fact that reaction times appear to be quicker for nouns than for other words (Beaumont, 1982). Because reaction times are measured in milliseconds for this type of task, it is important for the subjects to respond quickly so that the difference in

reaction times for the words and the non-words will be larger and the effect will not be washed out by the difficulty of the task.

For this experiment, a list of 32 concrete nouns were randomly selected from what is commonly referred to as the Brown Corpus (Nelson & Kucera, 1982). The Brown Corpus was organized according to the frequency of use in the American population and was generated from over 500 samples within 15 literary genres, ranging from newspaper reports to philosophical essays. The words for this experiment were selected from the first 6,000 words of the corpus.

A group of 32 pronounceable non-words was created to match the words regarding number and position of vowels and consonants. Each word was checked against the second edition of Webster's New Universal Unabridged Dictionary to make sure it was not a real word (McKechnie, 1983).

After the words and non-words were established, they were divided into two equal groups. Each group had an equal number of words and non-words. This was done so that the responses made by each hand could be counterbalanced--one hand responding to the first group and the other hand responding to the second group.

A quasi-random number set of one's and zero's was created to determine which side the stimuli would be presented. For each of the above groups, the words and non-

words were then equally divided and randomly assigned a presentation side (left or right); in this way, there were an equal number of words and non-words presented on each side of fixation.

Because objects begin to blur at about 5° eccentricity from the fixation point, this degree of eccentricity was used as the outer limit of stimulus presentation (Beaumont, 1982). Research conducted on monkeys also found that the retina is vertically divided by a 1° strip which widens to pass around the fovea (Beaumont, 1982). A stimulus that is projected to this area is bilaterally presented by means of the splenium. Although direct evidence for this strip has yet to be found in humans, it seems prudent to assume that a similar arrangement may at some point be found. It was decided, therefore, that stimuli for this experiment should be presented outside a margin of 2° of visual angle. With the above information in mind, the stimuli were centered on the screen between 1° and 5° to the left and right of fixation.

One of the factors that had to be considered during this experiment was the length of time it takes a saccadic eye movement to bring a stimulus into foveal vision so that the length of the presentation time could be determined. If the presentation time were longer than the latency of the saccadic eye movement, then it would be impossible to

determine whether or not the stimulus was brought into foveal vision. Researchers that have studied divided visual field presentations of rather complex stimuli, presented between 2-5° left or right of fixation and in positions not predictable by the subject, have found mean latencies of saccadic eye movements in the 180-200 milliseconds range with standard deviations of about 20-25 milliseconds (Beaumont, 1982). With this in mind, this experiment used a presentation time of 180 milliseconds; this time is contiguous with the lowest range even when using the largest standard deviation reported.

Paper and pencil tasks. The visual-spatial paper and pencil task that was used was the French's Paper Folding Test (French, 1963) from the Educational Testing Service. This task involved imagining the folding and unfolding of a piece of paper in which a hole had been punched through all thicknesses of the folds. Subjects not only had to visualize and maintain the folds of the paper, but they also had to visualize and count the number of holes in the paper after the hole had been punched and the pages were mentally unfolded. The number correct and the number of errors were calculated.

This task is a fitting complement to the Shepard and Metzler task in that it differs from Shepard and Metzler on two important dimensions: first, it is a paper and pencil

task that, although it is timed, does not require immediate reaction; consequently, subjects have more time to mentally manipulate the material. Secondly, it is an orientation task and the Shepard and Metzler is a visualization task. Therefore, these two tasks cover a broad range of spatial ability skills and test-taking scenarios.

Similarly, the paper and pencil verbal task is quite different from the reaction time measure. For this study, the Extended Range Vocabulary Test was administered to test the subject's knowledge of word meanings. This task consisted of a list of 48 words and 5 choices for each answer, only one of which was correct. The number of correct responses and the number of errors were calculated for this task.

The CAB-N mathematics test (Hakstian & Cattell, 1977) was also administered. This test was used to assess the subject's ability to solve simple mathematical calculation problems. It consists of 40 problems involving addition, subtraction, multiplication, and division of whole numbers and fractions. The number of correct responses and the number of errors were also calculated for this task.

The Edinberg Handedness Inventory (Oldfield, 1971) was used as an additional indicator of handedness along with the self-reported handedness measure. This inventory consists of ten questions involving the hand used to manipulate

different types of objects, such as scissors and a knife; and there are questions on which hand is used for writing, throwing, and drawing. The subject's marked each question with either a plus sign or two plus signs based on the strength of their preference. Two questions were added which asked about foot preference and eye preference. The 12 questions of the handedness measure were used to calculate an overall handedness score by converting the plus signs in the "right preference" column to positive numbers and the plus signs in the "left preference" column to negative numbers. If the subjects entered one plus sign in the column, a score of 1 or -1 was recorded for right or left preference respectively. If two plus signs were entered, a score of 2 or -2 was recorded. An overall score was then recorded by summing the converted scores for all of the questions which had a range from -24 to 24.

Procedure

Subjects participating in the experiment were required to sign a consent form that outlined exactly what was expected of them as subjects. The consent form included a section that stated that their participation was voluntary, and the subjects could choose not to continue with the experiment at any time.

After the subjects signed the consent form, they were then asked to begin one of three tasks that included the

following: a reaction time visual-spatial task; a reaction time verbal task; or a battery of paper and pencil tasks that included a handedness inventory. Each subject completed all three segments of the experiment during one session that lasted approximately one hour.

Results

Paper and Pencil Tests

Males and females from each handedness group were compared on each of the paper and pencil tests. The number of correct answers and incorrect answers were tallied for each of the paper and pencil tasks. No points were taken off for unanswered questions. ANOVAs were performed to examine the number of correct answers as well as the number of incorrect answers. Since all of the paper and pencil tasks utilized a guessing penalty, the number of correct and incorrect answers were not mutually exclusive.

Table 1 outlines the means of the correct answers and errors on the math task for each of the groups that were analyzed. The ANOVA on the number of correct answers on the mathematical task showed no significant main effect for sex ($F[1,78]=.412, p=.523$); but it did show a significant main effect for handedness, with sinistrals performing significantly better than dextrals ($F[1,78]=8.458, p=.005$). There was no significant interaction ($F[1,78]=.001, p=.970$).

There were also no significant differences for sex ($F[1,78]=.019, p=.890$) or handedness ($F[1,78]=2.048, p=.156$) in the number of errors committed on the mathematical task. In addition, there was no significant interaction for sex and handedness ($F[1,78]=.360, p=.550$).

TABLE 1

Mean and Standard Deviations for
CAB-N Math Task by Sex and Handedness

	<u>By Sex</u>		<u>By Hand Group</u>	
	<u>Correct</u>	<u>Errors</u>	<u>Correct</u>	<u>Errors</u>
<u>Female</u>	12.35 (2.92)	2.15 (2.61)	<u>Left</u> 13.53 (3.05)	1.73 (2.06)
<u>Male</u>	12.78 (3.23)	2.08 (2.24)	<u>Right</u> 1.60 (2.80)	2.50 (2.69)
<u>Total</u>	12.56 (3.06)	2.11 (2.41)	<u>Total</u> 12.56 (3.06)	2.11 (2.14)

By Sex and Hand Group

	<u>Correct</u>	<u>Errors</u>
<u>Female</u>		
<u>Left</u>	13.30 (2.96)	1.60 (1.32)
<u>Right</u>	11.40 (2.63)	2.70 (3.41)
<u>Male</u>		
<u>Left</u>	13.75 (3.21)	1.85 (2.64)
<u>Right</u>	11.80 (3.02)	2.30 (1.78)
<u>Total</u>	12.56 (3.06)	2.11 (2.14)

Table 2 outlines the means for the number correct and the number of errors on the French's Paper Folding Test. For the French's Paper Folding Test, which measured spatial ability, there was no significant main effect for handedness on the number of correct answers ($F[1,78]=.590, p=.445$); however, there was a significant main effect for sex with the males outscoring the females ($F[1,78]=9.847, p=.01$).

As far as errors were concerned on the French's Paper Folding task, there was a marginally significant difference between the sexes ($F[1,78]=3.815, p=.054$), with males making more errors (See Table 2).

The mean scores for the number correct and errors on the vocabulary task are shown in Table 3. The number of correctly identified synonyms on the Extended Range Vocabulary Test showed significant differences between the sexes, with females outscoring males ($F[1,78]=3.955, p=.05$). However, there was no significant handedness effect ($F[1,78]=.140, p=.710$), nor was there a significant difference for the interaction of sex and handedness ($F[1,78]=1.541, p=.218$).

Regarding the number of errors on the paper and pencil vocabulary task, there was no significant difference between the sexes ($F[1,78]=.238, p=.627$) or between the handedness groups ($F[1,78]=.305, p=.582$), nor was there any interaction of sex and handedness ($F[1,78]=1.151, p=.287$).

TABLE 2

Mean and Standard Deviations for Paper Folding
Spatial Task by Sex and Handedness

	<u>By Sex</u>		<u>By Hand Group</u>	
	<u>Correct</u>	<u>Errors</u>	<u>Correct</u>	<u>Errors</u>
<u>Female</u>	9.48 (4.12)	5.40 (4.22)	<u>Left</u> 11.70 (6.07)	4.28 (3.62)
<u>Male</u>	13.05 (5.85)	3.73 (3.35)	<u>Right</u> 10.83 (4.53)	4.85 (4.12)
<u>Total</u>	11.26 (5.34)	4.56 (3.88)	<u>Total</u> 11.26 (5.34)	4.85 (3.88)

<u>By Sex and Hand Group</u>		
	<u>Correct</u>	<u>Errors</u>
<u>Female</u>	<u>Left</u> 9.60 (4.26)	5.45 (3.86)
	<u>Right</u> 9.35 (4.08)	5.35 (4.66)
<u>Male</u>	<u>Left</u> 13.80 (6.94)	3.10 (3.03)
	<u>Right</u> 12.30 (4.57)	4.35 (3.62)
<u>Total</u>	11.26 (5.34)	4.56 (3.88)

TABLE 3

Mean and Standard Deviations for
Extended Range Vocabulary Test by Sex and Handedness

	<u>By Sex</u>		<u>By Hand Group</u>	
	<u>Correct</u>	<u>Errors</u>	<u>Correct</u>	<u>Errors</u>
<u>Female</u>	21.30 (9.49)	9.30 (6.89)	<u>Left</u> 22.98 (9.11)	9.25 (7.27)
<u>Male</u>	20.53 (9.47)	10.05 (6.82)	<u>Right</u> 18.85 (9.40)	10.10 (6.40)
<u>Total</u>	20.91 (9.43)	9.68 (6.82)	<u>Total</u> 20.91 (9.43)	9.68 (6.82)

By Sex and Hand Group

		<u>Correct</u>	<u>Errors</u>
<u>Female</u>	<u>Left</u>	24.65 (9.99)	8.05 (6.52)
	<u>Right</u>	17.95 (7.84)	10.55 (7.19)
<u>Male</u>	<u>Left</u>	21.30 (8.05)	10.45 (7.94)
	<u>Right</u>	19.75 (10.87)	9.65 (5.67)
	<u>Total</u>	20.91 (9.43)	9.68 (6.82)

A Pearson correlation was performed on each of the components of the paper and pencil tasks (number correct and number of errors) as well as with the results of the handedness inventory. Table 4 shows the matrix of correlations. For each of the tasks, the number of errors was significantly negatively correlated with the number correct (mathematical task, $r = -.39$, $p < .01$, two-tailed; vocabulary task, $r = -.31$, $p < .01$, two-tailed; paper folding spatial task, $r = -.57$, $p < .01$, two-tailed). Also, the score on the handedness inventory was negatively correlated with the number of correct mathematical problems ($r = -.31$, $p < .01$, two-tailed). Since the handedness inventory was scored so that a greater positive score indicated a greater degree of dexterity, this negative correlation would suggest that the more dextrally-oriented the subject, the lower the score on the mathematical task. Also, the number of mathematical errors was positively correlated with errors on the verbal task ($r = .29$, $p < .01$, two-tailed). In addition, spatial errors were also positively correlated with verbal errors ($r = .23$, $p < .05$, two-tailed).

Reaction Time Measures

The analysis of the mental rotation reaction time measure consisted of measuring the error rate and the reaction time for each degree of rotation. The analysis of error rate showed that females made more errors than males

TABLE 4

Correlation Matrix for the Edinberg Handedness
Inventory and the Paper and Pencil Tasks

	Math Correct	Math Error	Spatial Correct	Spatial Error	Verbal Correct	Verbal Error
Handed. Invent.	-.31**	.18	-.09	.14	-.10	.03
Math Correct		-.39**	.16	-.22	.06	-.05
Math Error			.02	.01	-.08	.29**
Spatial Correct				-.57**	.01	.05
Spatial Error					.15	.23*
Verbal Correct						-.31**

* Two-tailed significance, $p < .05$

** Two-tailed significance, $p < .01$

Note: Negative scores on handedness inventory reflect left-handedness, and positive scores reflect right-handedness. All significance tests for correlation coefficients were based on 78 degrees of freedom.

($F[1,78]=5.478$, $p=.022$), but there were no significant differences for the handedness groups ($F[1,78]=1.143$, $p=.288$) or for the interaction of handedness and sex ($F[1,78]=.802$, $p=.373$).

A repeated measures ANOVA was performed to analyze reaction time. The within-subjects variable of degree of rotation was measured at five levels which corresponded to the degrees of rotation for each of the stimuli. The analysis showed that there was no between-subject effect for sex ($F[1,76]=.43$, $p=.513$), for handedness ($F[1,76]=.86$, $p=.357$), or for the interaction of sex and handedness ($F[1,76]=1.38$, $p=.243$). Also, there were no significant within-subject effects for sex by degree of rotation ($F[4,304]=.88$, $p=.473$), handedness by degree of rotation ($F[4,304]=1.09$, $p=.363$), or sex by handedness by degree of rotation ($F[4,304]=1.65$, $p=.163$). There was, however, a main effect for degree of rotation ($F[4,304]=67.46$, $p<.001$).

Another repeated measures ANOVA was performed that divided the degree of rotation by whether the stimulus was the same or different. However, there were no between-subject effects for sex ($F[1,76]=.98$, $p=.325$), for handedness ($F[1,76]=.08$, $p=.780$), or for the interaction of handedness and sex ($F[1,76]=1.11$, $p=.295$). Figures 2 and 3 show the mean reaction time for each sex at each of the degrees of rotation for both same and different objects.

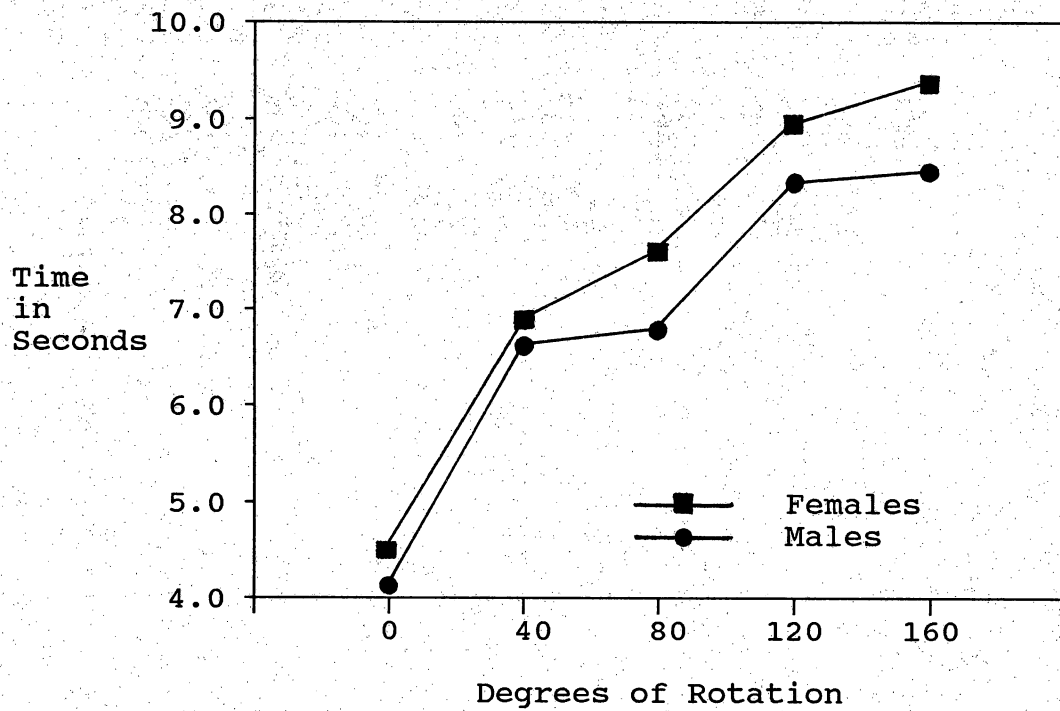


Fig. 2. Reaction time in seconds for "Same" objects.

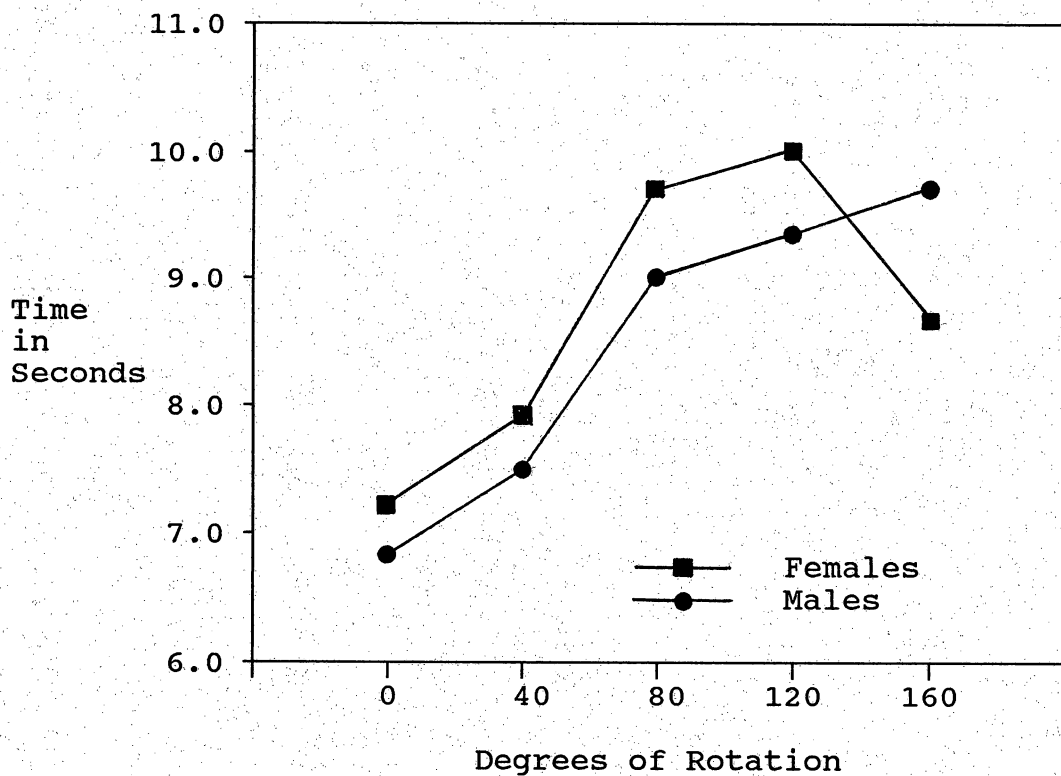


Fig. 3. Reaction time in seconds for "Different" objects.

Regarding objects that were the same, there were no within-subject differences for sex by degree of rotation ($F[4,304]=.38, p=.824$), handedness by degree of rotation ($F[4,304]=.56, p=.694$), or sex by handedness by degree of rotation ($F[4,304]=1.89, p=.112$). Again, there was a main effect for degree of rotation ($F[4,304]=62.38, p<.001$). (See Figure 2 for reaction time by degree of rotation for same objects.)

For objects that were different, there was a significant main effect for degree of rotation ($F[4,304]=24.93, p<.001$). Also, for objects that were different, there was a marginally significant within-subject effect for sex by degree of rotation ($F[4,304]=2.39, p=.051$). A Dunn Multiple Comparisons test was performed to determine if the difference was between the sex groups at 80, 120, and 160 degrees of rotation. This test showed that females' mean reaction time dropped significantly at the largest degree of rotation; whereas, the males' mean reaction time continued to rise ($t[4]=5.25, p<.05$). There was no handedness by degree of rotation effect ($F[4,304]=.75, p=.561$), and there was no significant effect for the interaction of sex, handedness, and degree of rotation ($F[1,76]=1.03, p=.394$). (See Figure 3 for reaction time by degree of rotation for different objects.)

The lexical decision task was analyzed to investigate two different measures, namely speed and accuracy. Since the task involved two different presentation sides (left and right) and two different types of stimuli (words and non-words), a repeated measures ANOVA was used to examine the accuracy of the sexes and handedness groups at both of these levels.

The ANOVA for accuracy showed no significance between-subject effects for sex ($F[1,76]=.79$, $p=.378$), handedness group ($F[1,76]=.03$, $p=.852$), or sex by handedness interaction ($F[1,76]=.05$, $p=.816$). There were also no within-subject effects for presentation side ($F[1,76]=2.83$, $p=.097$), sex by presentation side ($F[1,76]=1.92$, $p=.170$), handedness group by presentation side ($F[1,76]=.01$, $p=.921$), or sex by handedness group by presentation side ($F[1,76]=1.92$, $p=.170$).

There was a main effect for word type ($F[1,76]=12.05$, $p=.001$) with subjects responding more accurately to the non-words ($\bar{X}=13.94$) than to the words ($\bar{X}=13.11$). However, there were no significant interactions for sex by word type ($F[1,76]=.40$, $p=.530$), handedness group by word type ($F[1,76]=.28$, $p=.600$), or sex by handedness group by word type ($F[1,76]=1.11$, $p=.296$).

Regarding the combination of the two within-subject factors, there was no significant interaction for

TABLE 5

Results of Lexical Decision Task
ANOVA for Accuracy Measure

<u>Between-Subjects</u>	<u>F</u>	<u>Sig. of F</u>
Sex	0.79	.378
Handedness	0.03	.852
Sex by Handedness	0.05	.816
 <u>Within-Subjects (Word Type)</u>		
Word	12.05	.001
Sex by Word	0.40	.530
Handedness by Word	0.28	.600
Sex by Handedness by Word	1.11	.296
 <u>Within-Subjects (Presentation Side)</u>		
Side	2.83	.097
Sex by Side	1.92	.170
Handedness by Side	0.01	.921
Sex by Handedness by Side	1.92	.170
 <u>Within-Subjects (Word Type and Presentation Side)</u>		
Side by Word	2.43	.123
Sex by Both	0.31	.580
Handedness by Both	0.00	.999
Sex by Handedness by Both	0.01	.912

TABLE 6

Results of Lexical Decision Task
ANOVA for Reaction Time Measure

<u>Between-Subjects</u>	<u>F</u>	<u>Sig. of F</u>
Sex	0.88	.352
Handedness	0.06	.809
Sex by Handedness	0.19	.668
 <u>Within-Subjects (Word Type)</u>		
Word	35.40	.001
Sex by Word	1.94	.168
Handedness by Word	0.10	.750
Sex by Handedness by Word	0.58	.447
 <u>Within-Subjects (Presentation Side)</u>		
Side	0.17	.683
Sex by Side	0.99	.323
Handedness by Side	0.35	.556
Sex by Handedness by Side	0.46	.498
 <u>Within-Subjects (Word Type and Presentation Side)</u>		
Side by Word	3.87	.053
Sex by Both	1.25	.292
Handedness by Both	0.14	.935
Sex by Handedness by Both	0.19	.436

presentation side by word type ($F[1,76]=2.43$, $p=.123$), sex by presentation side by word type ($F[1,76]=.31$, $p=.580$), handedness group by presentation side by word type ($F[1,76]=.00$, $p=.999$), or the four-way interaction of sex by handedness group by presentation side by word type ($F[1,76]=.01$, $p=.912$). (See Table 5 for a summary of values.)

Another repeated measures ANOVA was utilized with the same variables as the accuracy ANOVA to analyze reaction time. Yet again, there were no between-subject effects with the reaction time ANOVA for sex ($F[1,76]=.88$, $p=.352$), handedness group ($F[1,76]=.06$, $p=.809$), or the sex by handedness group interaction ($F[1,76]=.19$, $p=.668$).

There were also no within-subject effects for presentation side ($F[1,76]=.17$, $p=.683$), sex by presentation side ($F[1,76]=.99$, $p=.323$), handedness group by presentation side ($F[1,76]=.35$, $p=.556$), or sex by handedness group by presentation side ($F[1,76]=.46$, $p=.498$).

There was a main effect for word type ($F[1,76]=35.40$, $p=.001$) with subjects taking longer to respond to the words ($\bar{X}=2.757$) than to the non-words ($\bar{X}=2.408$). However, there were no significant interactions for sex by word type ($F[1,76]=1.94$, $p=.168$), handedness group by word type ($F[1,76]=.10$, $p=.750$), or sex by handedness group by word type ($F[1,76]=.58$, $p=.447$).

Regarding the combination of the two within-subject factors, there was a marginally significant interaction for presentation side by word type ($F[1,76]=3.87$, $p=.053$), with faster reaction time to non-words on the left side and faster reaction time to words on the right side. However, there were no significant interactions between sex by presentation side by word type ($F[1,76]=.12$, $p=.731$), handedness group by presentation side by word type ($F[1,76]=.05$, $p=.826$), or the four-way interaction of sex by handedness group by presentation side by word type ($F[1,76]=1.92$, $p=.170$). (See Table 6 for a summary of values.)

An ANOVA was performed on the lexical decision reaction time data to find out if a preferred hemisphere could be discovered for each sex in each handedness group. Since the presentation side determines which hemisphere the material first enters, reaction time should have taken longer if the material had to cross over to the other hemisphere for processing. Since the material presented to one side is processed in the contralateral hemisphere first, subjects should have responded quicker to material presented on the same side that is lateralized for language. Those subjects with bilateral representation should have responded equally fast to material presented on either side. The following formula was used to obtain a preference score where RF

represents the sum of the reaction times for stimuli presented in the right visual field, and LF represents the sum of the reaction times for stimuli presented in the left visual field: $[(RF - LF)/(RF + LF)]100$. This formula was used to create preference indicators for both words and non-words. If a preference for the right hemisphere is shown, the number will be highly positive; likewise, a preference for the left hemisphere will be highly negative. Bilateral preference will be close to zero.

ANOVAs were performed for sex and handedness to determine if there were differences in hemispheric preference. For the words, there was no significant effect for sex ($F[1,78]=.002$, $p=.963$), handedness ($F[1,78]=.212$, $p=.647$), or the interaction between sex and handedness ($F[1,78]=.186$, $p=.667$). For the non-words, there was also no effect for sex ($F[1,78]=2.31$, $p=.133$), handedness ($F[1,78]=.181$, $p=.672$), or the interaction between sex and handedness ($F[1,78]=3.012$, $p=.087$).

Discussion

The intention of this study was to examine the effects of gender and handedness on two types of cognitive abilities tasks: visual-spatial abilities and verbal abilities. Also, the relationship between different types of tests utilized to measure these abilities were examined as well. The two different types of tests that were utilized were paper and pencil tests and tests that measured reaction time. Also, the relationship between mathematical ability and the two previously mentioned cognitive abilities was examined.

On the mathematical paper and pencil task, sinistrals performed significantly better than dextrals. This result was highlighted not only by the ANOVA but also by the negative correlation of the handedness scores and correct answers on the mathematical task. The results of the mathematical task were unexpected based on a simple examination. If the hypothesis that dextrals are more lateralized for spatial ability and thus perform better at those tasks than sinistrals is correct, and the hypothesis that mathematical tasks are highly correlated with spatial ability is correct, then the results of the mathematical task are puzzling.

However, some research has shown that a spatial strategy may not be appropriate for all mathematical tasks

(Halpern, 1986). In fact, research has shown that some types of math, such as algebra, may lend itself to a more linear or verbal strategy. Since the tasks in the present experiment involved basic mathematical skill (i.e., basic algebra), it makes sense that sinistrals would perform better on these problems. Therefore, the hypothesis that dextrals and males do better on mathematical tasks due to the correlation between mathematical ability and spatial abilities must take into account the nature of the mathematical task utilized.

If Levy's hypothesis is correct, males and dextrals should perform better on spatial tasks than females and sinistrals. Although there was no significant difference in correct responses for sex and handedness, females made more errors on the mental rotation reaction time task. Also, an interaction effect for sex and orientation was found for the different stimuli. Figure 2 shows that females' mean reaction time dropped at 160° ; whereas, males' mean reaction time continued to rise. One explanation for this finding is that females might utilize a different strategy for stimuli rotated at larger degrees. Another explanation might be that females had a harder time determining that the mirror images were different and just guessed with the stimuli at larger degrees of rotation. This explanation might account for females making more errors as well.

It is surprising that greater sex differences or handedness differences were not found on the Shepard and Metzler task, since the findings using this task have proven to be robust (Maccoby & Jacklin, 1974). One explanation for the lack of a sex difference might be attributed to the two sexes using different strategies to solve the rotation problems. However, this explanation is weakened by the finding of main effects for orientation for the combined stimuli, the "different" stimuli, and the "same" stimuli. Although a change in strategy might have occurred with the "different" stimuli at the largest degrees of rotation, subjects, for the most part, responded as though they were mentally rotating the objects in all three cases. The pattern of response is just like the pattern that Shepard and Metzler (1971) found.

Another explanation may be found in the way the experiment was designed. Due to time limitations, the subjects were only given a brief explanation of what was involved with the task, and they were only given 10 practice trials. The Shepard and Metzler task is very difficult, and the subjects may have required a certain amount of practice to become proficient at it and to acquire a thorough understanding of what was involved with the task. In short, the true differences might not be noticeable until a certain amount of training has taken place. It is possible that

with more practice males would improve and females would stay at the same level. Also, it is important to note that Shepard and Metzler (1971) used many practice trials before they started testing.

Another related problem that might have had an effect is that the full stimulus set was not used; therefore, the subjects did not have as many stimuli per category as the subjects run by Shepard and Metzler. These extra stimuli presented during this test were presented over several trials, which might have helped the subjects by simulating a practice effect.

The statistical analysis did not reveal any handedness differences, sex differences, or interaction between the two for the lexical decision task. Any number of problems could have hampered the lexical decision task. For example, one area that is mentioned as a problem area in the literature is that the experimenter can never be sure that the subject is actually focusing on the fixation point (Beaumont, 1982). Subjects tend to try to second guess which side the stimulus will appear for the next trial. If they guess wrong, they could miss the stimulus altogether. If they guess right, the stimulus is bilaterally transferred to the brain.

Another possible way to use the data would be to look at reaction times on each visual half-field for individual differences and categorize subjects by their individual

scores on the preference scale. For example, individuals who have verbal ability bilaterally represented would score more evenly on each half-field of a verbal task because there would be less interhemispheric transfer of information. Likewise, on a task of verbal ability, a person with laterally represented verbal ability would score higher on the ipsilateral half-field where verbal abilities were lateralized. Also, a purely spatial task could be utilized in the same way to gather information about the laterality of spatial abilities.

The correlation of the number of errors on the verbal paper and pencil task with the number of errors on the mathematical task and the correlation between the number of errors on the verbal and the number of error on the spatial task is an interesting finding. One possible explanation is that some students are more willing to guess on these particular types of tests; and, therefore, more errors were made overall. Nonetheless, the result does not confirm or disconfirm any of the hypotheses put forth in this study.

Since the findings of this paper are so inconclusive, nothing can be said about the relationship between the reaction time and paper and pencil tasks for verbal and spatial ability. It might be that this particular combination of tasks might reveal similar findings for each area if some of the problems mentioned earlier are overcome.

Summary

The results of the analysis of data for this paper, for the most part, do not seem to confirm or disconfirm the hypotheses presented by Levy (1979). However, if Levy's (1979) hypotheses are correct, they would account for the finding that sinistrals outperformed dextrals on the mathematical task used because the type of task used might require a more verbal type of problem-solving strategy. If this is the case, they would also explain the negative correlation between dextrality and the number of correct responses on the mathematical task. Had the chosen mathematical task been a more spatially-oriented task (such as graphing sets of numbers or solving geometry or topology problems), then, according to Levy's hypothesis, dextral males probably would have outperformed all others.

The findings on the mathematical tasks also point to the possibility that there might be other processes at work behind the spatial and verbal tasks. Some researchers have discussed the possibility that differences in reasoning ability might also have a part to play in tasks of spatial and verbal abilities (Harshman, Hampson, & Berenbaum, 1983). On an anecdotal note, some of the subjects told the experimenters after the session was over that they used certain reasoning strategies to solve the mental rotation task. While some subjects said they actually turned the

objects in their minds as the task required, others used a strategy of counting the boxes and remembering the angles for each object and did not rotate the objects at all. Whether this strategy worked or not, it could account for some of the differences in scores.

All in all, this paper has shown, experimentally and through a review of the literature, that there are many aspects of the human intellect which interact with each other in various ways--including visual-spatial ability, verbal ability, mathematical ability, and possibly reasoning ability.

This paper has shown that the human mind is a complex bio-psychological system and the path to understanding it is often convoluted and confusing. This is amply illustrated by the various contradictory findings in the literature on cognitive abilities. However, it is hopeful that with continued research the intricacies and mysteries of the human intellect will begin to unfold.

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