1

National Library
of Canada

52749
Bibliothèque nationale
du Canada

CANADIAN THESES
ON MICROFICHE

0-315-04855-7
THÈSES CANADIENNES
SUR MICROFICHE

NAME OF AUTHOR/NOM DE L'AUTEUR Teresa Elizabeth ANUZA

TITLE OF THESIS/TITRE DE LA THÈSE Elimination of Sex Differences in Mental Rotation: Effects
of Sex, Hand and Visual Field of Presentation on a Spatial Task.

UNIVERSITY/UNIVERSITÉ Carleton University

DEGREE FOR WHICH THESIS WAS PRESENTED/
GRADE POUR LEQUEL CETTE THÈSE FUT PRÉSENTÉE Master of Arts (M.A.)

YEAR THIS DEGREE CONFERRED/ANNÉE D'OBTENTION DE CE GRADE 1981

NAME OF SUPERVISOR/NOM DU DIRECTEUR DE THÈSE Dr. W. Jones

Permission is hereby granted to the NATIONAL LIBRARY OF CANADA to microfilm this thesis and to lend or sell copies of the film. L'autorisation est, par la présente, accordée à la BIBLIOTHÈQUE NATIONALE DU CANADA de microfilmer cette thèse et de prêter ou de vendre des exemplaires du film.

The author reserves other publication rights, and neither the thesis nor extensive extracts from it may be printed or otherwise reproduced without the author's written permission. L'auteur se réserve les autres droits de publication; ni la thèse ni de longs extraits de celle-ci ne doivent être imprimés ou autrement reproduits sans l'autorisation écrite de l'auteur.

DATED/DATE

August 31, 1981

SIGNED/SIGNÉ

Teresa Anuza

PERMANENT ADDRESS/RÉSIDENCE FIXE

Ms. Teresa Anuza

138-90th Avenue

LA SALLE, Quebec

H8R 2Z4

National Library of Canada
Collections Development Branch

Canadian Theses on
Microfiche Service

Bibliothèque nationale du Canada
Direction du développement des collections

Service des thèses canadiennes
sur microfiche

NOTICE

AVIS

The quality of this microfiche is heavily dependent upon the quality of the original thesis submitted for microfilming. Every effort has been made to ensure the highest quality of reproduction possible.

If pages are missing, contact the university which granted the degree.

Some pages may have indistinct print especially if the original pages were typed with a poor typewriter ribbon or if the university sent us a poor photocopy.

Previously copyrighted materials (journal articles, published tests, etc.) are not filmed.

Reproduction in full or in part of this film is governed by the Canadian Copyright Act, R.S.C. 1970, c. C-30. Please read the authorization forms which accompany this thesis.

THIS DISSERTATION
HAS BEEN MICROFILMED
EXACTLY AS RECEIVED

La qualité de cette microfiche dépend grandement de la qualité de la thèse soumise au microfilmage. Nous avons tout fait pour assurer une qualité supérieure de reproduction.

S'il manque des pages, veuillez communiquer avec l'université qui a conféré le grade.

La qualité d'impression de certaines pages peut laisser à désirer, surtout si les pages originales ont été dactylographiées à l'aide d'un ruban usé ou si l'université nous a fait parvenir une photocopie de mauvaise qualité.

Les documents qui font déjà l'objet d'un droit d'auteur (articles de revue, examens publiés, etc.) ne sont pas microfilmés.

La reproduction, même partielle, de ce microfilm est soumise à la Loi canadienne sur le droit d'auteur, SRC 1970, c. C-30. Veuillez prendre connaissance des formules d'autorisation qui accompagnent cette thèse.

LA THÈSE A ÉTÉ
MICROFILMÉE TELLE QUE
NOUS L'AVONS REÇUE

ELIMINATION OF SEX DIFFERENCES
IN
MENTAL ROTATION:
EFFECTS OF SEX, HAND AND
VISUAL FIELD OF PRESENTATION
ON A SPATIAL TASK

By

Teresa E. Anuza

Thesis presented to the Faculty of
Graduate Studies of Carleton
University in partial fulfillment
of the requirements for the
degree of Master of Arts

Department of Psychology
Carleton University
Ottawa, Ontario
April, 1981

The undersigned recommend to the Faculty
of Graduate Studies and Research acceptance of the thesis

"Elimination of Sex Differences in Mental Rotation:
Effects of Sex, Hand and Visual Field of Presentation on a Spatial Task"

submitted by Teresa E. Anuza
in partial fulfillment of the requirements for
the degree of Master of Arts

.....
Thesis Supervisor

.....
Chairman, Department of Psychology

Carleton University

April 1981

ABSTRACT

Thirty male and female subjects (with 10 right handers, 10 non-familial left handers and 10 familial left handers in each group) performed a mental rotations task, in which they were required to decide whether a stimulus was the same as the standard or its mirror image. Two-sided and four-sided line drawings were rotated in five different orientations from 0 to 180 degrees. The stimuli were presented for 100 msec. at 7 degrees from central field fixation in the right and left visual fields to ensure transmission to the contralateral hemisphere.

There was no significant difference in performance between the sexes, either in response times or errors or on an index of inefficiency. Right handers showed faster reaction times than left handers. A stimulus difference was noted. The two-sided stimulus resulted in faster RT's and fewer errors as well as a steeper slope for the function relating RT to angle of rotation.

Visual field differences were not apparent either in overall response times or in speed of mental rotation, though there was a small left visual field advantage in efficiency.

The results are discussed in terms of response time strategies and in terms of right hemisphere specialization for spatial processing.

Acknowledgements

I wish to express my sincere appreciation to Dr. B. Jones, Department of Psychology, Carleton University for his guidance and support throughout the development of this thesis. I would also like to thank Dr. B. Petrusic for his questions and thoughts.

4

TABLE OF CONTENTS

LIST OF FIGURES.....	i
LIST OF TABLES.....	ii
LIST OF APPENDICES.....	iii
INTRODUCTION.....	1
Mental Rotation	2
Lateralization of Function in the Cerebral Hemispheres	9
Handedness	14
Sex Differences and Lateralization	19
Sex Differences in Spatial Ability	21
THE EXPERIMENT.....	26
METHOD.....	30
Subjects	30
Materials and Apparatus	31
Procedure	32
RESULTS.....	34
RTc	34
RT	36
Errors	37
Index of Inefficiency	37
Curve Fitting	38
DISCUSSION.....	40
Summary and Conclusion	49
BIBLIOGRAPHY	
APPENDICES	

LIST OF FIGURES

Figure 1 - The two stimuli (standard form)

Figure 2 - Least-square linear regression lines for mean RT (secs.) for standard and mirror image forms as a function of angle of orientation. RT increases at a rate of 3.9 msec. per degree for standard forms and at 2.8 msec. per degree for mirror image forms.

Figure 3 - Least-square linear regression lines for mean RTc (secs.) as a function of angle of orientation. RTc increases at a rate of 3.4 msec. per degree.

Figure 4 - Least-square linear regression lines for mean RTc (secs.) as a function of handedness. The rates of increase in RTc are 1.6 msec. per degree, 3.1 msec. per degree and 5.4 msec. per degree for right handers (RH), non-familial left handers (LHNF) and familial left handers (LHF) respectively.

Figure 5 - Least-square linear regression lines for mean RTc as a function of angle for Stimulus 1 and Stimulus 2 presented in the left (LVF) and right (RVF) visual fields.

Figure 6 - Least-square linear regression lines for mean number of errors as a function of angle of orientation. Errors increase at a rate of .0058 errors per msec. for the left visual field (LVF) and at a rate of .0070 errors per msec. in the right visual field (RVF).

LIST OF TABLES

- Table 1 - (a) Male Subjects (b) Female Subjects
Mean Response Times (RTc) for correct responses
across the Main Factors of Sex, Handedness,
Stimulus, Visual Field, and Angle.
- Table 2 - (a) Male Subjects (b) Female Subjects
Mean Response Times (RT) for overall responses
across the Main Factors of Sex, Handedness,
Stimulus, Visual Field, and Angle.
- Table 3 - (a) Male Subjects (b) Female Subjects
Mean Error Rates out of 20 responses across
the Main Factors of Sex, Handedness, Stimulus,
Visual Field, and Angle.
- Table 4 - (a) Male Subjects (b) Female Subjects
Means on the Index of Inefficiency across the
Main Factors of Sex, Handedness, Stimulus,
Visual Field, and Angle.
- Table 5 - Means and Standard Deviations for each
Handedness Group (Right Handers (RH),
Non-Familial Left Handers (LHNF) and Familial
Left Handers (LHF)) on the Index of
Inefficiency.
- Table 6 - Goodness-of-Fit Statistics for the Main
Variables for Least-Square Linear, Logarithmic
and Power (Exponent less than one) Fits.

LIST OF APPENDICES

- APPENDIX I -
- (1) ANOVA Summary Table for RTc : Five-way for Sex, Handedness, Stimulus, Visual Field and Angle of Orientation.
 - (2) ANOVA Summary Table for RT : Five-way for Sex, Handedness, Stimulus, Visual Field and Angle of Orientation.
 - (3) ANOVA Summary Table for ERRORS : Five-way for Sex, Handedness, Stimulus, Visual Field and Angle of Orientation.

APPENDIX II - Mean RTc for All Subjects

- (a) Mean RTc's for Male Right Handers
- (b) Mean RTc's for Male Non-Familial Left Handers
- (c) Mean RTc's for Male Familial Left Handers
- (d) Mean RTc's for Female Right Handers
- (e) Mean RTc's for Female Non-Familial Left Handers
- (f) Mean RTc's for Female Familial Left Handers

Introduction

This study deals with the idea that the right cerebral hemisphere, in the majority of normal human beings, is specialized for spatial processing and with an attempt to account for variation in spatial ability in terms of differences between the sexes and between handedness groups in cerebral lateralization (Bogen & Gazzaniga, 1965; Dimond & Beaumont, 1974; Levy, 1974; McGee, 1979; Witelson, 1976).

The experiment will make use of a particular spatial task, which is convenient to call mental rotation. An ability to solve rotational problems has sometimes been taken to define spatial ability. In Guilford's (1947) words spatial ability is "to move, turn, twist, rotate an object or objects and to recognize a new appearance or position after the presented manipulation has been performed". Rotational problems are ubiquitous in paper and pencil tests of spatial abilities (see Petrusic, Varro & Jamieson, 1978) and like almost all spatial tests, show pronounced male superiority, in terms of mean performance.

Experimentally a particular mental rotation task has achieved wide acceptance thanks to the work of Shepard and his colleagues (Cooper & Shepard, 1976; Shepard, 1975; Shepard & Metzler, 1971). The subject, in these experiments, is asked to decide whether a visual stimulus is

in standard form or is the mirror image of the standard form. The forms are presented at varying orientations and the subject's response time (RT) is recorded. In general, RT is a monotonically increasing function of angle of orientation up to 180 degrees and a decreasing function from 180 to 360 degrees (Cooper & Shepard, 1973). This experimental form of the rotation problem also results in male superiority in both mean RT and in the rate of change in RT as a function of angle, "the rate of mental rotation" in Shepard's terms (Kail, Carter & Pellegrino, 1979; Petrusic et al., 1978).

The aim of this thesis is to elucidate this sex difference and to bring into focus sex-differences in hemisphere specialization (Allen, 1974; Bryden, 1979; Hannay & Boyer, 1978; Harris, 1978; Jones, 1979, 1980; Kail & Siegel, 1978; Lake & Bryden, 1978; Levy, 1978; McGlone & Davidson, 1973; Milstein, Small, Malloy & Small, 1979). Since handedness is also clearly associated with variation in hemispheric specialization (Andrews, 1977; Annett, 1964; Corballis & Beale, 1976; Hécaen & Sauguet, 1971; Jones, 1980; Lake & Bryden, 1976; Levy & Reid, 1978; Milstein et al., 1979), how sex and handedness interact for the mental rotation task is of some interest. Accordingly a review of

the literature will ensue examining in turn , experimental data on mental rotation and the general relationship between handedness differences and of sex differences to hemispheric specialization and to spatial ability.

Mental Rotation

Introspection and informal questioning have shown that adults can be said to rotate mentally, internal representations of various shapes in order to make decisions about them. Nevertheless the idea of an internal representation remains obscure. In the earlier studies of Shepard and his colleagues (1971, 1973), the impression was given that subjects would rotate a mental image in much the same way as they would rotate a physical object by hand. In all events, the process was thought to be rapid, efficient and holistic. Later studies (Hochberg & Gellman, 1977; Petrusic et al., 1978; Pylyshyn, 1979) have implied that the process of mental rotation may be more complex and more piecemeal than was originally conceived.

In mental rotation studies the subject is typically presented with a two or three-dimensional shape and is asked

to judge whether it is the "same" or "different" from a standard form. The reaction time for correct "same" decisions has typically been found to be a linear function of the angular rotation of the portrayed form (e.g. Cooper, 1975; Cooper & Shepard, 1973; Kail et al., 1979; Metzler & Shepard, 1974; Petrusic et al., 1978; Shepard & Metzler, 1971). Although mental rotation may not play a role in most ordinary processes of recognition, it may play an important role in other more specialized activities, including reading a map, moving furniture about a room or finding our way in the world.

Most of the experimental paradigms currently used to study mental rotation, while diverse, involve RT measurements (Cooper & Shepard, 1973), either of the time required to respond to a spatially transformed object after it has been presented or to prepare for such a transformed object before it has been presented, or of the time required to differentiate a transformed stimulus from the standard. Typically the subject judges whether a form presented in various orientations is the same as the standard form or the mirror image of it.

Cooper and Shepard's (1973) research showed that the function relating reaction time to orientation of

alphanumeric characters was symmetrical with respect to the 180 degree orientation, linearly increasing up to 180 degrees and linearly decreasing from 180 to 360 degrees. In their terms mental rotation is counterclockwise for orientations between 0 and 180 degrees and clockwise for orientations between 180 and 360 degrees. The symmetrical RT function indicated that the internal representations of the stimuli were rotated through the minimum angle necessary to return the representation of the form to the upright position, which implied that subjects identified the alphanumeric characters and determined their orientation prior to the onset of mental rotation. Hock and Tromley's (1978) work supported this hypothesis since they found that their subjects would mentally rotate letters of the alphabet only when they were presented in orientations in which they were not perceptually upright. That is, rotation was not necessary when orientation of the stimulus was close to zero degrees. Similar observations were made (Corballis, Zbrodoff, Shetzer & Butler, 1978) in experiments involving identity and orientation decisions for disoriented alphanumeric characters.

Cooper and Shepard (1978) have argued that information concerning the internal processes preceding the subject's

overt response on each trial can be collected by monitoring eye fixation. They found that the sequence of fixations could often be divided into three distinct and successive patterns. The first is indicative of a search for corresponding ends of the objects, the second represents the rotational transformation itself, and the third indicates the process of decision making as to sameness or difference. Although the times associated for each of the phases have been found to increase with the angular difference between the two objects, by far the greatest increase can be attributable to the stage concerning the transformational process.

For Cooper (1976) and Shepard (1975), mental rotation is an analog to an external rotation of an object. Cooper (1976) took the linear relationship between RT and angle of orientation as evidence that the internal process underlying the observed reaction times involves an ordered series of stages in a one-to-one correspondance to the successive stages in the rotation of an external object (Cooper, 1976). Therefore, according to these researchers (Cooper & Shepard, 1973; Shepard, 1975), each intermediate stage through which this internal process passes consists of a readiness to respond discriminantly to a particular external orientation, if such an object were to be presented.

At this point caution should be exercised before too many generalizations are made from the studies of Shepard and his colleagues. Their studies generally used very small and very highly trained subject groups (e.g. Metzler & Shepard, 1974). In a few studies, subjects were specifically trained in mental rotation. Therefore statements may be made about what a person is capable of if properly trained, but it is by no means certain that under normal circumstances all persons would use mental rotation, as described by Cooper and Shepard (1973), to solve these kinds of tasks.

Just and Carpenter (1976) for example, found that the rotation functions for visual and tactile alphanumeric characters were very similar. They suggested that some aspects of the rotation process were similar across modalities. They implied that eye fixations could be a method for externalizing internal processes that are also used in verbal tasks, rather than an indication of an imagistic processing.

Two recent studies have found stimulus disparities in the rate of mental rotation. Hochberg and Gellman (1977) found that rotated shapes with salient landmarks had lower slopes and intercepts in their time/angle function than for

the shapes in which these features were made less distinguishable. Petrusic et al. (1978) demonstrated that the rate of mental rotation in general increases with stimulus symmetry. These results present problems for Cooper and Shepard's theory since they claim that differences in stimuli may affect decision time but not the time required for transformation of the stimulus. While Cooper claims that mental imagery mimics or is an analog to, the physical world, Petrusic et al. (1978) suggest that a more abstract process may be involved in mental rotation. Pylyshyn (1979) argues that the linear RT function in mental rotation arises from a more piecemeal than holistic process "in which analysis of the stimulus figure interacts with the comparison task". He states that the rate of mental rotation is a function of practice, intrinsic properties of the stimulus, and the nature of the comparison task carried out on the rotated image.

This brief survey is sufficient to show that although Shepard's mental rotation task may be said to be a paradigm example of a spatial task, the underlying processes may be a good deal more complex than Shepard originally supposed.

Lateralization of Function in the Cerebral Hemispheres

Study upon study has shown that the two cerebral hemispheres of the human brain may be specialized for certain tasks or for certain kinds of processing (Kimura, 1969; Kimura & Durnford, 1974; White, 1969). The left hemisphere appears to be specialized for verbal or linguistic performance, while the right hemisphere is said to be more concerned with spatial performance. Several other dichotomies have been suggested (Bogen, 1969). For example, the left hemisphere has been called logical and analytical, while the right is said to be visuospatial, synthetic and holistic. Moreover, most attempts to categorize hemisphere differences apply best to right handers and to males rather than to left handed persons or to females. In short there are strong indications that sex and handedness contribute to the variation in bilateral differentiation of the central nervous system. Later sections will be concerned with sex and handedness interactions with respect to hemisphere lateralization of functions.

Hemispheric asymmetry has been studied in clinical groups through patients with lateralized lesions (Milner,

1969) or patients with surgical interruption of the corpus callosum (Gazzaniga, 1970; Trevarthen & Sperry, 1973) and in the normal population by means of tachistoscopic stimulation and dichotic listening (Dimond & Beaumont, 1974). EEG studies have also been performed (Marsh, 1978; Willis, Wheatley & Mitchell, 1978).

Due to the crossed anatomical nature of the human brain, the left cerebral hemisphere controls the right side of the body and vice versa. That is, the physiological properties of the interhemispheric pathways are such that tactual information from the left hand reaches the right hemisphere by direct sensory channels but reaches the left hemisphere by commissural channels. Similarly, the contralateral visual field is represented in a hemisphere directly while the ipsilateral representation is by way of the commissures (Gazzaniga & LeDoux, 1978). Some research has suggested that the view of the world created in a hemisphere by direct sensory channels is largely duplicated in the contralateral hemisphere by way of the commissural pathways (Dimond, 1972; Gazzaniga, 1970; Gazzaniga & LeDoux, 1978). Information rapidly presented to the right visual field (RVF) for example, is picked up and sent first to the left hemisphere and then to the right.

The hemisphere responsible for language in most right handed people, is normally the left. In the past it has been referred to as the dominant hemisphere since left hemisphere damage often results in serious deficits in communication skills. The non-verbal right side of the brain was, for a long time, thought to be subservient to the left. More recent work has demonstrated that it is neither subservient nor silent, but may have specialized functions of its own, including perhaps musical and spatial skills (e.g. Geschwind, 1979).

Tapping the processing or functioning of a single hemisphere in a normal subject with intact commissural connections is not a simple task. In testing the functioning of one hemisphere over another for visual processing, a stimulus may be tachistoscopically presented to one of the two visual fields and measures of reaction time or accuracy or occasionally, both are taken. Given rapid presentation, the subject does not have time to change eye fixation (The time required to change eye fixation is usually estimated at about 200 msec. (e.g. Woodsworth & Schlosberg, 1954.)) and it is assumed that the hemisphere contralateral to the field of vision containing the form is primarily responsible for performance.

The great majority of previous studies which have required recognition rather than any form of problem solving, have shown verbal material to be most accurately recognized in the right visual field (RVF) suggesting that the left hemisphere is specialized for verbal processes (see e.g. Dimond & Beaumont, 1974). Non-verbal stimuli, such as dots about a line, abstract forms and so on, tend to be more accurately or more quickly discriminated in the left visual field (LVF) (e.g. Kimura & Durnford, 1974). However, the effects obtained with non-verbal stimuli do not seem as consistent as the results obtained with verbal material. The variability for so-called right hemisphere tests may be due in part to the verbal nature of "non-verbal" tasks. Even if no obvious verbal stimuli or responses are used language processing may still be taking place resulting in a left hemisphere advantage for some subjects.

We should also be aware of the considerable variabilities in hemispheric lateralization studies in general. Even the verbal/non-verbal dichotomy is not consistent across studies. The direction and magnitude of the visual laterality difference for verbal tasks, is a complex function of many factors including, according to White (1972), acquired reading habits, stimulus presentation

47

procedures, and dominances of eye, hand and hemisphere. One may also add position of stimuli in the visual field since Worrall and Coles (1976) found a slight overall left field advantage for letters presented at clock face positions with respect to central fixation, though along the horizontal meridian, letters were more accurately recognized in the RVF.

Bilateral presentation of alphanumeric characters seem to reverse the right field advantage that was noted previously (Heron, 1957; White, 1969). Heron (1957) found more accurate perception of letter groups presented in the LVF. Moreover, Jones and Santi (1978) found a right field advantage for letter discrimination only when subjects were allowed to make eye movements contingent upon brief presentation of a letter in either visual field. Since the subjects in the Eyes Fixed condition showed equivalent accuracy across fields, the right and left hemispheres may be able to handle letter recognition more or less equally. The RVF advantage may reflect a bias toward the right side of the display which effects correct recognition when subjects have the use of eye movements.

It is becoming clearer that left-right dichotomies are likely to be too simplistic in speaking of cognitive

functions in humans. The specific contributions of the two cerebral hemispheres and the various cerebral regions may be as much a function of the subject as of the task. Some researchers (e.g. Willis et al., 1978) suggest that hemispheric specialization is a function of the task processing demands and not simply related to the perceptual requirements. In her EEG study, Willis and her colleagues observed that while a purely perceptual task showed more right hemisphere processing, an area task, requiring the subject to find the minimal set of measurements needed to find the area of a face of a configuration, showed left hemisphere specialization.

Handedness

Geschwind (1979) claims that the phenomenon of handedness is one of the most commonplace manifestations of cerebral dominance, as well as one of the most puzzling. A strong, though imperfect, correlation is said to exist between cerebral dominance and handedness (Goodglass & Quadfasal, 1954). The left hemisphere is dominant for language in the vast proportion of dextrals but in only a small majority of left handers (Levy, 1974). Left and right

handlers with or without a family history of sinistrality show different degrees and kinds of laterality effects in dichotic listening studies as well as in visual half-field stimulation experiments (e.g. Dimond & Beaumont, 1974).

Right hemisphere speech has been found to be more common in left handed people (Milner, Branch & Rasmussen, 1964). According to some researchers (Beaumont, 1974; Levy, 1974) left handlers, irrespective of direction of lateralization, are less completely lateralized than are right handlers (Goodglass & Quadfasal, 1954; Hécaen & Ajuriaguerra, 1964). This conclusion was based on the following observations. The Wada test usually shows more sinistrals than dextrals manifesting bilateral language. In lateralization tests with normal people, sensory field differences are typically smaller for left handlers than for right handlers. Sinistrals tend to become aphasic following a lesion to either hemisphere, more frequently than do dextrals. The complete recovery from aphasia is more frequent in left handlers (e.g. Dimond & Beaumont, 1974). Hécaen and Sauguet (1971) found that right hemisphere lesions cause language disturbances only in familial left handlers. They claim that the representation of language in familial left handed subjects is characterized not only by

bilaterality but also by a less marked degree of cerebral localization within each hemisphere. Therefore the mirror-image left handed subjects should be found among those with a family history of left handedness.

Hardyck and Petrinovich (1977) have proposed a classification of handedness and lateralization of cerebral function. Right handed individuals with no family history of left handedness should be the most strongly lateralized and the left handed with a positive family history of left handedness should show bilateral localization of functions. The non-familial left handers would be classified as identical in cerebral lateralization with the right handers with no family history of left handedness.

This classification is in fact based on that of Annett (1964). She argues that non-familials have an inherited bias toward right handedness and left hemisphere speech. Handedness and braininess may be binomially distributed and familials detected with sinistral handedness may have speech represented in the right hemisphere.

Levy and Reid (1978) have suggested a further classification of left handers. They claim that left handed subjects who write with an upright or normal, as opposed to inverted, hand posture, are more likely to have speech

represented in the right hemisphere. However, McKeever (1972) suggests that hand posture while writing correlates strongly with familial handedness and is not therefore, an independent predictor of underlying lateralization.

Though there is some agreement that the familial and non-familial distinction is related to cerebral lateralization, studies of these groups of left handers have so far produced a number of discrepant results. For example, Zurif and Bryden (1969) found that non-familials had a significant RVF advantage for sequential bilateral letter recognition though they observed no visual field advantage in familial left handers. Two other studies reported exactly the opposite findings using unilateral sequential presentation of single letters (Higenbottom, 1973; McKeever et al., 1973). Hines and Satz (1974) found the expected left hemisphere superiority for unilateral presentation of single letters for groups of right handers, non-familial left handers and familial left handers. McKeever and VanDeventer (1977) on the other hand found that familial left handers showed superior left hemisphere recognition of letters, while non-familial left handers showed no hemispheric asymmetry. Still other experiments have noted atypical dominance in the processing of visual

verbal information, in markedly left handed, as opposed to weakly left handed subjects (Bryden, 1973; McKeever et al., 1973).

Similar discrepancies can be observed in auditory studies. While two studies demonstrated a left hemisphere effect for verbal material in weakly left handed people (Satz et al., 1967; Knox & Boone, 1970), another study found markedly left handed subjects, as opposed to those weakly left handed, showed the left hemisphere effect (Dee, 1971). The Zurif and Bryden (1969) study showed a left hemisphere advantage in non-familials but not in the familial left handed group. However, Satz et al. (1967) found a left hemisphere advantage for the familial left handers and no advantage in the non-familial group. Yet another study showed atypical auditory lateralization in both familial and non-familial left handers (Higenbottom, 1973).

Handedness or the existence of a family history of left handedness may also interact with sex differences. Lake and Bryden (1976) found that females with familial sinistrality tended to show more left ear superiorities, regardless of their handedness and males with familial sinistrality were consistently right ear superior. The laterality of subjects without a family history of sinistrality, however, was more

a function of their handedness and the sex differences disappeared. Jones (1980) using a categorization task, found a predominant right field advantage for right handed and non-familial left handed males and a predominant left field advantage for the familial left handed males. The females showed no consistent field advantage.

Sex Differences and Lateralization

Buffery and Gray (1972) concluded that females are more lateralized than males, taking early acquisition of language in females to imply early specialization of the left hemisphere. However, most researchers claim that females are less lateralized than males (e.g. Hannay & Malone, 1976; Jones, 1979, 1980; Levy, 1974), in the sense that language may be represented in both hemispheres. Levy (1974) has claimed that females and left handed subjects do better on tests of verbal ability than on tests of spatial ability because both are more likely to have bilateral speech representation.

In the study by Jones (1980) on the categorization of faces as male or female, males showed a RVF advantage

consistent with the cerebral hemisphere specialized for speech production. This hemisphere is said to be responsible for categorization and labelling (Levy, 1969). A left hemisphere advantage was found for right handers and non-familial left handers, while a right hemisphere advantage for familial left handers was noted. Familial left handed females were found to be twice as strongly lateralized as female right handers and not significantly different from male right handers. This data did not support the hypothesis that left handers are less strongly lateralized than right handers (e.g. Hécaen & Sauguet, 1971; Levy & Reid, 1978).

A study by Milstein et al. (1979) had subjects solve simple multiplication problems presented visually to one cerebral hemisphere while various competing stimuli were presented to the other hemisphere. Females and dextrals made more correct responses than males or sinistrals. The type of error which subjects made depended upon which hemisphere received the problem. The right hemisphere yielded more errors of commission and the left more errors of omission. Right handed males made more correct responses when the problem was presented to the left hemisphere, as well as fewer errors of commission and

generally fewer of omission. Milstein et al. suggested that left handed males and right handed females have similar patterns of correct responses and errors of commission but opposite patterns of errors of omission.

Sex Differences in Spatial Ability

A general difference has been repeatedly observed between males and females on spatial tasks. Males typically show faster and more accurate performances (e.g. Cooper & Shepard, 1973; Maccoby & Jacklin, 1974). There are several hypotheses to account for this difference. Some suggest that the degree of lateral specialization of the cerebral hemispheres differs between males and females, though as has already been noted, there is some disagreement as to whether males (Harris, 1978; Levy, 1973; Witelson, 1976) or females (Buffery & Gray, 1972) are more lateralized and what functions are involved. Other researchers (e.g. Bryden, 1979) have suggested that these differences may be due to differing cognitive strategies. That is, involving a processing difference as opposed to a biological difference. The dependent variable in most of these studies is response

time. It has been observed that females have a tendency to be more cautious and conservative in making their decisions than are males, particularly among the age range of college undergraduates, from which most samples are taken. Harris (1978) has suggested that males and females may have the same brain organization but that females may use language maladaptively to solve spatial problems. Theories involving attentional factors (Kinsbourne, 1974) and visual scanning processes (Heron, 1957) have also been proposed. Social factors have also often, if rather vaguely, entered into the discussion of sex differences (Maccoby & Jacklin, 1974).

This thesis is concerned with sex differences in spatial ability and with a particular spatial task, mental rotation. Males show decidedly better spatial skills than females with only 20 to 25% of females exceeding the average performance of males (Harris, 1978). General differences in spatial ability between men and women have been reviewed in detail elsewhere (e.g. Harris, 1978) and the mental rotation task will be concentrated on here. Harris (1978) in fact, believes the characterization of spatial ability implies mental imagery of a distinctly kinetic as opposed to a static kind. Harris claims that this kinetic quality is evidenced in the linearly increasing function of the angular

difference in orientation and reaction time and by the fact that rotation in depth takes no longer than rotation in the picture plane (Shepard & Metzler, 1974).

Handedness is often found to interact with hemispheric specialization. McGlone and Davidson (1973) found sex differences in spatial skills on the Spatial Relations Test. Males performed significantly better than females. There was a significant interaction between ear superiority and sex. Females with higher left ear scores, implying right hemisphere language, were worse on the Spatial Relations Test than any other group. There was a significant interaction between ear superiority and hand preference. Relatively more left handers with higher left ear scores fell below the median on the Spatial Relations Test. The effect was especially marked in the case of left handed females, with higher left ear scores. Finally females and left handers with left ear superiority on the dichotic listening test had the lowest scores on the Block Design Test. That is, not all left handers did worse than right handers, it was primarily those that showed higher left ear scores.

Metzler and Shepard (1974) found that the rate of rotation was slightly though not significantly, higher for

left handers and for females. In one of two studies, the four female subjects were among the five subjects whose RT functions showed the highest intercepts as well as the steepest slopes. Three of these women had the highest error scores and the most variable reaction times. Though for every subject, the overall linearity and coincidence of functions for the depth and picture plane pairs were found. The females and left handers, especially the left handed females, were slower in the rate of mental rotation for all pairs of shapes. Both men and women took longer the greater the difference in orientation between the two shapes. The reaction times for females increased relatively more than the men's as the difference in orientation of the two shapes increased.

As was stated earlier, decision times were typically found to increase linearly for orientations up to 180 degrees and then found to decrease almost symmetrically. The slope of this function represents the speed of mental rotation (Cooper & Shepard, 1973). Petrusic et al. (1978) found that female subjects showed higher intercepts and steeper slopes than males in a mental rotation task. That is, the females took longer to make the "same/different" judgements. The difference could not obviously be

attributed to a speed-accuracy trade-off strategy since males made fewer errors than females everywhere but for the zero degrees rotation. Similar results were obtained in a study by Kail and his colleagues (1979). The single significant sex difference in performance was that men mentally rotated stimuli more rapidly than women. The slope of the reaction time and degree of rotation function was steeper for women, as well as more variable. Women and men were similar in the accuracy of their judgements, the intercepts of the latency functions and the precision with which the linear function characterized the latency data. It was suggested by Kail et al. that the sex difference in slope was due to differences in the strategies of mental rotation used by a proportion of the women.

Tapley and Bryden (1977) believe the sex difference to be fundamentally spatial as opposed to analytic in nature. In their study, they found that sex differences were greatest for correlations with the Paivio questionnaire for good visual imagery. While frequent use of visual imagery was related to mental rotation rate in men, it seemed more likely to be affected by other components, such as the comparison and confirmation processes, in women.

The Experiment

The aim of the experiment is to examine possible sex and handedness differences in hemispheric specialization for spatial abilities. A modified version of Shepard's mental rotation task will be used and this section will detail some plausible predictions for the sex, handedness and visual field variables.

Previous experiments (Cooper & Shepard, 1973; Kail et al., 1979; Petrusic et al., 1978) have indicated that males should perform more efficiently in this task than females. The mental rotation task typically shows a linear increase in RT as the orientations of the stimuli approaches 180 degrees. On the face of it, there seems every reason to assume that the function of RT and angle of rotation should be linear across both visual fields and for both sexes. Previous studies (e.g. Petrusic et al., 1978) have indicated that both the intercepts and the slopes of the RT function should differ significantly between sexes. The slopes which Shepard and his colleagues consider to represent the speed of mental rotation are expected to be steeper for women. Males are also likely to make fewer errors than

women in this task (e.g. Maccoby & Jacklin, 1974). Errors should also increase as does RT as a function of the degree of rotation, the greater the angle of rotation, the more errors. Mirror image or "different" judgements are likely to produce more errors and require more time than "same" judgements (Cooper & Shepard, 1978).

Hemispheric specialization will be studied through brief presentation of stimuli to either visual field. The group will also be classified with respect to hand preference and family history of left handedness. Right handed and non-familial left handed males are typically expected to perform faster and more accurately in this spatial task, specifically when the forms are presented to the left visual field (Kimura & Durnford, 1974). This would imply, as in previous studies (see e.g. Dimond & Beaumont, 1974), a greater specialization for spatial tasks in the right hemisphere. While the non-familial males are likely to perform in a similar manner to right handed males (Hécaen and Sauguet, 1971; Jones, 1980), the familial group is not expected to do as well. Hardyck and Petrinovich's (1977) theory states that this group should be bilateral and therefore show no field advantages. Annett (1964) would claim that they should show no bias toward left hemisphere

language and for that reason could possibly demonstrate a right visual field advantage for this kind of spatial task.

Female right handers may be expected to be the least efficient of all of the groups. This could indicate bilateral language representation or a lack of lateralization for spatial abilities (Harris, 1978; Levy, 1974). This result would be in keeping with the many previous studies showing poorer or slower performance in spatial tasks for women (Maccoby & Jacklin, 1974; Wittig & Peterson, 1979). It follows that for this group of women there should be no differences in speed or accuracy between the visual fields. It is more difficult to predict for the group of left handed females. Familial left handed women may show opposite field effects to those of right handed males, since according to at least one theory (Annett, 1964) they should not have inherited any predisposition to localize language in the left hemisphere. Therefore some may have a cerebral organization that is the mirror image of that for right handed males. At the same time, this group of women may prove to be as efficient as right handed males in performance, since they may be equally lateralized but in the opposite direction (Hécaen & Sauguet, 1971). From the research done so far it is difficult to predict which

direction non-familial left handed females will lean toward, that is, which if any visual field will show an advantage. It is possible that this group will perform very similarly to the right handed females, indicating similar cerebral organization (Hécaen & Sauguet, 1971).

Thus the results of the experiment should serve to further clarify the relationship of sex differences and lateralization of cerebral functioning, with regards to spatial ability. The interaction of handedness with each of these factors will be examined.

Method

Subjects

Sixty subjects were recruited, mainly from the Carleton University student population. An equal number of males and females were run, categorized as right handed, left handed familial or left handed non-familial, according to responses on a modified Edinburgh Handedness Inventory (Oldfield, 1971). On average the right handers scored a laterality quotient on this questionnaire of between 75 and 80 out of 100, indicating preference for their right hand. The left handed groups displayed average scores of between -70 and -80 percent.

Left handed subjects were placed in the familial category if they had either parents, siblings or grandparents, who were left handed. Those with left handed grandparents generally had other members in the family, such as uncles or aunts who were also left handed. Thus all twenty members of the left handed familial group had in their family, one first degree relative or at least two second degree relatives, who were left handed.

Materials and Apparatus

The experimental task required each subject to judge whether a form presented rapidly to either visual field, in various orientations, was the same as the standard form or its mirror image.

The stimuli consisted of two asymmetrical black line drawings (Figure 1). The first stimulus consisted of a right angle, with the longer side pointing down and the shorter side pointing to the right. The ratio of the longer side to the shorter side was approximately 4:1. The second stimulus consisted of a four sided figure with no right angles and no obvious landmark features. The four sides were all of different lengths.

Forty-two slides were designed. Each of 40 slides contained one stimulus presented in the center of either the left or right visual field. The slides were generated from the factorial combination of the two standard forms, five angles of rotation and whether the comparison stimulus was a mirror image or simply a rotation of the standard. Two slides contained each standard in the central visual field. The standard forms are shown in Figure 1. The five angles of rotation were 0, 45, 90, 135 and 180 degrees.

Stimulus One

FIGURE 1

Stimulus Two

Slides were projected onto a screen placed approximately 95 cm. in front of the subject by means of a Random Access Slide Projector and a Kodak Carousel Slide Projector with a Gerbrands electronic shutter attached to each. The subject was provided with a keybox which allowed two possible responses. Responses were timed using locally constructed equipment and RTs were recorded manually.

Procedure

Subjects were seated at a table with the keybox placed immediately in front of them. A "same" response was required if the comparative stimulus was the same as the standard and "mirror" if it was the mirror image of the standard, regardless of the orientation. The hand used in responding was randomized across subjects. Each stimulus was projected for 100 msec. at a visual angle of approximately 7 degrees from the central field.

Each subject carried out 200 experimental trials, blocked according to stimulus and visual field. Subjects were instructed to maintain a central fixation after a warning tone was delivered by the timing equipment. The left visual field presented images rotated clockwise while

the right visual field would have the object rotated counterclockwise. Extensive pilot testing revealed no overall difference in RT or error due to the direction of rotation. Rotating the image in this manner reduced differences in the visual angle between stimuli. Pilot testing also showed among other things, that presenting to each visual field in blocks rather than at random had no effect on the rate of rotation. Monitoring or not monitoring eye movements also had no effect.

Results

A number of dependent measures were analyzed by means of a six-way analysis of variance (ANOVA) with Sex and Handedness as between-subject factors and Stimulus, Standard or Mirror Forms, Visual Field and Angle of Orientation as within-subject factors. The measures were response times for correct responses, RT_c (the usual dependent measure in rotation studies), overall response times, RT , error rates and an index of inefficiency, In , which combined error rates and response times in a single measure. ANOVA Summary Tables for each dependent measure are shown in Appendix I and the data subject by subject are given in Appendix II.

RT_c

As in previous studies correct responses were faster for standard forms than for mirror forms, $F(1,54) = 59.69$, $p < .0001$ and both sets of response times increased as a function of Angle of Orientation (Figure 2). Since there were no significant interactions involving this factor mean RT_c 's are given in Table 1 collapsed across the factor of form of the stimulus.

Figure 2

Mean RT (secs.) for Standard and Mirror Image Forms as a Function of Angle of Orientation.

Rate of Increase in RT for Standard Forms = 3.9 msec. per degree.

Rate of Increase in RT for Mirror Forms = 2.8 msec. per degree.

TABLE 1a

Mean Response Times for Correct Responses (RTc), across the Factors of Handedness (Right Handers (RH), Non-Familial Left Handers (LHNF), Familial Left Handers (LHF)), Stimulus (two-sided (1) and four-sided (2)), Visual Field (Left (LVF) and Right (RVF)), and Angle (0, 45, 90, 135, 180 degrees).

<u>MALES</u>							
<u>HAND</u>	<u>STIM</u>	<u>VF</u>	<u>0</u>	<u>45</u>	<u>90</u>	<u>135</u>	<u>180</u>
RH	1	LVF	.8973	.9835	1.141	1.246	1.409
		RVF	.9036	1.018	1.219	1.254	1.347
	2	LVF	1.308	1.595	1.610	1.744	1.541
		RVF	1.330	1.417	1.624	1.670	1.410
LHNF	1	LVF	1.094	1.061	1.860	1.577	1.719
		RVF	.9858	1.276	1.723	1.674	1.653
	2	LVF	1.223	1.629	1.825	1.727	1.648
		RVF	1.360	1.373	1.656	1.757	1.627
LHF	1	LVF	.9811	1.123	2.043	2.230	2.263
		RVF	1.036	1.372	1.731	2.398	2.280
	2	LVF	1.228	1.810	1.954	2.115	2.160
		RVF	1.321	1.675	1.893	2.133	2.423

TABLE 1b

Mean Response Times for Correct Responses (RTc), across the Factors of Handedness (Right Handers (RH), Non-Familial Left Handers (LHNF), Familial Left Handers (LHF)), Stimulus (two-sided (1) and four-sided (2)), Visual Field (Left (LVF) and Right (RVF)), and Angle (0, 45, 90, 135, 180 degrees).

FEMALES

<u>HAND</u>	<u>STIM</u>	<u>VF</u>	<u>0</u>	<u>45</u>	<u>90</u>	<u>135</u>	<u>180</u>
RH	1	LVF	1.038	1.120	1.285	1.251	1.337
		RVF	.9363	.9797	1.263	1.301	1.280
	2	LVF	1.328	1.307	1.394	1.439	1.366
		RVF	1.259	1.215	1.255	1.352	1.376
LHNF	1	LVF	1.309	1.428	1.700	1.911	1.938
		RVF	1.260	1.377	1.694	1.919	1.941
	2	LVF	1.841	2.197	2.278	2.359	2.428
		RVF	1.932	2.170	2.177	2.476	2.304
LHF	1	LVF	1.152	1.266	1.959	1.995	2.054
		RVF	1.136	1.350	1.729	1.839	1.927
	2	LVF	1.750	2.267	2.207	2.367	2.397
		RVF	1.673	1.908	2.261	2.330	2.153

The ANOVA showed a significant effect of Angle of Orientation, $F(2,216) = 29.44$, $p < .0001$. This effect is illustrated in Figure 3. However, there was no significant effect of sex, $F(1,54) < 1$, and no significant Sex $\times$ Angle interaction, $F(4,216) < 1$. In other words mean RTc was statistically equivalent for the two sexes and the rate of change in RTc, the "mental rotation" effect, was also equivalent.

There was a significant effect of Handedness, $F(2,54) = 3.90$, $p < .03$, and a significant Handedness $\times$ Angle interaction, $F(8,216) = 3.00$, $p < .003$, shown in Figure 4. Right handers tended to respond more rapidly than left handers and showed a slower rate of change in RTc. It is of interest that the rate of change for non-familial left handers is intermediate between right handers and familial left handers.

The subjects' correct responses tended to be significantly more rapid given the two-sided figure, $F(1,54) = 22.84$, $p < .0001$, confirming Petrusic et al's. (1978) finding. The Stimulus $\times$ Angle interaction was also significant, $F(4,216) = 7.22$, $p < .0001$. However, contrary to Petrusic et al. the rate of change for the two-sided figure (4.3 msec. per degree) was faster than the rate of

Figure 3

Mean RT_c (secs.) as a Function of Angle of Orientation.
Rate of Increase in RT_c = 3.4 msec. per degree.

Figure 4

Mean RTc (secs.) as a Function of Handedness.

Rates of Increase in RTc: Right Handers (RH) = 1.6 msec/degree

Non-Familial Left Handers (NF) = 3.1 msec/degree

Familial Left Handers (F) = 5.4 msec/degree.

change for the four-sided figure (2.5 msec. per degree). The Stimulus x Visual Field x Angle interaction was significant, $F(4,216) = 2.52$, $p < .04$, and is illustrated in Figure 5. RT_c for the four-sided figure increased less rapidly for both visual fields.

There was no significant effect of Visual Field, $F(1,54) = 1.35$, and as is apparent from Figure 5, no significant Visual Field x Angle interaction, $F(4,216) = 1.01$. The increase in RT_c is essentially parallel for the two visual fields for both stimuli. The spatial rotation problem was solved equally rapidly whether presentation was to the right hemisphere or to the left hemisphere and the increase in RT_c was also equivalent for the two hemispheres.

No other interactions reached the .05 level of significance.

RT

Overall response times for the five-way interaction are tabulated in Table 2. Inspection of Tables I and II confirmed by ANOVA revealed no essential differences in the pattern of results compared to analysis of RT_c . The obvious inference is that response times for errors are

Figure 5

Mean RTc as a Function of Angle of Orientation for Stimulus 1 and Stimulus 2 presented in the Left (LVF) and Right (RVF) Visual Fields.

TABLE 2a

RT

Mean Overall Response Times, across the Factors of Handedness (Right Handers (RH), Non-Familial Left Handers (LHNF), Familial Left Handers (LHF)), Stimulus (two-sided (1) and four-sided (2)), Visual Field (Left (LVF) and Right (RVF)), and Angle (0, 45, 90, 135, 180 degrees).

MALES

<u>HAND</u>	<u>STIM</u>	<u>VF</u>	<u>0</u>	<u>45</u>	<u>90</u>	<u>135</u>	<u>180</u>
RH	1	LVF	.8980	.9729	1.143	1.227	1.392
		RVF	.8911	1.001	1.204	1.250	1.280
	2	LVF	1.309	1.583	1.642	1.815	1.580
		RVF	1.344	1.435	1.597	1.607	1.424
LHNF	1	LVF	1.098	1.173	1.761	1.658	1.682
		RVF	.9781	1.291	1.689	1.656	1.626
	2	LVF	1.249	1.595	1.747	1.724	1.724
		RVF	1.315	1.550	1.721	1.812	1.710
LHF	1	LVF	.9880	1.143	2.048	2.056	2.371
		RVF	1.033	1.430	1.968	2.486	2.279
	2	LVF	1.225	1.686	1.958	2.204	2.196
		RVF	1.354	1.560	1.907	2.190	2.205

TABLE 2b

RT

Mean Overall Response Times, across the Factors of Handedness (Right Handers (RH), Non-Familial Left Handers (LHNF), Familial Left Handers (LHF)), Stimulus (two-sided (1) and four-sided (2)), Visual Field (Left (LVF) and Right (RVF)) and Angle (0, 45, 90, 135, 180 degrees).

<u>FEMALES</u>							
<u>HAND</u>	<u>STIM</u>	<u>VF</u>	<u>0</u>	<u>45</u>	<u>90</u>	<u>135</u>	<u>180</u>
RH	1	LVF	1.041	1.113	1.342	1.243	1.358
		RVF	.9469	.9986	1.280	1.286	1.285
	2	LVF	1.315	1.381	1.453	1.438	1.394
		RVF	1.191	1.280	1.311	1.319	1.317
LHNF	1	LVF	1.311	1.425	1.723	1.981	1.990
		RVF	1.250	1.381	1.583	1.913	2.002
	2	LVF	1.812	2.146	2.261	2.453	2.494
		RVF	1.936	2.199	2.324	2.283	2.351
LHF	1	LVF	1.115	1.315	2.108	2.056	2.034
		RVF	1.137	1.340	1.777	1.894	2.027
	2	LVF	1.816	2.143	2.146	2.256	2.311
		RVF	1.703	1.993	2.176	2.386	2.215

Figure 6

Mean Number of Errors as a Function of Angle of Orientation.

Rate of Increase in Errors :

Left Visual Field (LVF) = .0058 errors/msec.

Right Visual Field (RVF) = .0070 errors/msec.

TABLE 3a

Error Rates

Mean Error Rates out of Twenty Responses, across the Factors of Handedness (Right Handers (RH), Non-Familial Left Handers (LHNF) Familial Left Handers (LHF)), Stimulus (two-sided (1) and four-sided (2)), Visual Field (Left (LVF) and Right (RVF)) and Angle (0, 45, 90, 135, 180 degrees).

			<u>MALES</u>				
<u>HAND</u>	<u>STIM</u>	<u>VF</u>	<u>0</u>	<u>45</u>	<u>90</u>	<u>135</u>	<u>180</u>
RH	1	LVF	.600	.700	1.40	1.40	.700
		RVF	.400	.400	.300	1.80	1.40
	2	LVF	1.50	2.70	2.90	2.00	1.60
		RVF	1.80	2.10	3.00	2.30	1.70
LHNF	1	LVF	.800	.800	1.80	1.40	1.90
		RVF	.400	.600	1.20	1.40	1.00
	2	LVF	.800	2.40	2.30	2.20	1.80
		RVF	1.20	1.10	1.60	3.10	2.00
LHF	1	LVF	.400	.500	1.10	1.60	1.30
		RVF	.300	.700	2.00	2.00	1.10
	2	LVF	1.20	2.20	2.60	2.30	2.20
		RVF	.500	1.20	3.30	3.10	2.20

TABLE 3b

Error Rates

Mean Error Rates out of Twenty Responses, across the Factors of Handedness (Right Handers (RH), Non-Familial Left Handers (LHNF), Familial Left Handers (LHF)), Stimulus (two-sided (1) and four-sided (2)), Visual Field (Left (LVF) and Right (RVF)) and Angle (0, 45, 90, 135, 180 degrees).

			<u>FEMALES</u>				
<u>HAND</u>	<u>STIM</u>	<u>VF</u>	<u>0</u>	<u>45</u>	<u>90</u>	<u>135</u>	<u>180</u>
RH	1	LVF	.800	.900	1.30	2.20	1.80
		RVF	.900	.700	1.50	2.00	2.00
	2	LVF	1.90	2.90	2.70	2.90	2.50
		RVF	1.80	2.40	3.60	3.00	2.70
LHNF	1	LVF	.000	.200	.900	1.20	1.60
		RVF	.000	.100	1.10	1.00	1.60
	2	LVF	.900	2.40	2.70	2.40	2.90
		RVF	1.20	1.50	3.20	3.00	2.10
LHF	1	LVF	.000	.400	.700	1.60	1.80
		RVF	.200	.100	.400	1.80	1.60
	2	LVF	1.00	1.50	2.00	2.10	2.60
		RVF	1.30	1.10	3.10	2.90	1.90

fundamentally equivalent to response times for correct responses.

Errors

The analysis of the error data tabulated in Table 3, coincided reasonably well with the analysis of response times. There were three main differences. The effect of Handedness was not significant, $F(2,54) < 1$, and the Handedness x Angle interaction $F(4,216) = 1.27$, was not significant. More interestingly the Visual Field x Angle interaction illustrated in Figure 6, was significant, $F(4,216) = 4.49$, $p < .002$. Error rates increase significantly more rapidly for the right visual field than for the left visual field, i.e. although no "rotation" advantage was found for the right hemisphere in response times, right hemisphere processing minimizes the rate of increase in incorrect responses.

Inefficiency

Since both error rates and response times were an increasing function of Angle of Orientation, it is

worthwhile combining the two measures in a single index. Accordingly an index of "inefficiency" was computed as

$$\text{Inefficiency} = \ln [\text{Error Rate}/RT + 1].$$

Essentially the index measures the number of errors made per unit of response time. The log transform results in an unbounded measure which is also convenient for ANOVA since the distribution is skewed. Data for the five-way interaction are shown in Table 4. The ANOVA revealed a pattern of results comparable to the error analysis though there was a marginal effect of Handedness, $F(2,54) = 2.56$, $p < .09$. The means and standard deviations for each Handedness group are shown in Table 5. Right handers tend to be the most inefficient.

Curve Fitting

A significant effect of Angle of Orientation or significant interactions with Angle of Orientation imply a significantly linear change in the dependent measure and in the figures least-squares linear regression lines have been fit to the data points. This procedure also allows a

TABLE 4a

Index of Inefficiency

Means on Index of Inefficiency across the Factors of Handedness (Right Handers (RH), Non-Familial Left Handers (LHNF), Familial Left Handers (LHF)), Stimulus (two-sided (1) and four-sided (2)), Visual Field (Left (LVF) and Right (RVF)), and Angle (0, 45, 90, 135, 180 degrees).

<u>MALES</u>							
<u>HAND</u>	<u>STIM</u>	<u>VF</u>	<u>0</u>	<u>45</u>	<u>90</u>	<u>135</u>	<u>180</u>
RH	1	LVF	.1535	.2181	.3321	.2983	.1504
		RVF	.1216	.1524	.0796	.3588	.3166
	2	LVF	.2822	.4312	.4439	.3141	.2876
		RVF	.3512	.3688	.4607	.3876	.3691
LHNF	1	LVF	.2340	.2061	.2605	.2539	.3260
		RVF	.1330	.1619	.2358	.2788	.2084
	2	LVF	.1982	.4271	.3692	.3940	.3336
		RVF	.2805	.2375	.3903	.4712	.3373
LHF	1	LVF	.1162	.1391	.1879	.2853	.2004
		RVF	.0847	.1409	.2947	.3065	.2007
	2	LVF	.2498	.3441	.3783	.3397	.3618
		RVF	.1382	.2499	.4338	.4416	.3749

TABLE 4b

Index of Inefficiency

Means on Index of Inefficiency across the Factors of Handedness (Right Handers (RH), Non-Familial Left Handers (LHNF), Familial Left Handers (LHF)), Stimulus (two-sided (1) and four-sided (2)), Visual Field (Left (LVF) and Right (RVF)), and Angle (0, 45, 90, 135, 180 degrees).

<u>FEMALES</u>							
<u>HAND</u>	<u>STIM</u>	<u>VF</u>	<u>0</u>	<u>45</u>	<u>90</u>	<u>135</u>	<u>180</u>
RH	1	LVF	.1725	.2058	.2248	.4289	.3636
		RVF	.1840	.2176	.2818	.3163	.4041
	2	LVF	.3836	.4645	.4439	.4458	.4370
		RVF	.3705	.4377	.5898	.4562	.4706
LHNF	1	LVF	.0000	.0388	.1283	.1844	.2343
		RVF	.0000	.0312	.1763	.1592	.2261
	2	LVF	.1701	.2985	.3505	.2899	.3639
		RVF	.1848	.2264	.3621	.3641	.2971
LHF	1	LVF	.0000	.8750	.0996	.1916	.2251
		RVF	.0426	.0258	.0436	.2177	.1872
	2	LVF	.1860	.2097	.2386	.2732	.3125
		RVF	.1796	.1619	.3703	.3494	.2467

TABLE 5

Means and Standard Deviations for each Handedness Group (Right Handers (RH), Non-Familial Left-Handers (LHNF), and Familial Left Handers (LHF)) on the Index of Inefficiency.

	<u>MEAN</u>	<u>STANDARD DEVIATION</u>
<u>RH</u>	.3294	.2217
<u>LHNF</u>	.2456	.2150
<u>LHF</u>	.2229	.2228

convenient comparison with other data (e.g. Kail et al., 1979; Petrusic et al., 1978) where linear fits have been applied. However, it is obvious that the functions in the present case tend to asymptote. RTc or error rates are little different between 135 and 180 degrees. Accordingly the data were also fit by a negatively accelerating two-parameter logarithmic function by means of least-squares and by two-parameter power functions with exponents less than one. A comparison of fits for linear and log functions for each cell of the design and for the main variables is shown in Table 6. The log fits are negatively accelerating functions for 19 of the 24 cell means and for all the major effects (Angle, Sex x Angle, Handedness x Angle, Stimulus x Angle, Visual Field x Angle).

TABLE 6

Goodness-of-Fit Statistics (r^2) for the main Variables for Least-Squares Linear, Logarithmic and Power (Exponent less than One) Fits.

<u>Variable</u>	<u>Linear</u>	<u>Logarithmic</u>	<u>Power</u>
Angle	.8943	.9597	.9633
Stimulus 1	.9050	.9597	.9313
Stimulus 2	.8125	.9420	.9420
Left Visual Field	.8888	.9657	.9658
Right Visual Field	.8994	.9481	.9569
Males	.8919	.9549	.9583
Females	.9168	.9668	.9714
Right Handers	.8572	.9235	.9290
Non-Familials	.8422	.9355	.9392
Familials	.9346	.9772	.9824

Discussion

Despite the differences between this experiment and the usual procedures in a mental rotation experiment there were significant correspondences with typical rotation data. Standard forms were classified more rapidly than mirror image forms. Response times increased in a significantly linear fashion as a function of angle, though logarithmic fits tended to be superior to linear fits. There were also stimulus differences in mean response times and in the rate of change in response times for the two stimuli (c.f. Petrusic et al., 1978). A small advantage was found for right handers compared to left handers which was also observed by Metzler and Shepard (1974) for rotation problems. However, there was no sign of the sex difference which has been consistently observed in the usual version of Shepard's mental rotation task (Kail et al., 1979; Metzler & Shepard, 1974; Petrusic et al., 1978). The failure to find sex differences may be of some importance and it will be discussed in detail below.

The mental rotation task did not result in a visual field difference in the time taken to correctly solve a

mental rotation problem nor was there a difference between the visual fields in the rate of increase in RT_c . However, a left visual field advantage was observed in the rate at which errors increased as a function of angle of orientation. This effect was also reflected in the inefficiency index. Subjects become increasingly more inefficient when presentation is to the RVF and processing is via the left hemisphere.

A number of authors (e.g. Petrusic et al., 1978; Pylyshyn, 1979) have noted that a difference between stimuli in the rate of change in RT_c is difficult to square with Shepard's theory that the rotation problem must involve some holistic or "imagistic" strategy. As Petrusic et al. note "failures to find effects of stimulus differences on slope of the judgement-time by angle-of-rotation plot have been cited as support for the conventional view of mental rotation [i.e. as a general analogue operation] (p.146, 1978)". Since there clearly are stimulus differences in slope Petrusic et al. and Pylyshyn have argued that the process is much more piecemeal and linked to demands of a particular stimulus. For some stimuli a feature by feature comparison of standard and mirror forms may be appropriate. For others a "landmark" feature may serve to distinguish the

two forms (c.f. Hochberg & Gellman, 1977) Since a stimulus effect was observed for both visual fields and by inference for both hemispheres, it may be that a similar perhaps piecemeal strategy, was adopted by both hemispheres and the slower rate of increase in inefficiency for the left visual field may reflect right hemisphere specialization for spatial tasks rather than a difference between the hemispheres in the way in which spatial information is processed. It will be argued below that the procedure of the present experiment makes it difficult to infer details of the processing strategy from differences in the slopes of the RTc functions. Rather the stimulus difference in slope may reflect a more global timing strategy on the part of the subject.

As in other experiments right handers were generally faster at reaching a correct decision than left handers. It may be, as some have claimed (Levy, 1974), that right handers are more consistently lateralized and are therefore more prepared to deal with this task in a specific manner. Within the group of left handers, there is reason to continue examining the division according to family background of left handers. There was some indication in the slopes of the RTc functions that non-familial left

handlers more closely resembled right handlers than did the familial left handlers. This is consistent with Annett's (1964) accounts of handedness groups. Hécaen and Sauguet (1971) found that non-familial left handlers were almost exclusively left-hemisphere dominant for speech as were right handlers, which could imply right hemisphere dominance for spatial processing.

It is worth noticing, however, that right handlers tend to be somewhat more inefficient. Though the effect was significant only beyond the .10 level for some right handlers at least the advantage in time is acquired by increasing overall inefficiency. Clearly the handedness effects revealed here would bear careful analysis in a speed-accuracy trade-off design (e.g. Wood & Jennings, 1976) which allows speed of responding to be experimentally controlled.

No overall sex differences were found for any of the dependent measures nor were there any of the interactions suggested in the introduction, between sex and other variables. There are at least two plausible explanations for this failure to observe a sex difference in mental rotation. One possibility is that the visual field manipulation which results in contralateral processing of

information leads females to adopt an appropriate strategy for dealing with a spatial problem. One might argue that females may prefer a verbal, analytical mode of processing which is less suited to spatial problems (c.f. Harris, 1978). Hence females take longer on average to classify rotated stimuli. Cueing each hemisphere independently may therefore induce a more efficient, perhaps holistic, processing in females. Since the focus of the present experiment was on possible differences in hemispheric specialization this account has some appeal.

However, it is difficult to sustain. It has already been noted that the stimulus difference is consistent across the visual fields. A difference between the stimuli in the "rate of rotation" tends to suggest that the holistic imagistic strategy envisaged by Shepard and his associates is too simple. It appears far more likely that a more piecemeal analytic process is adopted by both hemispheres whether the subject is male or female.

An alternative explanation of the equality of the sexes may lie in the response strategies which subjects adopted in this situation. The stimulus was presented for 100 msec. compared to the potentially unlimited inspection period allowed in the typical mental rotation experiment. Given

unlimited time there may be some advantage to delaying a response until the subject can be virtually certain of being correct. On the other hand, when inspection time is severely limited as it was unavoidably, in the present experiment relatively rapid responding before the information has faded from short-term memory is likely to be more successful in the sense of being more accurate.

Following this assumption the present data may be explained by supposing that subjects set both a minimum and a maximum time in which they are willing to respond. The experimental procedure was such that subjects would rapidly learn that delaying responses beyond a certain point (particularly in the case of the four-sided figure) would not increase and might in fact decrease efficiency. Consequently the design forces subjects to adopt a "bandwidth" of response times, within which males and females solve rotational problems with equal efficiency.

Although RTc's for the two-sided stimulus obtained here were comparable to those obtained by Petrusic et al. (1978), RTc's for the four-sided figure in this experiment were considerably faster on the average than in the earlier experiment and the rate of increase in RTc was much slower for this figure (2.5 msec. per degree compared to 6.7 msec.

per degree). This effect suggests that subjects do fix a maximum time for responses. Moreover, the functions were better described, as we have seen, as asymptoting negatively accelerated functions rather than as non-accelerated linear functions. A superior log and power fit was obtained for both stimuli and for both visual fields. This effect also suggests a fixed bandwidth of response times. The rate of increase in response rate slows down as subjects approach the upper limit of response times they are willing to allow.

On this account the longer a subject delays responding under the present conditions the more he or she is likely to be in error. Obviously response times and error rates must be positively correlated since both increase as a function of angle of orientation. Therefore, the partial correlation between RT_c and errors independent of angle is of interest as a rough check on the theory. The partial correlation was computed and found to be sharply positive ($r = .33$).

The reader is undoubtedly aware that speed-accuracy trade-off analysis of the relationship between some measure of accuracy and response time (see e.g. Wood & Jennings, 1976) in general demonstrates a strong positive correlation between accuracy and RT, i.e. a negative correlation between

RT and error rates. These results are not inconsistent with the present findings since two different levels of analysis are involved. The speed-accuracy trade-off experiment involves a "macro-process" in which a measure of accuracy is obtained for a number of RT deadlines. The present data may be described as the result of a "micro-process" in which one bandwidth of RTs was obtained analogous to a single deadline in the trade-off experiment. In other words, these data would be represented by a single point on a speed-accuracy trade-off. At a "macro" level of analysis the correlation across subjects between mean RT and the error rate averaged over all factors was in fact negative ($r = -.27$). One may speculate that some subjects are more successful at maintaining information in store and hence tend to be more accurate.

A further advantage of the bandwidth theory is that it seems capable of accounting for the discrepancy between the present study and that of Petrusic et al. (1978) with respect to the slopes of the RTc functions. Although subjects processed the four-sided figure more slowly and in effect, more inefficiently in both experiments, the rate of increase in RTc was significantly faster for the two-sided figure in the present case and significantly slower in the

Petrusic et al. study. On the bandwidth account subjects require longer to process the four-sided figure at zero degrees but cannot afford to delay responses beyond the upper limit of the bandwidth. As a consequence the rate of change in RT must be slower for the four-sided figure.

Essentially the argument given here is that the rapid presentation of the stimulus exerts a control over subjects' timing strategies which is not exerted in the usual free-inspection rotation paradigm. Given as much time as they please women may take longer to respond than men and may also tend to increase more rapidly the time taken to solve rotation problems as the difficulty of the problem increases. Although this strategy has been regarded as less efficient (e.g. Kail et al., 1979; Petrusic et al., 1978) it is not unadaptive. For a free-inspection there is, as we have noted, some advantage to delaying a response, particularly as the experiment imposes no obvious cost associated with longer RTs. In the present case the cost is that information fades from store and the subject is likely to become less accurate by delaying beyond a certain time. Females certainly take longer than males in a typical rotation experiment and perhaps longer than they need for comparable accuracy. However, this difference may not be

difference in spatial ability per se but a difference in response strategy. Females may respond more conservatively than males but this may not be a sufficient reason to assume that females have poorer spatial abilities.

Summary and Conclusion

This study set out to examine the relationship between sex and handedness with regards to cerebral lateralization of spatial abilities. The lack of significant sex differences separates this study from those previously conducted. At least two explanations for this lack of a sex difference have some plausibility. It has been suggested that the most appropriate account is based on a comparison of response time strategies in this experiment and the more typical mental rotation paradigm. The procedure here may have forced females to work within the same time-frame as the males and the two groups therefore produced the same results.

If women do tend to be more cautious or conservative in this type of "forced-response" situation, then social factors, may be more important in accounting for variation

between the sexes, than biological or neurological explanations. At all events we may need to explain variation in response time strategy rather than variation in spatial ability.

There was an indication of right hemisphere specialization for this spatial task in the rate of change of the index of inefficiency across all subjects, though the effect was small. Possibly different subjects use different strategies or the same subjects may use a mixture of strategies. Mental rotation may be the first process tried and then perhaps more propositional methods may be attempted.

Right handed females did seem to behave differently from other groups, their response times were high but their error rates were also high. This may imply that what was in the past treated as a sex difference may reflect an interaction of sex and handedness. Handedness needs to be examined more carefully in the future with respect to spatial ability. In the present case the right handed groups did noticeably better than the left handed groups in rate of rotation or more precisely in the rate of increase in RT.

The stimulus differences were noted in other studies. What is of interest is the fact that although the intercepts of the RT function fell within the same range as those observed in previous experiments, the two-line figure in the present case showed the steeper RT function. The four-sided stimulus was nevertheless less efficiently processed, subjects 0 degree RT's were so high that they could not increase very rapidly and still be assured of a correct response.

In noting the differences between this experiment and previous related studies, it should be observed that naive subjects were used in this experiment, unlike many of the early studies by Shepard and his colleagues where small groups of highly trained subjects were used, including at times, Shepard himself. In those cases the subjects knew they were supposed to rotate a figure mentally before reaching any decisions. In some cases they were taught exactly how to perform the operation or at least they were taught exactly how to respond to the question "How did you solve the rotation problem?". In this study subjects were given no instruction or advice on how to reach decisions.

It appears that individuals can be trained to perform this task through a number of processes. Therefore ,

depending on previous experience, a subject could approach this task in a number of ways, if not specifically instructed beforehand. However, for very simple figures, such as the two-sided figure used here, mental rotation seems one of the simplest methods. Informal interviewing after the experiment revealed this often to be the case. Mental rotation of the two-sided stimulus seemed almost automatic. But most subjects were unclear on how they reached a decision involving the second stimulus. Several stated that they first attempted mental rotation but found it confusing and often tried to form some other strategy to deal with the second stimulus.

More studies should be run to further examine the effects of a time restriction on stimulus viewing. It would be of considerable interest to examine sex differences in rotation as the stimulus presentation time is increased or as RTs are controlled by a deadline method.

The difference between stimuli needs closer examination. The question remains open as to what makes it easier to reach a decision for one stimulus as opposed to another. Some stimuli are easier to rotate, perhaps because they have obvious landmark features (Hochberg & Gellman, 1977) and as Petrusic et al. (1978) have noted stimulus

symmetry may also be a determinant of the slope of mental rotation functions.

Clearly the most important finding here is the failure to find sex differences for a spatial task. If the theory suggested here can be sustained a radical revision of our theories about the relationship between sex and spatial ability will become essential.

References

- Allen, M.J. Sex differences in spatial problem-solving styles, Perceptual & Motor Skills, 1974, 39, 843-846.
- Andrews, R.J. Aspects of language lateralization correlated with familial handedness, Neuropsychologia, 1977, 15, 769-778.
- Annett, M. A model of the inheritance of handedness and cerebral dominance, Nature, 1964, 204, 59-60.
- Beaumont, J.G. Handedness and Hemisphere Function, in Dimond S.J. & Beaumont J.G. (Eds.), Hemisphere Function in the Human Brain, New York: Halsted Press Book, 1974.
- Bogen, J.E. The other side of the brain II: An appositional mind, Bulletin of the Los Angeles Neurological Society, 1969, 34, 135-162.
- Bogen, J.E. & Gazzaniga M.S. Cerebral commissurotomy in man: Minor hemisphere dominance for certain visuospatial functions, Journal of Neurosurgery, 1965, 394-399.
- Bryden, M.P. Perceptual asymmetry in vision: Relation to handedness, eyedness, and speech lateralization, Cortex, 1973, 9, 418-432.
- Bryden, M.P. Sex-related differences in cerebral organization, in Wittig M.A. & Peterson A.C. (Eds.) Sex Related Differences in Cognitive Functioning, New York: Academic Press, 1979.
- Buffery, M.W.H. & Gray, J.A. Sex Difference in the development of perceptual and linguistic skills, in Ounsted I.C. & Taylor D.C. (Eds.) Gender Differences: Their Ontogeny and Significance, London: Churchill, 1972.
- Corballis, M.C. & Beale, I.L. The Psychology of Left and Right, Hillsdale, N.J.: Lawrence Erlbaum Assoc. Inc., 1976.

- Corballis, M.C., Zbrodoff, N.J. Shetzer, L.I. & Butler, P.B. Decisions about identity and orientation for rotated letters and digits, Memory & Cognition, 1978, 6, 98-107.
- Cooper, L.A. Demonstration of a mental analog of an external rotation, Perception & Psychophysics, 1976, 19, 296-302.
- Cooper, L.A. & Shepard, R.N. Chronometric Studies of the Rotation of Mental Images, in W.G. Chase (Ed.) Visual Information Processing, New York: Academic Press, 1973.
- Cooper, L.A. & Shepard, R.N. Transformations of Representations of Objects in Space, in Carterette E.C. & Friedman M.P. (Eds.) Handbook of Perception, Vol. VIII, Perceptual Coding, New York: Academic Press, 1978.
- Dee, H.L. Auditory asymmetry and strength of manual preference, Cortex, 1971, 7, 236-245.
- Dimond S. The Double Brain, Condon: Churchill Livingstone, 1972
- Dimond, S. & Beaumont, J.G. (Eds.) Hemisphere Function in the Human Brain, New York: Halsted Press Book, 1974.
- Gazzaniga, M.S. The Bisected Brain, New York: Appleton-Century-Crofts, 1970.
- Gazzaniga, M.S. & LeDoux, J.E. The Integrated Mind, New York: Plenum Press, 1978.
- Geschwind, N. Specializations of the Human Brain, Scientific American, Sept. 1979, 241, 180-199.
- Goodglass, H. & Quadfasel, F.A. Language laterality in left handed aphasics, Brain, 1954, 77, 521-548.
- Guilford, J.P. Printed Classification Tests, AAF Report No. 5, Washington, D.C. : GPO.
- Hannay, H.J. & Boyer, C. Sex differences in hemispheric asymmetry revisited, Perceptual & Motor Skills, 1978, 47, 317-321.

- Hannay, H.J. & Malone, D.R. Visual field recognition memory for right-handed females as a function of familial handedness, Cortex, 1976, 12, 41-48.
- Hardyck, C. & Petrinovich, L.F. Left-Handedness, Psychological Bulletin, 1977, 84, 385-404.
- Harris, L.J. Sex differences in spatial ability in Kinsbourne M. (Ed.) Asymmetrical Function of the Brain, Cambridge: Cambridge University Press, 1978.
- Hécaen, H. & Ajuriaguerra, J. Left-Handedness, New York: Grune and Stratton, 1964.
- Hécaen, H. & Sauguet, J. Cerebral dominance in left-handed subjects, Cortex, 1971, 7, 19-48.
- Heron, W. Perception as a function of retinal locus and attention, American Journal of Psychology, 1957, 10, 38-48.
- Higenbottom, J.A. Relationships between sets of lateral and perceptual preference measures, Cortex, 1973, 9, 402-409.
- Hines, D. & Satz, P. Cross-modal asymmetries in perception related asymmetry in cerebral function, Neuropsychologia, 1974, 12, 239-247.
- Hochberg, J. & Gellman, L. The effect of landmark features on mental rotation times, Memory & Cognition, 1977, 5, 23-26.
- Hock, H.S. & Tromley, C.L. Mental rotation and perceptual uprightness, Perception & Psychophysics, 1978, 24, 529-533.
- Jones, B. Sex and visual field effects on accuracy and decision making when subjects classify male and female faces, Cortex, 1979, 15, 551-561.
- Jones, B. Sex and handedness as factors in visual-field organization for a categorization task, Journal of Experimental Psychology: Human Perception & Performance, 1980, 6, 494-500.
- Jones, B. & Santi, A. Lateral asymmetries in visual perception with and without eye movements, Cortex, 1978, 14, 164-168.

- Just, M.A. & Carpenter, P.A. Eye fixations and cognitive processes, Cognitive Psychology, 1976, 8, 441-480.
- Kail, R., Carter, P. & Pellegrino, J. The locus of sex differences in spatial ability, Perception & Psychophysics, 1979, 26, 182-186.
- Kail, R. & Siegel, A. Sex and hemispheric differences in the processing of verbal and spatial information, Cortex, 1978, 14, 557-563.
- Kimura, D. Spatial localization in left and right visual fields, Canadian Journal of Psychology, 1969, 23, 445-458.
- Kimura, D. & Durnford, M. Normal Studies on the Function of the Right Hemisphere in Vision in Dimond S. & Beaumont J.G. (eds.) Hemisphere Function in the Human Brain, New York: Halsted Press Book, 1974.
- Kinsbourne, M. The Mechanism of Hemispheric Control of the Lateral Gradient of Attention, in Rabbitt (Ed.) Attention and Performance V, New York: Academic Press, 1974.
- Knox, A. W. & Boone, D.R. Auditory laterality and tested handedness, Cortex, 1970, 6, 164-173.
- Lake, D.A. & Bryden, M.P. Handedness and sex differences in hemispheric asymmetry, Brain & Language, 1976, 8, 266-282.
- Levy, J. Possible basis for the evolution of lateral specialization of the human brain, Nature, 1969, 224, 614-615.
- Levy, J. Psychobiological implications of bilateral asymmetry, in Dimond S. & Beaumont J.G. (Eds.) Hemisphere Function in the Human Brain, New York: Halsted Press, 1974.
- Levy, J. & Reid, M. Variations in cerebral organization as a function of handedness and hand posture in writing and sex, Journal of Experimental Psychology: General, 1978, 107, 119-144.
- Maccoby, E. & Jacklin, C. The Psychology of Sex Differences, Stanford: Stanford University Press, 1974.

- Marsh, G.R. Asymmetry of the electrophysiological phenomena and its relation to behavior in humans, in Kinsbourne M. (Ed.) Asymmetrical Function of the Brain, Cambridge: Cambridge University Press, 1978.
- McGee, M.G. Human Spatial Abilities: Psychometric studies and environmental, genetic, hormonal and neurological influences, Psychology Bulletin, 1979, 86, 889-912.
- McGlone, J. & Davidson, W. The relation between cerebral speech laterality and spatial ability with special reference to sex and hand preference, Neuropsychologia, 1973, 11, 105-113.
- McKeever, W.F., VanDeventer, A.D. & Suberi, M. Avowed, assessed, and familial handedness and differential hemispheric processing of brief sequential and non-sequential visual stimuli, Neuropsychologia, 1973, 11, 235-238.
- McKeever, W.F. & VanDeventer, A.D. Visual and auditory language processing asymmetries: Influences of Handedness, Familial Sinistrality and Sex, Cortex, 1977, 13, 225-241.
- Metzler, J. & Shepard R.N. Transformational studies of the internal representation of three-dimensional objects, in Solso I.P., (Ed.) Theories in Cognitive Psychology: The Loyola Symposium, Potomac, Maryland: Lawrence Erlbaum, 1974.
- Milner, B., Branch, C. & Rasmussen, T. Observations on cerebral dominance in A.V.S. deReuck (Ed.) CIBA Symposium on Language Disorders, London: Churchill, 1964.
- Milstein, V., Small, I.F., Malloy, F.W. & Small, J.G. Influence of sex and handedness on hemispheric functioning, Cortex, 1979, 15, 439-449.
- Oldfield, R.C. The assessment and analysis of handedness: The Edinburgh Inventory, Neuropsychologia, 1971, 9, 97-113.

Petrusic, W.M., Varro, L. & Jamieson, D.G. Mental Rotation Validation of Two Spatial Ability Tests, Psychological Research, 1978, 40, 139-148.

Pylyshyn, Z.W. The rate of "mental rotation" of images: a test of a holistic analogue hypothesis, Memory and Cognition, 1979, 7, 19-28.

Satz, P., Achenbach, K. & Fennell E. Correlations between assessed manual laterality and predicted speech laterality in a normal population, Neuropsychologia, 1967, 5, 295-310.

Shepard, R.N. Form, Formation and Transformation of internal representations, in Solso R. (Ed.) Information Processing and Cognition: The Loyola Symposium, Hillsdale, N.J.: Lawrence Erlbaum, 1975.

Tapley, S.M. & Bryden, M.P. An investigation of sex differences in spatial ability, Canadian Journal of Psychology, 1977, 31, 122-130.

Trevarthen, C. & Sperry, R.W. Perceptual unity of the ambient visual field in human commissurotomy patients, Brain, 1973, 96, 547-570.

White, N.J. Laterality differences in Perception: a review, Psychological Bulletin, 1969, 72, 387-405.

White, N.J. Hemispheric asymmetries in tachistoscopic information processing, British Journal of Psychology, 1972, 63, 497-508.

Willis, S.G., Wheatley G.H. & Mitchell O.R. Cerebral processing of spatial and verbal-analytic tasks: an EEG study, Neuropsychologia, 1978, 17, 473-484.

Witelson, S. Sex and the single hemisphere: right hemisphere specialization for spatial processing, Science, 1976, 193, 425-427.

Wittig, M.A. & Peterson, A.C. Sex-Related Differences in Cognitive Functioning, New York: Academic Press, 1979.

Wood, C.C. & Jennings, J.R. Speed-accuracy tradeoff functions in choice reaction time: Experimental designs and computational procedures, Perception & Psychophysics, 1976, 19, 92-101.

Woodworth, R.S. & Schlosberg, H. Experimental Psychology, New York: Holt, Rinehart and Winston, Inc., 1954.

Worrall, N. & Coles, P. Visual field differences in recognizing letters, Perception & Psychophysics, 1976, 20, 21-24.

Zurif, E.B. & Bryden, M.P. Familial handedness and left-right differences in auditory and visual perception, Neuropsychologia, 1969, 7, 179-187.

APPENDIX I

- (1) ANOVA TABLE for RTc : Five-way for Sex, Handedness, Stimulus, Visual Field and Angle.
- (2) ANOVA TABLE for RT : Five-way for Sex, Handedness, Stimulus, Visual Field and Angle.
- (3) ANOVA TABLE for ERRORS : Five-way for Sex, Handedness, Stimulus, Visual Field and Angle.

ANOVA TABLE FOR RT_c (FIVE-WAY)

Source	Sum of Squares	Degrees of Freedom	F	P <
Mean	3161.672	1	363.60 +	.00001
Sex(S)	5.361	1	.62	.4358
Hand(H)	67.861	2	3.90 +	.0261
SxH	12.210	2	.70	.5000
Error	469.557	54		
Figure(F)	28.551	1	22.84 +	.00001
FxS	2.750	1	2.20	.1439
FxH	.343	2	.14	.8721
FxSxH	6.814	2	2.72	.0746
Error	67.516	54		
Visual Field(VF)	.322	1	1.35	.2510
VFxS	.257	1	1.07	.3047
VFxH	.049	2	.10	.9038
VFxSxH	.287	2	.60	.5531
FxVF	.067	1	.53	.4699
FxVFxS	.007	1	.05	.8207
FxVFxH	.020	2	.08	.9253
FxVHxSxH	.047	2	.18	.8327
Error	6.866	54		
Angle(A)	62.110	4	29.44 +	.00001
AxS	1.312	4	.62	.6475
AxH	12.651	8	3.00 +	.0033
AxSxH	2.916	8	.69	.6992
Error	113.921	216		
FxA	5.716	4	7.22 +	.00001
FxAxS	.103	4	.13	.9714
FxAxH	1.144	8	.72	.6721
FxAxSxH	.949	8	.60	.7781
Error	42.774	216		
VFxA	.3793	4	1.01	.4013
VFxAxS	.1465	4	.39	.8146
VFxAxH	.3270	8	.44	.8981
VFxAxSxH	.5535	8	.74	.6567
Error	20.2151	216		
FxVFxA	.7784	4	2.52 +	.0423
FxVFxAxS	.2950	4	.95	.4335
FxVFxAxH	.8792	8	1.42	.1885
VxVFxAxSxH	.3429	8	.55	.8142
Error	16.6934	216		

+ Reach Significance

ANOVA TABLE FOR RT (FIVE-WAY)

Source	Sum of Squares	Degrees of Freedom	F	P <
Mean	3191.675	1	370.22 +	.00001
Sex(S)	5.919	1	.69	.4110
Hand(H)	69.520	2	4.03	.0233
SxH	11.482	2	.67	.5179
Error	465.530	54		
Figure(F)	26.482	1	18.53 +	.0001
FxS	2.290	1	1.60	.2110
FxH	.653	2	.23	.7965
FxSxH	7.030	2	2.46	.0950
Error	77.168	54		
Visual Field(VF)	.312	1	1.34	.2524
VFxS	.279	1	1.19	.2792
VFxH	.222	2	.48	.6234
VFxSxH	.126	2	.27	.7636
Error	12.592	54		
FxVF	.046	1	.45	.5050
FxVFxS	.114	1	1.11	.2973
FxVFxH	.186	2	.91	.4097
FxVFxSxH	.104	2	.51	.6061
Error	5.545	54		
Angle(A)	64.096	4	36.51 +	.00001
AxS	1.283	4	.73	.5717
AxH	12.809	8	3.65 +	.0005
AxSxH	2.610	8	.74	.6531
Error	94.806	216		
FxA	5.360	4	8.67 +	.00001
FxAxS	.054	4	.09	.9865
FxAxH	1.135	8	.92	.5025
FxAxSxH	.558	8	.45	.8890
Error	33.375	216		
VFxA	.243	4	.79	.5347
VFxAxS	.107	4	.35	.8456
VFxAxH	.351	8	.57	.8026
VFxAxSxH	.307	8	.50	.8570
Error	16.662	216		
FxVFxA	.499	4	2.08 +	.0847
FxVFxAxS	.439	4	1.83	.1241
FxVFxAxH	.454	8	.95	.4781
FxVFxAxSxH	.604	8	1.26	.2663
Error	12.958	216		

+ Reach Significance

ANOVA TABLE FOR ERROR RATES (FIVE-WAY)

Source	Sum of Squares	Degrees of Freedom	F	P <
Mean	3062.408	1	270.71 +	.00001
Sex(S)	2.521	1	.22	.6388
Hand(H)	20.045	2	.89	.4182
SxH	25.002	2	1.11	.3386
Error	610.875	54		
Figure(F)	386.468	1	120.30 +	.00001
FxS	4.687	1	1.46 +	.2323
FxH	2.105	2	.33	.7221
FxSxH	6.515	2	1.01	.3696
Error	173.475	54		
Visual Field(VF)	.0008	1	.00	.9779
VFxS	.368	1	.34	.5621
VFxH	1.972	2	.91	.4075
VFxSxH	.395	2	.18	.8334
Error	58.315	54		
FxVF	1.021	1	.78	.3817
FxVFxS	.0008	1	.00	.9800
FxVFxH	.552	2	.21	.8111
VxVFxSxH	3.802	2	1.45 +	.2440
Error	70.875	54		
Angle(A)	285.472	4	37.20 +	.00001
AxS	15.542	4	2.03 +	.0920
AxH	19.438	8	1.27 +	.2624
AxSxH	7.048	8	.46	.8837
Error	414.400	216		
FxA	40.628	4	6.35 +	.0001
FxAxS	1.525	4	.24	.9165
FxAxH	14.162	8	1.11	.3602
FxAxSxH	5.485	8	.43	.9032
Error	345.700	216		
VFxA	23.928	4	4.49 +	.0017
VFxAxS	4.978	4	.93	.4447
VFxAxH	10.162	8	.95	.4733
VFxAxSxH	6.972	8	.65	.7312
Error	287.660	216		
FxVFxA	15.992	4	2.99 +	.0198
FxVFxAxS	2.895	4	.54	.7058
FxVFxAxH	4.598	8	.43	.9025
FxVFxAxSxH	6.015	8	.56	.8083
Error	289.000	216		

+ Reach Significance

APPENDIX II

MEAN RTc FOR ALL SUBJECTS

- (a) Mean RTc's for Male Right Handers
- (b) Mean RTc's for Male Non-Familial Left Handers
- (c) Mean RTc's for Male Familial Left Handers
- (d) Mean RTc's for Female Right Handers
- (e) Mean RTc's for Female Non-Familial Left Handers
- (f) Mean RTc's for Female Familial Left Handers

MEAN RT_C's FOR MALE RIGHT HANDERS

		STIMULUS 1		STIMULUS 2	
		<u>LVF</u>	<u>RVF</u>	<u>LVF</u>	<u>RVF</u>
<u>Ss1</u>					
Stan.	0°	.882	.531	1.95	1.62
	45°	.481	.708	1.63	1.67
	90°	.965	.660	2.17	.969
	135°	1.24	1.13	1.51	1.49
	180°	1.18	.903	1.25	1.45
Mir.	0°	.707	.651	1.75	1.65
	45°	.736	.918	2.14	1.50
	90°	.915	1.04	1.94	2.08
	135°	1.00	1.44	1.60	2.96
	180°	1.27	1.41	1.83	.836
<u>Ss2</u>					
Stan.	0°	.702	.821	1.06	1.05
	45°	.632	.626	1.09	1.40
	90°	.719	.893	1.48	1.99
	135°	.967	.857	1.56	1.96
	180°	.896	1.09	1.43	1.76
Mir.	0°	.886	.900	1.84	1.59
	45°	.771	.969	1.75	1.98
	90°	.886	.930	1.91	2.53
	135°	.771	1.13	1.77	1.66
	180°	1.02	1.57	1.51	2.08
<u>Ss3</u>					
Stan.	0°	.838	.821	1.35	1.13
	45°	.975	1.07	1.47	1.05
	90°	1.40	1.17	1.75	1.47
	135°	1.18	1.28	2.02	1.66
	180°	1.77	1.41	1.77	1.57
Mir.	0°	1.07	1.38	1.60	1.63
	45°	1.01	1.59	2.13	2.36
	90°	1.44	1.96	2.16	2.35
	135°	2.10	1.42	2.51	2.87
	180°	1.48	2.04	2.55	1.90
<u>Ss4</u>					
Stan.	0°	.279	.342	.469	.407
	45°	.506	.345	.645	.600
	90°	.553	.440	.489	.662
	135°	.443	.613	.401	.610
	180°	.495	.488	.341	.366
Mir.	0°	.461	.446	.473	.650
	45°	.532	.602	.517	.585
	90°	.593	.674	.705	.950
	135°	.572	.664	.716	.740
	180°	1.56	.534	.743	.586

MALE - RH

		STIMULUS 1		STIMULUS 2	
<u>Ss5</u>		<u>LVF</u>	<u>RVF</u>	<u>LVF</u>	<u>RVF</u>
	0°	.732	.620	.931	1.96
	45°	.817	.570	3.06	1.76
Stan.	90°	.882	.951	2.04	1.90
	135°	1.30	1.04	2.54	1.63
	180°	1.68	1.15	1.37	2.78
	0°	.612	.976	1.32	2.10
	45°	1.13	.995	1.45	1.79
Mir.	90°	1.42	1.52	1.92	2.19
	135°	2.49	1.49	2.80	1.43
	180°	2.31	1.75	2.26	2.37
<u>Ss6</u>					
	0°	.890	.834	1.06	.799
	45°	.867	1.06	.862	1.42
Stan.	90°	1.03	1.69	1.46	.808
	135°	1.40	1.68	2.36	.947
	180°	2.00	1.56	1.57	.867
	0°	1.16	1.24	1.05	1.20
	45°	1.24	1.41	1.71	1.05
Mir.	90°	1.95	1.59	1.66	1.92
	135°	2.25	1.67	1.54	1.65
	180°	1.72	1.14	1.31	1.24
<u>Ss7</u>					
	0°	.442	.488	.478	.693
	45°	.597	.501	1.58	.768
Stan.	90°	1.30	.940	1.57	1.07
	135°	.738	.989	1.37	1.18
	180°	.700	.816	1.02	1.15
	0°	.965	.749	1.04	1.17
	45°	.781	1.34	1.14	1.05
Mir.	90°	.789	1.16	1.17	1.14
	135°	.774	1.26	1.39	1.30
	180°	1.34	1.52	1.73	1.21
<u>Ss8</u>					
	0°	.908	1.03	.720	.713
	45°	1.14	1.16	1.11	1.16
Stan.	90°	.832	1.03	.798	1.18
	135°	1.09	.887	1.60	1.25
	180°	1.03	1.18	.942	.739
	0	1.18	.975	.898	.981
	45	1.08	.979	1.11	.998
Mir.	90	.976	.678	1.14	.984
	135	.910	1.20	.828	1.50
	180	1.06	.817	1.04	1.09

MALE - RH

		STIMULUS 1		STIMULUS 2	
		<u>LVF</u>	<u>RVF</u>	<u>LVF</u>	<u>RVF</u>
<u>Ss9</u>					
	0°	.658	.670	1.92	1.90
	45°	.670	.691	1.46	1.54
Stan.	90°	.993	.820	2.19	1.70
	135°	.754	.682	1.89	2.05
	180°	1.28	1.14	2.02	1.84
	0°	.849	.675	2.08	1.83
	45°	.728	.757	2.36	1.93
Mir.	90°	.750	.840	1.95	1.96
	135°	.875	.975	2.22	1.70
	180°	1.44	1.56	2.31	1.91
<u>Ss10</u>					
	0°	1.63	1.56	2.09	1.39
	45°	2.73	1.60	2.52	1.87
Stan.	90°	2.35	2.15	2.15	2.30
	135°	1.73	2.72	2.33	1.88
	180°	2.00	2.22	2.08	1.27
	0	2.09	2.36	2.05	2.10
	45	2.25	2.45	2.14	1.80
Mir.	90	2.07	3.24	2.21	1.77
	135	2.32	1.90	1.88	2.88
	180	1.89	2.13	1.71	1.17

MEAN RT_c's FOR MALE NON-FAMILIAL LEFT HANDERS

		STIMULUS 1		STIMULUS 2	
		<u>LVF</u>	<u>RVF</u>	<u>LVF</u>	<u>RVF</u>
<u>Ss1</u>					
	0°	.507	.660	.556	.742
	45°	.757	1.00	.962	1.19
Stan.	90°	1.50	.910	1.05	1.27
	135°	1.81	1.30	1.13	1.63
	180°	1.57	1.24	1.28	1.40
	0°	1.04	.861	.803	1.55
	45°	1.03	1.43	.968	.950
Mir.	90°	1.46	1.74	1.20	1.12
	135°	1.27	1.80	1.05	1.57
	180°	1.24	1.42	1.32	1.47
<u>Ss2</u>					
	0°	.610	.569	1.58	1.60
	45°	.635	.608	2.38	1.48
Stan.	90°	.681	.671	2.46	2.75
	135°	.764	.663	1.39	2.05
	180°	.871	1.01	2.05	2.03
	0°	.910	.839	1.24	2.47
	45°	.845	.451	2.03	1.67
Mir.	90°	.928	.848	2.10	3.07
	135°	.901	.757	2.36	2.94
	180°	1.43	1.20	1.84	2.33
<u>Ss3</u>					
	0°	.303	.283	.455	.267
	45°	.356	.316	.420	.272
Stan.	90°	.621	.440	.405	.338
	135°	.473	.427	.584	.722
	180°	.376	.252	.403	.373
	0°	.424	.438	.452	.593
	45°	.556	.404	.554	.445
Mir.	90°	.517	.591	.354	.574
	135°	.574	.469	.389	.534
	180°	.401	.406	.509	.486
<u>Ss4</u>					
	0°	.539	.600	1.02	1.03
	45°	.634	.683	.944	1.33
Stan.	90°	1.02	1.03	1.10	1.02
	135°	.893	1.03	1.59	.709
	180°	1.91	1.43	1.66	1.51
	0°	.803	.844	.728	1.41
	45°	.738	.767	1.23	1.14
Mir.	90°	.892	1.07	1.83	1.44
	135°	1.04	2.06	1.13	1.70
	180°	1.20	2.07	1.12	1.24

MALE LBNF

		STIMULUS 1		STIMULUS 2	
		<u>LVF</u>	<u>RVF</u>	<u>LVF</u>	<u>RVF</u>
<u>Ss9</u>					
	0°	.729	.983	.506	.644
	45°	.912	.926	.926	.969
Stan.	90°	1.11	.943	1.04	.631
	135°	.961	.975	.852	.981
	180°	1.14	.920	.731	.795
	0°	.917	.950	1.03	.949
	45°	.855	.819	.536	.519
Mir.	90°	1.07	.870	.668	.795
	135°	1.08	.867	.535	.513
	180°	.960	.999	.586	.800
<u>Ss10</u>					
	0°	.750	.766	.935	.826
	45°	1.02	1.18	1.29	1.36
Stan.	90°	1.56	2.02	1.22	1.47
	135°	1.10	1.28	1.32	1.65
	180°	1.59	1.61	1.74	1.63
	0°	1.01	.969	1.24	1.16
	45°	1.30	1.69	1.21	.873
Mir.	90°	1.37	1.36	1.47	2.08
	135°	1.92	1.62	1.50	1.05
	180°	2.06	1.90	1.51	1.38

2 2
OF / DE

A

MALE LBNF

		STIMULUS 1		STIMULUS 2	
		<u>LVF</u>	<u>RVF</u>	<u>LVF</u>	<u>RVF</u>
<u>Ss5</u>					
	0°	.682	.859	.633	.557
	45°	1.21	2.03	2.50	1.73
Stan.	90°	3.29	3.89	1.75	1.06
	135°	3.50	2.46	1.58	1.30
	180°	2.30	1.60	.838	.955
	0°	1.34	1.13	.693	.968
	45°	1.30	2.41	1.42	1.19
Mir.	90°	3.25	3.12	1.73	1.64
	135°	3.15	2.30	1.49	3.32
	180°	1.66	2.43	1.21	1.12
<u>Ss6</u>					
	0°	1.13	1.33	1.72	2.08
	45°	2.36	1.85	2.46	2.38
Stan.	90°	4.03	3.03	4.15	2.00
	135°	2.58	1.71	2.68	1.91
	180°	2.18	2.33	2.15	1.97
	0°	3.22	2.17	3.08	1.98
	45°	2.05	1.65	2.74	2.23
Mir.	90°	3.70	2.91	2.22	2.77
	135°	1.81	3.76	3.71	3.85
	180°	3.27	3.21	2.39	2.01
<u>Ss7</u>					
	0°	1.31	1.38	2.38	1.71
	45°	1.44	1.32	3.98	3.36
Stan.	90°	3.42	2.88	4.97	3.30
	135°	2.77	3.46	2.80	3.91
	180°	3.14	2.53	4.18	4.13
	0°	2.47	1.39	1.60	3.61
	45°	2.17	2.87	2.20	3.51
Mir.	90°	2.86	2.80	2.76	2.90
	135°	3.00	2.96	4.15	1.62
	180°	3.22	2.09	3.72	3.96
<u>Ss8</u>					
	0°	1.37	1.28	1.65	1.54
	45°	1.42	1.51	1.91	.984
Stan.	90°	2.01	1.53	1.87	1.25
	135°	1.64	1.83	2.42	1.45
	180°	1.89	2.05	1.91	1.63
	0°	1.80	1.39	2.15	1.50
	45°	1.66	1.57	1.90	1.83
Mir.	90°	1.89	1.78	2.11	1.60
	135°	2.28	1.72	1.80	1.69
	180°	1.92	2.33	1.78	1.63

MEAN RT_c's FOR MALE FAMILIAL LEFT HANDERS

		STIMULUS 1		STIMULUS 2	
		<u>LVF</u>	<u>RVF</u>	<u>LVF</u>	<u>RVF</u>
<u>Ss1</u>					
	0°	.616	.635	.601	.654
	45°	.648	.674	.582	.571
Stan.	90°	.576	.663	.548	.621
	135°	.833	.663	.592	.754
	180°	.646	.698	.524	.617
	0°	.559	.815	.472	.505
	45°	.827	.734	.675	.568
Mir.	90°	.801	.689	.468	.596
	135°	.607	.816	.724	.448
	180°	.843	.793	.466	.624
<u>Ss2</u>					
	0°	.930	1.00	1.59	2.71
	45°	1.09	3.96	2.25	2.78
Stan.	90°	3.22	2.20	1.99	6.38
	135°	10.30	8.26	3.44	6.34
	180°	8.95	9.43	2.58	10.77
	0°	1.44	2.31	1.78	2.58
	45°	1.58	2.85	1.51	6.27
Mir.	90°	7.21	5.26	3.90	1.87
	135°	4.08	8.39	4.58	3.11
	180°	5.99	7.55	11.32	6.52
<u>Ss3</u>					
	0°	.845	1.15	.692	.879
	45°	.923	1.38	1.76	1.17
Stan.	90°	1.68	1.77	1.14	1.60
	135°	1.42	1.75	1.41	1.81
	180°	1.52	1.99	.852	1.40
	0°	.947	1.17	.917	1.03
	45°	1.15	1.71	1.27	1.21
Mir.	90°	1.53	1.57	1.76	2.26
	135°	2.09	1.90	1.26	2.06
	180°	1.31	1.34	1.62	1.16
<u>Ss4</u>					
	0°	.896	.718	1.68	.812
	45°	.972	.804	1.33	.953
Stan.	90°	1.90	1.29	1.49	1.67
	135°	1.83	2.22	1.89	1.85
	180°	1.92	1.46	1.42	2.08
	0°	1.70	1.27	1.51	1.57
	45°	1.30	1.20	1.19	1.16
Mir.	90°	2.51	2.45	2.11	1.29
	135°	2.51	2.07	2.04	1.79
	180°	3.03	2.11	1.86	2.46

MALE LHF

		STIMULUS 1		STIMULUS 2	
		<u>LVF</u>	<u>RVF</u>	<u>LVF</u>	<u>RVF</u>
<u>Ss5</u>					
	0°	.953	.771	.945	1.08
	45°	1.09	.963	1.79	1.23
Stan.	90°	1.45	.953	1.35	1.63
	135°	1.63	.927	2.09	2.26
	180°	1.55	1.44	2.07	2.26
	0°	1.23	1.14	1.31	1.41
	45°	1.38	1.61	1.91	1.31
Mir.	90°	1.53	1.53	2.72	2.09
	135°	1.46	1.49	2.91	2.45
	180°	1.80	2.05	1.82	2.31
<u>Ss6</u>					
	0°	1.07	1.14	1.26	.654
	45°	1.48	.776	1.74	1.38
Stan.	90°	3.33	2.31	2.57	1.849
	135°	1.87	3.66	2.41	.786
	180°	2.43	2.37	1.10	1.69
	0°	1.28	1.68	1.53	2.71
	45°	2.08	1.99	1.34	2.80
Mir.	90°	3.65	1.92	2.73	1.79
	135°	1.67	3.54	1.94	1.46
	180°	2.64	2.64	1.77	1.66
<u>Ss7</u>					
	0°	.911	.822	1.06	1.14
	45°	.952	1.50	1.45	1.59
Stan.	90°	1.36	1.50	1.10	1.33
	135°	1.23	1.30	1.55	1.09
	180°	1.29	1.23	1.23	1.28
	0°	.957	1.05	1.59	1.12
	45°	1.06	1.09	1.40	1.38
Mir.	90°	1.28	1.31	1.66	1.68
	135°	1.22	1.22	1.04	1.27
	180°	1.02	1.03	1.29	1.38
<u>Ss8</u>					
	0°	.561	.514	.695	.727
	45°	.637	.664	.908	.836
Stan.	90°	1.29	.930	.913	.864
	135°	.762	.947	.835	.886
	180°	.713	1.20	1.01	1.02
	0°	.680	.586	.874	.622
	45°	.694	.712	.788	.578
Mir.	90°	1.11	.907	.748	.940
	135°	1.11	.700	.838	.503
	180°	.769	.988	.864	.600

MALE LHF

		STIMULUS 1		STIMULUS 2	
		<u>LVF</u>	<u>RVF</u>	<u>LVF</u>	<u>RVF</u>
<u>Ss9</u>					
	0°	1.44	1.13	1.67	1.34
	45°	1.40	1.47	2.92	2.48
Stan.	90°	1.58	2.25	3.05	2.70
	135°	1.79	1.59	2.83	2.17
	180°	2.01	1.59	2.52	2.02
	0°	1.17	1.10	1.42	1.69
	45°	.997	1.24	3.43	1.83
Mir.	90°	1.31	1.71	3.27	3.12
	135°	1.12	2.38	3.12	2.21
	180°	2.35	1.72	2.94	2.58
<u>Ss10</u>					
	0°	.720	.900	.832	.800
	45°	1.18	.804	1.65	1.08
Stan.	90°	2.28	1.35	2.89	2.13
	135°	2.15	2.27	3.03	2.65
	180°	2.56	2.52	2.92	2.91
	0°	.984	.806	2.07	2.36
	45°	.980	1.27	4.00	2.17
Mir.	90°	1.22	2.02	2.65	2.43
	135°	2.71	1.83	3.71	3.50
	180°	1.85	1.44	2.88	3.45

MEAN RT_c's FOR FEMALE RIGHT HANDERS

		STIMULUS 1		STIMULUS 2	
		<u>LVF</u>	<u>RVF</u>	<u>LVF</u>	<u>RVF</u>
<u>Ss1</u>					
	0°	.894	.851	1.18	1.24
	45°	.997	1.04	1.77	1.78
Stan.	90°	1.35	1.39	2.22	2.25
	135°	1.43	1.49	1.98	2.15
	180°	1.79	1.95	2.22	2.15
	0°	1.90	1.03	2.06	2.37
	45°	1.55	1.03	1.98	1.91
Mir.	90°	1.62	1.53	2.87	2.49
	135°	1.77	1.69	2.05	1.65
	180°	2.49	1.64	2.39	2.14
<u>Ss2</u>					
	0°	.854	.838	.941	.892
	45°	.899	.848	1.23	1.07
Stan.	90°	.884	.704	.947	1.16
	135°	.861	.805	1.03	1.31
	180°	.982	.746	1.18	.881
	0°	.894	1.16	1.16	1.04
	45°	.998	.935	.727	.872
Mir.	90°	1.02	.957	.958	1.01
	135°	.764	.976	.918	.994
	180°	.828	.716	.698	1.20
<u>Ss3</u>					
	0°	.605	.509	1.22	1.21
	45°	.884	.640	1.39	1.49
Stan.	90°	1.29	1.14	.841	1.72
	135°	1.04	1.14	1.28	1.91
	180°	1.11	1.36	1.77	1.33
	0°	.552	.585	1.11	1.16
	45°	.730	.678	.971	.820
Mir.	90°	1.23	1.14	1.21	.693
	135°	1.29	1.77	1.68	1.34
	180°	1.23	1.23	1.43	1.19
<u>Ss4</u>					
	0°	.885	.805	1.16	1.00
	45°	1.05	.990	1.13	1.10
Stan.	90°	1.26	1.44	1.16	1.21
	135°	1.41	1.79	1.31	.934
	180°	1.70	1.51	1.48	1.25
	0°	1.17	1.08	1.14	1.22
	45°	1.04	1.27	1.12	1.14
Mir.	90°	1.08	1.36	1.61	1.30
	135°	1.87	1.40	1.60	1.31
	180°	1.62	1.40	1.40	1.30

FEMALE RH

		STIMULUS 1		STIMULUS 2	
		<u>LVF</u>	<u>RVF</u>	<u>LVF</u>	<u>RVF</u>
<u>Ss5</u>					
	0°	.584	.442	1.10	.662
	45°	.699	.753	1.75	1.51
Stan.	90°	1.12	1.24	1.31	.664
	135°	1.00	.880	1.82	1.58
	180°	1.14	.549	1.38	1.16
	0°	.827	.785	1.33	1.97
	45°	.823	.800	1.18	1.05
Mir.	90°	1.30	.750	1.16	1.15
	135°	1.23	1.40	1.12	1.52
	180°	1.15	1.12	1.19	1.16
<u>Ss6</u>					
	0°	1.38	1.42	.959	.822
	45°	1.07	1.13	1.40	1.37
Stan.	90°	1.61	1.38	1.63	1.06
	135°	1.11	.936	.994	.960
	180°	1.15	1.83	1.02	.754
	0°	1.60	1.37	1.30	.911
	45°	1.35	1.55	1.13	1.25
Mir.	90°	1.54	1.58	1.19	1.27
	135°	1.20	2.14	2.27	1.12
	180°	1.12	1.64	1.12	1.95
<u>Ss7</u>					
	0°	.597	.593	.834	.690
	45°	.529	.544	.858	.710
Stan.	90°	.702	.601	.650	.690
	135°	.628	.590	.847	.938
	180°	.682	.636	1.01	1.15
	0°	.524	.726	1.08	.866
	45°	.512	.575	.752	.658
Mir.	90°	.721	.720	.792	.731
	135°	.729	.880	.720	.970
	180°	.726	.754	.757	.879
<u>Ss8</u>					
	0°	2.12	1.63	2.11	1.70
	45°	2.04	1.70	1.69	1.75
Stan.	90°	2.37	2.03	1.74	1.92
	135°	2.08	1.97	2.00	2.18
	180°	2.49	2.53	2.14	2.23
	0°	2.02	1.88	3.06	2.17
	45°	1.94	1.63	1.97	2.19
Mir.	90°	2.17	2.12	2.16	1.24
	135°	2.01	1.94	2.27	1.95
	180°	2.70	2.29	2.54	2.12

FEMALE RH

		STIMULUS 1		STIMULUS 2	
		<u>LVE</u>	<u>RVF</u>	<u>LVE</u>	<u>RVF</u>
<u>Ss9</u>					
	0°	.697	.617	1.14	1.90
	45°	1.75	.667	1.63	.928
Stan.	90°	.990	.959	2.00	1.34
	135°	1.03	1.13	1.31	1.14
	180°	.685	.511	.798	1.42
	0°	1.01	.644	1.84	1.57
	45°	1.55	.805	1.32	.857
Mir.	90°	1.05	1.15	1.48	1.01
	135°	1.10	1.02	1.38	1.39
	180°	.737	.832	.955	1.01
<u>Ss10</u>					
	0°	.763	.605	.718	.567
	45°	.772	.905	.924	.834
Stan.	90°	1.08	1.34	1.20	1.10
	135°	1.02	1.00	1.02	.826
	180°	.744	.757	.933	.807
	0°	.866	1.13	1.09	1.28
	45°	1.22	1.08	1.20	.924
Mir.	90°	1.29	1.70	.716	.888
	135°	1.32	1.52	1.14	.998
	180°	1.64	1.54	.882	1.01

MEAN RT_c's FOR FEMALE NON-FAMILIAL LEFT HANDERS

		STIMULUS 1		STIMULUS 2	
		<u>LVF</u>	<u>RVF</u>	<u>LVF</u>	<u>RVF</u>
<u>Ss1</u>					
	0°	.779	1.10	1.12	1.67
	45°	.995	1.01	1.79	3.14
Stan.	90°	1.05	1.47	1.61	1.93
	135°	1.56	1.23	2.32	2.81
	180°	1.93	1.87	2.10	2.06
	0°	1.12	1.68	1.84	2.71
	45°	1.38	1.03	1.89	1.83
Mir.	90°	1.08	1.10	2.42	3.16
	135°	1.76	1.58	2.35	2.33
	180°	1.67	2.15	2.94	1.97
<u>Ss2</u>					
	0°	.960	1.18	1.40	1.35
	45°	1.46	1.42	1.51	1.41
Stan.	90°	1.60	1.32	1.47	2.80
	135°	1.86	1.77	1.72	1.68
	180°	1.68	1.45	1.54	1.58
	0°	1.40	1.07	1.46	1.82
	45°	1.27	1.46	2.61	1.81
Mir.	90°	2.28	1.67	1.83	2.01
	135°	1.82	1.75	1.82	1.88
	180°	1.57	1.71	1.25	1.70
<u>Ss3</u>					
	0°	.893	.965	1.60	1.33
	45°	1.18	1.13	2.40	1.90
Stan.	90°	2.00	1.28	2.01	1.81
	135°	1.78	1.62	2.34	2.19
	180°	1.68	1.91	2.28	2.00
	0°	1.15	1.04	2.12	1.55
	45°	1.19	1.26	2.33	1.98
Mir.	90°	1.86	1.71	2.10	1.57
	135°	1.82	1.45	2.22	1.51
	180°	2.05	1.92	2.12	2.14
<u>Ss4</u>					
	0°	.786	.631	.812	.839
	45°	.814	.830	.973	1.36
Stan.	90°	1.05	1.40	.838	2.06
	135°	1.69	1.60	1.30	1.01
	180°	1.27	1.42	1.09	1.77
	0°	.910	.987	1.19	.875
	45°	1.12	.988	1.03	.859
Mir.	90°	1.21	1.28	1.25	1.03
	135°	1.25	1.24	.779	1.36
	180°	1.30	1.20	1.08	1.09

FEMALE LHNF

		STIMULUS 1		STIMULUS 2	
		<u>LVF</u>	<u>RVF</u>	<u>LVF</u>	<u>RVF</u>
<u>Ss5</u>					
	0°	.731	.568	2.52	1.49
	45°	.721	.896	2.44	.979
Stan.	90°	1.21	.719	3.19	1.18
	135°	1.08	1.10	3.06	2.98
	180°	1.58	1.30	1.94	1.61
	0°	1.01	.844	1.97	1.87
	45°	.793	.779	2.46	1.67
Mir.	90°	1.15	1.00	2.25	1.69
	135°	1.23	1.01	3.00	.989
	180°	1.47	1.30	1.43	1.59
<u>Ss6</u>					
	0°	1.64	1.64	1.97	1.82
	45°	2.89	2.15	2.65	2.33
Stan.	90°	2.57	1.98	2.63	2.62
	135°	2.25	3.06	3.55	5.03
	180°	2.86	2.64	4.84	3.83
	0°	2.28	1.51	3.87	3.88
	45°	2.76	2.24	3.44	4.13
Mir.	90°	3.14	2.81	4.01	3.62
	135°	2.37	3.02	4.44	4.50
	180°	2.39	3.07	4.26	5.12
<u>Ss7</u>					
	0°	1.48	1.02	.908	1.36
	45°	1.03	1.01	4.36	2.72
Stan.	90°	1.36	1.06	3.35	1.92
	135°	2.28	1.23	1.98	1.64
	180°	1.86	1.72	1.98	2.17
	0°	.944	1.24	2.74	3.25
	45°	1.20	.980	1.63	2.96
Mir.	90°	1.09	.901	3.12	3.28
	135°	1.46	1.88	1.97	1.68
	180°	2.35	1.26	3.44	2.55
<u>Ss8</u>					
	0°	2.06	1.65	1.52	2.05
	45°	1.73	1.25	3.07	3.55
Stan.	90°	2.25	1.38	2.15	2.87
	135°	1.63	1.91	3.71	2.85
	180°	2.40	2.82	2.29	3.02
	0	2.35	1.44	3.82	3.54
	45	1.83	2.50	3.00	2.74
Mir.	90	2.65	1.92	4.50	2.94
	135	2.70	2.10	3.68	4.05
	180	3.03	3.09	3.25	3.30

FEMALE LHNF

		STIMULUS 1		STIMULUS 2	
		<u>LVF</u>	<u>RVF</u>	<u>LVF</u>	<u>RVF</u>
<u>Ss9</u>					
	0	1.25	1.48	1.31	1.66
	45	1.62	1.30	1.15	1.45
Stan.	90	1.56	1.54	1.50	1.79
	135	1.38	1.47	1.48	1.48
	180	1.43	1.08	1.30	1.34
	0	1.61	1.24	1.15	1.23
	45	1.44	1.22	1.30	1.24
Mir.	90	1.35	1.52	2.03	.846
	135	1.56	1.38	1.64	1.24
	180	1.70	1.59	1.76	1.20
<u>Ss10</u>					
	0	1.53	1.12	1.67	1.82
	45	1.33	1.49	2.21	2.09
Stan.	90	1.43	1.97	1.21	1.59
	135	3.99	5.14	1.78	1.85
	180	2.57	1.83	3.38	2.85
	0	1.28	1.11	1.83	2.48
	45	1.76	2.56	1.64	3.21
Mir.	90	2.07	3.19	2.04	3.60
	135	2.72	2.78	2.00	2.27
	180	1.89	3.37	4.25	3.16

MEAN RT_C's FOR FEMALE FAMILIAL LEFT HANDERS

		STIMULUS 1		STIMULUS 2	
		<u>LVF</u>	<u>RVF</u>	<u>LVF</u>	<u>RVF</u>
<u>Ss1</u>					
	0°	1.06	1.42	1.77	1.33
	45°	1.82	2.24	2.56	1.84
Stan.	90°	3.48	2.67	2.10	1.99
	135°	2.02	2.26	1.67	1.74
	180°	2.47	2.84	2.17	1.60
	0°	1.58	1.80	1.12	2.38
	45°	1.43	2.18	3.17	1.70
Mir.	90°	2.69	3.60	1.70	1.83
	135°	4.00	2.49	1.65	1.46
	180°	2.53	2.84	3.23	1.56
<u>Ss2</u>					
	0°	1.15	.500	.723	.641
	45°	1.21	.762	1.98	1.16
Stan.	90°	1.55	1.66	2.27	1.73
	135°	2.00	1.96	2.52	2.13
	180°	2.71	3.04	2.60	2.71
	0°	1.02	1.53	1.76	2.14
	45°	1.26	1.87	1.81	1.22
Mir.	90°	1.66	1.52	3.91	1.91
	135°	2.92	2.15	3.61	3.28
	180°	3.45	1.61	1.99	2.72
<u>Ss3</u>					
	0°	1.16	1.21	1.06	1.87
	45°	1.37	1.01	2.11	2.03
Stan.	90°	2.10	1.30	2.21	1.71
	135°	1.36	1.95	1.84	2.44
	180°	2.60	2.22	1.71	1.73
	0°	1.11	1.11	1.75	1.88
	45°	1.50	1.29	1.50	1.63
Mir.	90°	2.23	1.57	2.25	1.95
	135°	2.41	1.74	1.53	1.92
	180°	2.42	2.11	2.22	1.94
<u>Ss4</u>					
	0°	.824	.814	4.25	3.68
	45°	.856	.867	7.50	2.37
Stan.	90°	1.55	1.59	2.24	2.72
	135°	1.78	1.46	1.95	3.68
	180°	1.73	1.84	2.36	2.33
	0°	1.11	1.45	6.19	2.45
	45°	1.33	1.42	2.68	1.67
Mir.	90°	1.45	1.75	2.74	2.64
	135°	1.54	1.84	5.18	1.75
	180°	2.03	2.31	4.41	4.53

FEMALE LHF

		STIMULUS 1		STIMULUS 2	
		<u>LVF</u>	<u>RVF</u>	<u>LVF</u>	<u>RVF</u>
<u>Ss5</u>					
	0°	.956	1.01	.937	1.85
	45°	1.06	1.01	1.75	2.51
Stan.	90°	2.55	1.91	1.76	4.17
	135°	3.75	3.48	2.95	2.98
	180°	3.02	1.85	5.84	2.77
	0°	1.26	1.70	3.17	3.46
	45°	1.72	2.80	3.22	2.90
Mir.	90°	2.15	2.53	5.28	2.67
	135°	2.63	3.20	2.06	3.11
	180°	1.99	2.11	2.71	3.76
<u>Ss6</u>					
	0°	.963	.980	.963	.929
	45°	1.47	.980	1.25	1.07
Stan.	90°	1.07	1.57	1.22	1.56
	135°	1.52	1.42	1.46	.916
	180°	1.26	1.10	1.32	.964
	0°	.944	1.41	1.13	1.56
	45°	1.27	1.59	1.24	1.78
Mir.	90°	1.63	1.39	1.09	1.15
	135°	1.34	1.41	1.23	1.57
	180°	1.69	1.72	1.07	1.27
<u>Ss7</u>					
	0°	.982	1.00	1.27	1.03
	45°	1.05	1.09	1.36	1.65
Stan.	90°	3.03	2.18	1.41	2.38
	135°	2.13	1.79	2.38	2.98
	180°	2.23	2.07	2.11	2.43
	0°	1.78	1.24	1.37	1.55
	45°	1.32	1.51	1.72	1.92
Mir.	90°	2.90	1.92	2.45	1.73
	135°	3.09	2.52	3.02	2.88
	180°	1.95	3.51	1.85	2.91
<u>Ss8</u>					
	0°	1.03	.764	.942	.716
	45°	1.23	1.07	2.09	1.64
Stan.	90°	1.76	1.44	2.30	2.28
	135°	1.51	1.24	2.83	1.77
	180°	1.74	1.10	2.00	1.67
	0°	1.19	1.10	1.84	1.74
	45°	1.10	1.50	1.83	1.68
Mir.	90°	1.96	1.70	1.89	1.59
	135°	1.95	1.72	2.21	2.92
	180°	2.00	1.41	1.90	1.24

FEMALE LHF

		STIMULUS 1		STIMULUS 2	
		<u>LVF</u>	<u>RVF</u>	<u>LVF</u>	<u>RVF</u>
<u>Ss9</u>					
	0°	.659	.653	1.30	.906
	45°	.568	.576	2.94	3.35
Stan.	90°	.949	1.21	1.71	2.38
	135°	1.29	.863	2.54	2.82
	180°	1.58	1.35	3.03	1.71
	0°	.860	1.05	1.46	1.18
	45°	.891	1.09	1.97	3.61
Mir.	90°	1.30	1.13	2.64	4.22
	135°	1.05	.853	3.57	2.83
	180°	1.28	1.40	2.13	2.01
<u>Ss10</u>					
	0°	1.20	.838	.900	1.10
	45°	1.12	.850	.894	1.15
Stan.	90°	1.40	.929	1.05	1.68
	135°	.826	1.06	1.40	1.72
	180°	1.12	.893	1.98	1.76
	0°	1.35	.746	1.05	1.05
	45°	1.70	1.26	1.70	1.24
Mir.	90°	1.72	.977	1.88	1.44
	135°	1.07	1.04	1.67	1.61
	180°	1.37	1.34	1.26	1.42

END

3 0 H 0 8 H 8 2

FIN