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Hand preference and hand of performance effects on visual centering tasks

Scarisbrick, David John, Ph.D.

City University of New York, 1988

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**Hand Preference and Hand of Performance Effects on
Visual Centering Tasks**

By

David J. Scarisbrick

**A dissertation submitted to the Graduate Faculty in Psychology in
partial fulfillment of the requirements for the degree of Doctor of
Philosophy. The City University of New York**

1988

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This manuscript has been read and accepted for the Graduate Faculty in Psychology in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

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Abstract

HAND PREFERENCE AND HAND OF PERFORMANCE EFFECTS ON VISUAL CENTERING TASKS

by

David J. Scarisbrick

Advisor: Professor J.R. Tweedy

The present thesis examined how left- and right-handers differ on several visuospatial centering tasks, and discussed the implications of these results regarding right hemisphere brain organization in left- and right-handers. Twenty-four left- and 24 right-hander males participated in a horizontal and vertical line and arrow bisection, and a two-dimensional centering task using both the left and right hands. In addition, all subjects completed an horizontal line bisection discrimination task.

When required to produce an estimate of center, both left- and right-handers, placed their estimates to the left of true center in the horizontal domain and above true center in the vertical range. In addition, left hand performances were always left of right hand performances in the horizontal domain in both left- and right-handers. The results of the bisection discrimination task

demonstrated a slight leftward bias on long lines and a slight rightward bias on medium and short lines, regardless of hand preference. These results are best interpreted using an hemispheric specialization and motor activation model. In addition, the results favor similar right hemisphere organization in left- and right-handers.

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who provided the truly needed emotional and financial support, and to my brother Tom who always knew I could do it. A special thanks to my son David who constantly reminded me that playing around is an important part of life

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Table of Contents

	<u>Page</u>
Abstract	iv
Acknowledgement	vi
List of Tables	xi
List of Figures	xii
Chapter 1. <u>General Introduction</u>	
Evidence for Anatomical Asymmetries between the Left and Right Cerebral Hemispheres	2
Functional Lateralization of the Cerebral Hemispheres	5
Handedness and its Relation to Hemispheric Specialization	9
Measures of Handedness	9
Population Estimates of Handedness	13
Theories of Relationship between Handedness and Cerebral Lateralization	14
Cerebral Anatomical Asymmetries in Left- and Right-Handers	16
Language Organization in Left- and Right-Handers	18

Right Hemisphere Functions in Left- and Right- Handers	20
Issues and Rationale for the Current Study	21
Chapter 2. <u>General Methodology</u>	
Sample Characteristics	
Subjects	25
Measures of Lateral Preference	26
Results of Lateral Preference Measures	29
Summary of Sample Characteristics	37
General Experimental Procedure	39
Chapter 3. <u>Horizontal and Vertical Line Bisection</u>	
Introduction	40
Methods	42
Results	46
Discussion	62
Chapter 4. <u>Bisection Discrimination</u>	
Introduction	67
Methods	69
Results	72
Discussion	89
Chapter 5. <u>Arrow Bisection</u>	
Introduction	92
Methods	98
Results	99
Discussion	108

Chapter 6. <u>Two-Dimensional Centering</u>	
Introduction.....	114
Methods.....	117
Results.....	124
Discussion.....	151
Chapter 7. <u>General Discussion</u>	
Summary of Results.....	155
Possible Mechanisms for Asymmetrical Performance on Horizontal Bisection.....	158
Possible Mechanisms for Asymmetrical Performance on Vertical Bisection.....	163
Implications for Brain Organization in Left- and Right-Handers.....	164
Clinical Implications.....	165
Footnotes.....	168
Appendicies	
Appendix A - Lateral Preference Inventory.....	169
Familial Handedness Questionnaire.....	170
Appendix B - Handwriting Posture Questionnaire.....	171
Appendix C - Target Test.....	172
Appendix D - Informed Consent Form.....	174
References.....	175

List of Tables

	<u>Page</u>
Table 1: Percent of subjects classified as having an inverted versus a non-inverted hand posture using a self and an experimenter classification questionnaire and picture designation of hand posture.	35
Table 2: Summary of ANOVA's for squares, circles, and horizontal and vertical rectangles	125

List of Figures

	Page
Figure 1. Mean ratio scores for eye, ear, hand, and foot preferences in left- and right-handers	30
Figure 2. Mean seconds to completion on the Target Test for left- and right-handers using their left and right hands.	33
Figure 3. Examples of horizontal and vertical line bisection stimuli	43
Figure 4. Mean percent deviation for horizontal and vertical line bisections for left- and right-handed subjects using their left and right hands.	47
Figure 5. Cumulative percent of left-handers at each percent deviation for horizontal line bisections with their left and right hands.	50
Figure 6. Cumulative percent of right-handers at each percent deviation for horizontal line bisections with their left and right hands	52
Figure 7. Mean percent deviation for short, medium and long horizontal and vertical line lengths.	55
Figure 8. Cumulative percent of left-handers at each percent deviation for vertical line bisections with their left and right hands.	58

<u>Figure 9.</u> Cumulative percent of right-handers at each percent deviation for vertical line bisections with their left and right hands.	60
<u>Figure 10.</u> Example of line bisection discrimination stimuli.	70
<u>Figure 11.</u> Mean percent error ("miss") of short, medium and long lines on bisection discrimination task	74
<u>Figure 12.</u> Mean percent of left and right "false alarms" at each percent deviation for left-handers.	76
<u>Figure 13.</u> Mean percent of left and right "false alarms" at each percent deviation for right-handers.	78
<u>Figure 14.</u> Mean percent of left and right "false alarms" for short, medium and long lines (Percent deviations of 4 and 8).	81
<u>Figure 15.</u> Mean percent of left and right "false alarms" for medium and long lines (Percent deviations of 2, 4, and 8).	84
<u>Figure 16.</u> Mean percent of left and right "false alarms" for medium and long lines at deviations of 2, 4, and 8 percent.	86
<u>Figure 17.</u> Modified version of the Muller-Lyer Figure ("arrow") with a small vertical transection line on center.	95
<u>Figure 18.</u> Mean percent deviations for leftward and rightward facing arrows for left-handers using their left and right hands.	100

<u>Figure 19.</u> Mean percent deviations for leftward and rightward facing arrows for right-handers using their left and right hands.	102
<u>Figure 20.</u> Mean percent deviations for leftward and rightward facing arrows of short, medium, and long length.	106
<u>Figure 21.</u> Mean percent deviations for downward and upward facing arrows for left-handers using their left and right hands.	109
<u>Figure 22.</u> Mean percent deviations for downward and upward facing arrows for right-handers using their left and right hands.	111
<u>Figure 23.</u> Examples of square centering stimuli.	118
<u>Figure 24.</u> Examples of circle centering stimuli.	120
<u>Figure 25.</u> Examples of rectangle centering stimuli.	122
<u>Figure 26.</u> Mean percent horizontal and vertical deviation for the left and right hand on the square stimuli.	128
<u>Figure 27.</u> Mean percent horizontal and vertical deviation on the square centering task in left- and right-handers using their left and right hands.	130
<u>Figure 28.</u> Mean percent horizontal and vertical deviation on small, medium and large squares.	132
<u>Figure 29.</u> Mean percent horizontal and vertical deviation on medium and large squares in left- and right-handers using their left and right hands.	135

<u>Figure 30</u> Mean percent horizontal and vertical deviation on the circle centering task in left- and right-handers using their left and right hands.	138
<u>Figure 31</u> Mean percent horizontal and vertical deviation for the left and right hand on the horizontal rectangle stimuli.	141
<u>Figure 32</u> Mean percent horizontal and vertical deviation on the horizontal rectangle centering task in left- and right-handers using their left and right hands.	143
<u>Figure 33</u> Mean percent horizontal and vertical deviation on small, medium and large horizontal rectangles.	146
<u>Figure 34</u> Mean percent horizontal and vertical deviation on the vertical rectangle centering task in left- and right-handers using their left and right hands.	149
<u>Figure 35</u> Mean percent horizontal and vertical deviation on short, medium, and large vertical rectangles.	152

Chapter 1

INTRODUCTION

Prior to the mid 19th century, the brain was portrayed as being anatomically and functionally symmetrical. This view was consistent with all other paired organ systems of the body, and was referred to as the "law of organic duality and functional unity." (Berker, Berker, & Smith, 1986). In the mid 1800's Paul Broca (1861, 1865 cited in Berker et al., 1986) published two articles that are the seminal works in the area of human cerebral lateralization. Broca's first paper (1861, cited in Berker et al., 1986) was a case study of a patient called Tan. This study presented evidence for speech being localized in the frontal lobes. Broca suggested that future research would clarify whether a particular convolution or convolution(s) were involved. In his second paper Broca (1865) specifically placed the center for articulate speech in the third left frontal convolution (Berker et al., 1986). In addition, he proposed a simple model of cerebral functional lateralization for language and handedness. He stated "Heretofore, I have designated right-handed

persons as those who preferably use their right hand and left-handers as those who preferably use their left hand. These impressions are derived from the external manifestations of the phenomenon, but if we should consider the phenomenon with regard to the brain and not in relation to its mechanical agents, we would say that most men are naturally 'left-brained' and that, by exception, some of them, those called left-handed, are on the contrary right-brained." (cited in Berker et al., 1986, p. 1068).

Evidence for Anatomical Asymmetries between the Left and Right Cerebral Hemispheres

The paired cerebral hemispheres are not mirror images of one another. Anatomical asymmetries between the left and right cerebral hemispheres were first observed in the late 19th century.

Several early authors (Cunningham, 1882 cited in Kertesz, Black, Polk & Howell, 1986; Eberstaller, 1884 cited in Von Bonin, 1962) suggested that differences existed in the direction and overall extent of the

Sylvian fissures in the left and right cerebral hemispheres. These early observations have been quantified and verified by more recent research. The Sylvian fissure is longer, and continues more horizontally on the left than the right side. Consequently, the posterior end of the Sylvian fissure is higher on the right side (Hochberg & LeMay, 1975; LeMay & Culebras, 1972; Rubens, 1976; Rubens, Mahowald, & Hutton, 1976).

Pfeiffer (1936, cited in Kertesz et al., 1986) suggested that the area of the planum temporale is larger in the left than the right hemisphere. The planum temporale roughly corresponds to the auditory association areas referred to as Wernicke's area. Geschwind and Levitsky (1968) measured the planum temporale of 100 human brains at postmortem. They found that the planum temporale was larger on the left in 65%, and larger on the right in 11%, of the human brains, with 24% showing no difference between the left and right planum temporale. Unfortunately, but unavoidably, no handedness information was available in this post-mortem study. This paper sparked an interest in gross anatomical differences between the left and right cerebral hemispheres and resulted in numerous publications using various techniques. Findings similar to

those of Geschwind and Levitsky (1968) were subsequently published by several research groups (Kopp, Michel, Carrier, Biron, & Duvillard, 1977; Teszner, 1972; Wada, Clarke & Hamm, 1975; Witelson & Pallie, 1973). Galaburda, Sanides and Geschwind (1978) provided additional cytoarchitectonic evidence that the temporo-parietal auditory cortex was larger on the left side of the brain.

Research examining the inferior frontal cortex, corresponding roughly to Broca's area, is more equivocal. Some authors found that the right (LeMay, 1977; Wada et al., 1975) and others that the left (Galaburda, 1980) side is larger.

Recent studies using in vivo computerized tomographic (CT), magnetic resonance imaging (MRI) and xenon-133 inhalation regional cerebral blood flow (rCBF) techniques have also found anatomical asymmetries between the left and right cerebral hemispheres. On CT, the right frontal area extends more anteriorly and has a greater width than the corresponding left frontal area (right frontopetalia). The left occipital area extends further posteriorly and has a greater width (left occipitopetalia) than the corresponding right occipital area (Chiu &

Damasio, 1980; LeMay, 1976; Naeser & Borod, 1986; Pieniadz & Naeser, 1984; Pieniadz, Naeser, Koff & Levine, 1983). The most noticeable asymmetry on MRI (inversion recovery image) is a sharper demarcation of the parietal sulci on the right, reflecting a larger left planum temporale (Kertesz et al., 1986). Gur, Packer, et al., (1980) using rCBF measures have demonstrated a greater grey to white matter in the left than the right hemisphere.

In sum, the evidence from different techniques has demonstrated that the left and right cerebral hemispheres are anatomically asymmetrical.

Functional Lateralization of the Cerebral Hemispheres

Since Broca's early work, various psychological functions have been posited to be primarily mediated by either the left or right cerebral hemisphere. However, few researchers would argue that only one side of the brain is solely involved in a particular function. The current conception of hemispheric lateralization is one in which each side of the

brain is viewed as being preferentially organized for certain functions, but that the whole brain is active during any particular task (Bryden, 1982; Luria, 1973; Walsh, 1978).

Recent evidence from normal subjects, patients with unilateral brain lesions, and commissurotomy subjects has shed new light on the types of functions which may be preferentially organized in either the left or right cerebral hemisphere.

In general, tasks which have a language component tend to be preferentially performed by the left hemisphere and are maximally disrupted by left hemisphere lesions, and tasks which are not easily verbally mediated or involve the appreciation of personal and extrapersonal space or spatial relationships preferentially involve the right hemisphere and are maximally disrupted by right hemisphere lesions (Bradshaw & Nettleton, 1983 ; DeRenzi, 1982; Hellman & Valenstein, 1979; Walsh, 1978). Aphasia, alexia, and agraphia are more common following left than right hemisphere lesions (Hellman & Valenstein, 1979). Commissurotomy patients can write with their right but not left hand, and can verbally name stimuli presented in the right

visual field (RVF) but not in the left visual field (LVF) (Bradshaw & Nettleton, 1983; Heilman & Valenstein, 1979).

The functions of the right hemisphere have been more elusive to define but research suggests that some functions in which the right hemisphere is preferentially involved include size discrimination, judgement of spatial location, two- and three-dimensional perception, part-whole completion, facial recognition, appreciation of humor, stereopsis, some emotional components of language, constructional abilities, and the appreciation of space (Bogen, 1979; Bradshaw & Nettleton, 1983; Bryden, 1981; De Renzi, 1982; Walsh, 1978).

DeRenzi (1982) divided the literature dealing with the appreciation of space into five sub-domains: space exploration, space perception, spatial thought, personal space cognition and topographical memory. Although lesions of either hemisphere may result in disorders in any or all of these sub-domains, a preponderance of evidence indicates that the right hemisphere is predominantly involved in each, and especially in space exploration and topographical memory.

Hemispatial neglect or inattention, in which the individual fails to

attend to the space contralateral to the lesioned hemisphere (DeRenzi, 1982; Heilman & Valenstein, 1979), is perhaps one of the most dramatic examples of a disorder of space exploration and perception. . Patients with neglect may fail to notice a person on their affected side, may only draw half a picture to copy or from memory, often bisect a horizontal line off center, and may frequently bump into objects on the neglected side. This disorder is most commonly associated with lesions of the parietal lobe of the right hemisphere (Bisiach, Bulgarelli, Sterzi, & Vallar, 1983; DeRenzi, 1982; Gainotti, 1972; Heilman & Valenstein, 1979; Mesulam, 1981; Schenkenberg, Bradford & Ajax, 1980; Weintraub & Mesulam, 1987), and such individuals exhibit neglect of the left half of the external world.

Thus, the evidence from studies using normal and brain-damaged individuals supports the view that the left and right cerebral hemispheres are not functionally symmetrical. Tasks that are or can be mediated by language tend to be performed more efficiently by the left hemisphere, whereas tasks that are spatial in nature are performed more efficiently by the right hemisphere.

Handedness and its Relation to Hemispheric Specialization

A. Measures of Handedness

Two basic techniques have been used to characterize an individual's handedness: manual performance tasks and hand preference questionnaires. Each assesses some aspect of handedness and correlates it with the subject's self-professed handedness (Bryden, 1982; Porac & Coren, 1977).

Performance measures are considered preferable to hand preference measures by some because they are continuously distributed, whereas hand preference measures are inherently binary or ternary (Bryden, 1982; Hardyck & Petrínovich, 1977). Grip strength as an indicator of hand preference has a long history (e.g. Galton, 1884 cited in Porac & Coren, 1977). Recent studies indicate that grip strength (measured with a dynamometer) is correlated with hand preference, but the relationship is far from perfect. In general, the concordance in right-handers is greater than in left-handers (Benton, Meyers & Polder, 1962; Hardyck &

Petrinovich, 1977). Satz, Achenbach and Fennel (1967) found that 87% of their right-handers were better with their right hand, while only 45% of their left-handers were better with their left hand. Johnstone, Galin and Herron (1979) report a correlation of 0.31 between grip strength and hand preference. Porac and Coren (1977) summarized the results of three studies (Johnstone et al., 1979; Provins & Cunliffe; 1972; Satz et al., 1976) using dynamometer grip strength as an index of hand preference. They found an overall concordance rate of only 59%. That is based upon grip strength alone, approximately 40% of the subjects would be misclassified with respect to hand preference. The low concordance probably reflects several factors unrelated to hand preference, especially for left-handers, since there are many daily situations in which the form of the tool strongly favors the right hand (e.g. scissors, can opener, soup ladle; Hardyck & Petrinovich, 1977).

The second class of performance measure commonly used involves fine motor control such as using tweezers to pick up small items (e.g. Benton, Meyers & Polder, 1962; Satz et al., 1967), finger tapping (Provins & Cunliffe, 1972; Satz et al., 1967) and aiming tasks (Borod, Koff, &

Caron, 1984; Tapley & Bryden, 1985). In general, both left- and right-handers perform all of these tasks better with their preferred hand. Again, however, there are many instances in which subjects, especially left-handers, would be misclassified (Benton et al., 1962; Provins & Cunliffe, 1972; Satz et al., 1967). On aiming tasks, Tapley and Bryden (1985) report a correlation between performance and a preference inventory of 0.75 ($p < 0.001$), and Borod et al. (1984) report a correlation of 0.77 ($p < 0.001$). Although both are highly significant, they only account for approximately 50% of the variance.

Preference measures are probably the most commonly used method of assessing handedness (Bryden, 1982; Hardyck & Petrinovich, 1977). Hand preference has been determined by self-report, hand used for writing, activities questionnaires and behavioral inventories. Self-report is problematic because each subject's report may be based upon different behaviors (e.g., relative strength or manual dexterity) when identifying hand preference. Hand used for writing is probably the most common basis for self-classification. Bryden (1977) found that hand used for writing was the best predictor of hand preference. However, assessing

hand preference by hand used for writing is problematic because of the social and cultural restrictions against writing with the left hand.

However, a recent study suggests that for individuals born after 1960 this may no longer be necessarily true (Beukelaar & Kroonenberg, 1985).

Hand preference questionnaires have proliferated recently. The most popular are those of Annett (1970), Crovitz and Zener (1962), Oldfield (1971), Porac and Coren (1977), and Bryden (1982). The types of behavior sampled are fairly similar across inventories, although the response may vary from "left, right or either" to "always left, usually left, both equally, usually right, and always right." The questions usually focus on the hand used for the aspect of the task requiring the greatest fine motor control. The major exception is that the Crovitz and Zener questionnaire (1962) includes reversed scored questions in which right-handers would normally use their left hand, e.g., holding a nail for hammering, or holding a potato to peel. Bryden (1977) administered both the Crovitz and Zener (1962) and the Oldfield (1971) questionnaires to a large sample of undergraduates, and factor analyzed the resulting data. He found three factors: (1) A handedness factor involving items such as

writing, throwing a ball, drawing, using a toothbrush, and holding a tennis racquet; (2) A Crovitz and Zener factor of the items which are reversed scored; and (3) An Oldfield factor of items such as using a broom, striking a match, and holding a box lid. Bryden (1982) felt the last factor items were infrequent activities which subjects have difficulty visualizing, and tended to be unreliable as measures of handedness. Thus Bryden's (1982) hand preference questionnaire is composed only of items loading heavily on the first factor.

The concordance between subjects' self-report on the hand preference questionnaires and behavioral assessment of hand preference is generally above 90% (Coren & Porac, 1978; Coren & Porac, 1981; Coren, Porac & Duncan, 1979; Raczkowski, Kalat & Nebes, 1974). In addition, test-retest reliabilities are very high, with most above 90% after one month (Raczkowski et al., 1974) and one year (Coren & Porac, 1978).

Population Estimates of Handedness

The population incidence of left-handedness has been estimated to be

anywhere from 1% to 30% (Hardyck & Petrinovich, 1977). This large range most likely results from the variety of methods used to determine handedness rather than a change over time in the actual incidence (Bryden, 1982; Hardyck & Petrinovich, 1977). When only self-report questionnaires and performance measures are considered, the incidence of left-handedness converges to about 10%. Annett (1973) reported that 11.64% of her sample were left- or ambidextrous; Bryden (1979) reported an incidence of 10.39%; Hardyck, Goldman and Petrinovich (1975) an incidence of 9.9%, and Porac and Coren (1977) an incidence of 11.8%. Hardyck and Petrinovich (1977) summarized these findings and estimated the incidence of left-handedness to be between 8% and 10%.

Theories of Relationship between Handedness and Cerebral Lateralization

Theories proposed to relate handedness to cerebral laterality for language have involved genetics (Annett, 1972, 1974; Levy & Nagylaki, 1972), and pre- or peri-natal neurological injury (Bakan, 1973, 1977,

1978; Satz and colleagues, 1972, 1973, 1985).

Levy and Nagylaki (1972) proposed a two gene-two allele model. One gene determines which cerebral hemisphere is dominant for language, and the second gene determines whether hand preference is ipsilateral or contralateral to language dominance. Annett (1972, 1974, 1978) has proposed a single "right-shift" gene model. If this "right-shift" factor is present, it will be manifested by a right sided bias. If the "right-shift" factor is absent, random or accidental environmental factors will determine handedness. Thus, Annett's model allows for environmental influences on handedness.

Other theories suggest pre- or perinatal influences which subsequently alter lateralization for language and hand preference. Bakan (1973, 1977, 1978) proposed that left-handedness and right brain lateralization for language is the result of neurological injury during birth. Satz and his colleagues (1972, 1973, 1985) also argue that some left-handers are the result of pre- or peri-natal birth trauma (pathological left-handers), while the remainder are probably genetic left-handers. This model also predicts a very small group of

pathological right-handers.

The theories of hand preference proposed are each insufficient to account for all the available data (Bryden, 1982). The theory which eventually proves to be most valid will have to incorporate genetic, and pre- and peri-natal hormonal (Geschwind & Behan, 1982) and birth stress influences (Bryden, 1982; Porac & Coren, 1981; Satz et al., 1985).

Cerebral Anatomical Asymmetries in Left- and Right-Handers

The left and right cerebral hemispheres are neither anatomically nor functionally symmetrical, and the observed asymmetries have been related to hand preference. It was noted that the left occipital pole extends further back than the right (Chu & Damasio, 1980; LeMay, 1976). In a CT study, LeMay (1976) found that the left occipital length was greater than the right in 78% of the right-handers but in only 42% of the left-handers, 40% of whom exhibited a greater right occipital length. Witelson's (1980) review of studies examining the relationship between cerebral anatomical asymmetries and hand preference found that

left-handers as a group demonstrate less or even reversed asymmetries compared to right handers with respect to blood supply volume, venous drainage patterns, and left-right asymmetries in the prefrontal, parietal opercular and occipital regions. Witelson (1985) examined the brains of 27 right- and 15 ambidextrous-handers at autopsy. The corpus callosum was 11% larger in the ambidextrous subjects' brains. Kertesz et al. (1986) noted that on MRI, the opercular parietal demarcation of sulci was sharper on the right in 60% of right- but only 10% of left-handers. In addition, the left occipital width was greater than the right in 90% of right- but in only 30% of the left-handers. In sum, there is considerable evidence that the brains of left- and right-handers are differently organized anatomically. However, two recent CT studies (Chui & Damasio, 1980; Koff, Naeser, Pienadz, Foundas, & Levine, 1986) failed to find any significant anatomical differences between left- and right-handers. The different results obtained in the CT studies are most likely due to methodologic factors such as the scan (slice) chosen to measure, the thickness and angulation of the scan, the identification of the midline, and the determination of the antero-posterior axis for

making width measurements.

This review of the evidence of cerebral anatomical asymmetries in left- and right-handers indicates that the brains of left-handers often times show less marked or even reversed cerebral asymmetries compared to right-handers' brains.

Language Organization in Left- and Right-Handers

Broca's original model of language lateralization and handedness has subsequently been modified. Recent studies examining unilateral brain lesions, and those employing sodium amytol and ECT, have shed new light on the relationship between hand preference and the hemisphere dominant for language functions (Bryden, 1982; Rasmussen & Milner, 1977; Warrington & Pratt, 1973). In general, the data generated from each type of study are in agreement (Bryden, 1982). In the case of right-handers, approximately 96% are left hemisphere dominant and 4% are right hemisphere dominant for language. The data from left-handers indicates that approximately 70% are left hemisphere dominant, 15% are

right hemisphere dominant, and 15% are bilaterally organized with respect to language. Thus, although both left- and right-handers are usually left-hemisphere dominant for language, many more left- than right-handers will exhibit right hemisphere and bilateral language organization.

In accord with these results, left- and right-handers have been shown to differ with respect to the incidence of aphasic language disturbance following unilateral cerebral injury, with left-handers being more likely than right-handers to suffer an aphasic disorder after a right hemisphere lesion (Goodglass & Quadfasel, 1954; Gloning & Quatember, 1966; Hécaen & Ajuriaguerra, 1963; Hécaen & Sauguet, 1971; Naeser & Borod, 1986; Russel & Espir, 1961).

Levy and Reid (1978) have proposed a relationship between brain organization and hand writing posture. They present evidence from tachistoscopic stimulus presentation studies that it is not left- or right-handedness per se that indicates cerebral organization but rather the subject's writing posture (inverted, or non-inverted). Levy and Reid argue that inverters have ipsilateral cerebral language dominance while

non-inverters have contralateral language organization. Two recent studies, using sodium amytol techniques, have failed to support this hypothesis (Strauss, Wada, & Kosaka, 1984; Volpe, Sidtis, & Gazzaniga, 1981).

Right Hemisphere Functions in Left- and Right-Handers

Relatively few experimental studies have specifically examined left- and right-hander performance differences on manual tasks, possibly due to the relatively low incidence of left-handers in the population (Bryden, 1982). In the available studies there is some disagreement regarding the organization of right hemisphere functions in left- and right-handers. Some authors find evidence of similar organization (DeRenzi, 1982; Masure & Benton, 1983), and others that there are differences (Borod, Carper, Naeser, & Goodglass, 1985; Levy & Reid, 1978). Gardner et al., (1977) examined left- and right-handers' ability on a tactual discrimination task. They found that, regardless of hand preference, accuracy was greater with the left hand, indicative of a

right-hemisphere proficiency on this task. McGlone and Davidson (1973) and Bryden (1973) administered a lateralized dot enumeration task, and found no difference in the performances of left- and right-handers. The data from patients with cerebral insults also support a position of similar right hemisphere organization in left- and right-handers. Left- and right-handers have been reported to show similar disturbances of space perception after right-hemisphere lesions (DeRenzi, 1982; Hécaen & Seuguet, 1971; Masure & Benton, 1982). In sum, the evidence favors the position that left- and right-handers' brains are organized similarly with respect to perceptual functions.

Issues and Rationale for Current Study

In order to systematically investigate whether left- and right-handers are similar in right hemisphere neural organization, the present study examined left- and right-handers' performance with both left and right hands on several visuospatial centering tasks which require the appreciation of extrapersonal space. Spatial centering tasks

were chosen because these have been shown to be extremely sensitive to right hemisphere damage (Heilman & Valenstein, 1979; Lezak, 1983; Schenkenberg et al., 1980).

The visuospatial tasks below were administered to all the subjects and the rationale for each:

Visual Line Bisection: Do left- and right-handers transect horizontal and vertical lines asymmetrically? Several studies have demonstrated that right-handers bisect horizontal lines and rods asymmetrically to the left of center (e.g., Bowers & Heilman, 1980; Bradshaw, Nettleton, Nathan, & Wilson, 1985). Only one study specifically looked at a small group of left-handers, and found that left-handers also transect horizontal lines to the left of center (Scarisbrick, Tweedy, & Kuslansky, 1987).

Horizontal Line Bisection Discrimination: If subjects asymmetrically transect horizontal lines, is this due to perceptual factors, such that the two unequal extents to the left and right of the transection are perceived as equal or is the deviation due to the motor factors involved in producing a line bisection? If we remove the motor

component of line bisection, by using a visual line bisection discrimination task, do left- and right-handers still view an asymmetrically transected horizontal line as being centrally bisected?

Arrow Bisection Task: If the obtained effects on horizontal line bisection are attributable to perceptual differences in the visual field, can the effects be experimentally accentuated or decreased via illusory manipulations of apparent extent? The stimuli used to test this were modified versions of the Muller-Lyer figure (see Figure 17), in which objective center is perceived as being off center in the direction of the head of the arrow. Thus, subjects' estimates of center were expected to deviate in the direction opposite to the direction of the arrow. If the differences in line bisection are due to perceptual differences in the visual field, will the deviations of center estimates on arrow bisection be larger when the arrow is facing to the left versus to the right?

Two-Dimensional Centering Task: If subjects are required to estimate the center of two-dimensional figures, in which they must simultaneously estimate the horizontal and vertical extent, are the deviation scores in the same direction as on the horizontal and vertical

lines bisections alone ? If so, subjects should place their estimates of center to the left and above objective center of two dimensional figures

Chapter 2

GENERAL METHODOLOGY

Subjects

Forty-eight males were recruited through class announcements, newspaper ads, and signs on the campus of Queens College of the City University of New York. There were 24 left- and 24 right-handers classified by self-report and writing hand. All subjects had normal or corrected to normal vision. Six subjects failed to enter their age on the questionnaire (1 right- and 5 left-handers). The average age of left- ($n=19$; $M= 21.53$ years) and right- ($n= 23$; $M= 21.35$ years) handers was not significantly different ($t[40]=.11$).

Sample Characteristics

The individuals studied were divided into groups of left- and right-handers based upon self-reported hand used for writing. Although some may argue that hand used to write may, because of cultural pressures, result in an erroneous classification of left- and right-handers, particularly in the right preference group, a recent study

indicates that for individuals born after 1960 this is probably no longer true (Beukelaar & Kroonenberg, 1986). In order to ensure the integrity of the handedness groups, all subjects received a battery consisting of a Lateral Preference Questionnaire (Porac & Coren, 1981), a behavioral assessment of hand performance, hand posture during writing, eye dominance, and a set of questions regarding familial sinistrality in first degree relatives.

The subjects were tested individually in a quiet room. A brief explanation of the experiment and procedures was given and informed consent was obtained (Appendix D). The experimenter always sat opposite the subject and all materials were presented on midline and without rotation in front of the subject.

Measures of Lateral Preference

Subjects completed a paper and pencil Lateral Preference Inventory (Porac & Coren, 1981). This is a behaviorally validated inventory which consists of 13 questions concerning which side of the body a subject prefers to use for various activities (See Appendix A). The subjects were instructed to read each question and circle either "left" or "right"

for the side they preferred to use for these activities. If they could not determine a preferred side they were instructed to circle "both." In addition, subjects were queried about their parents' and siblings' hand preference.

The data from the Lateral Preference Inventory were transformed to a ratio score using the formula $(R-L)/N$ where R is the number of "right" responses, L is the number of "left" responses, and N is the total number of questions used to determine each type of lateral preference. This ratio score can range from -1.0 (complete left preference) to +1.0 (complete right preference). Porac and Coren (1981) classified individuals as right sided if they had a positive score and left sided if they had a negative score. They included individuals with scores of 0.0 (ambilateral responders) in their left sided group.

Writing hand posture was determined separately by both the subject who filled out a questionnaire and the experimenter (Levy, 1984; See Appendix B). In addition, the subjects were required to circle a picture designation of hand posture of each hand when writing (Appendix B).

A behavioral assessment of hand proficiency was obtained by the

Target Test (Borod ,Koff, & Caron,1984). The Target Test consists of 64 "bullseye" targets, arranged in two 8 by 4 arrays. Each target consists of four concentric circles, the largest having a 12 mm and the smallest a 2 mm diameter (See Appendix C). The subjects were instructed to place a mark in the central smallest circle and to work as fast as possible. Each subject marked 32 targets with the left and 32 targets with the right hand. Order of hand was counterbalanced across subjects. The time to accurately mark the center of the 32 targets was recorded for each hand.

Behavioral assessment of eye dominance was obtained by the Cone Test (Harris, 1974; Miles, 1939). This is considered a test of eye dominance which is unconfounded by hand preference. The subject was told the task involved visual discrimination of relative brightness. The subject was instructed to pick up the cone with both hands, and place the wide end over both eyes, requiring the subject to look through the narrow opening. The experimenter stood approximately eight feet away and held a series of cards in front of his nose. On each card were two circles, one darker than the other. The subject responded either "left" or "right" depending upon which circle was judged darker. While the subject was

determining his response, the experimenter looked through the cone to determine which eye the subject was using. Each subject was given three trials with a different stimulus card on each trial. Between each trial, subjects were instructed to bring the cone to rest at the waist.

Results of Lateral Preference Measures

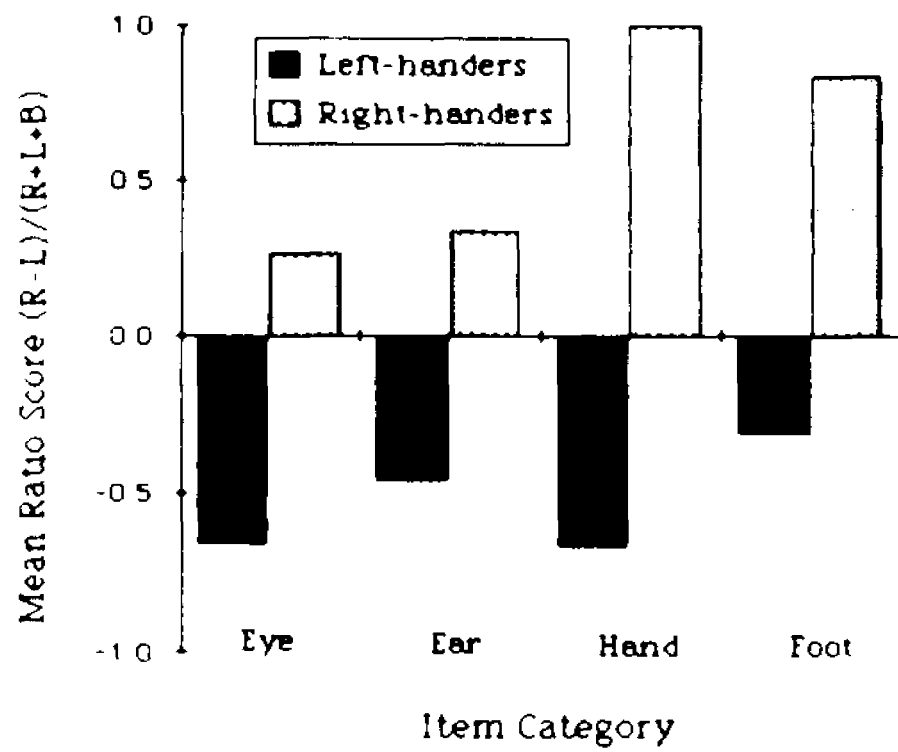
Twenty-five % of right- and 37.5% of left-handers reported one or more of their first degree relatives as left handed ($X^2=.875$, $df=1$, n.s.).

Figure 1 displays the mean ratio scores for items involving the hand, eye, ear and foot from the Lateral Preference Inventory for left- and right-handers. Right-handers had positive mean ratio scores while left-handers had negative scores for each category. Left- and right-handers' ratio scores were significantly different for each item category (Eye: $t[46]= 3.74$; Ear: $t[46]= 3.39$; Hand: $t[46]=13.27$; Foot: $t[46]= 5.59$, $p < .001$). Hand preference appeared to be the most robust measure with 100% of the self classified right-handers scoring 1.0 and 100% of the self classified left-handers scoring ≤ 0.0 ($-1.0=50\%$; $-0.5=33\%$; $0.0=17\%$).

A X^2 analysis revealed that eyedness and hand preference were

Figure 1. Mean ratio scores for eye, ear, hand, and foot preferences in left- and right-handers.

Lateral Preference Inventory



independent. Forty-two % of left- and 33% of right-handers were left eye dominant, while 58% of left- and 67% of right-handers were right eye dominant ($\chi^2=.356$; $df=1$, n.s.)

Figure 2 displays the mean completion time in seconds on the Target Test for both left- and right-handers using their left and right hands. An ANOVA with preferred hand as the between groups variable and hand used as the within groups variable resulted in a significant interaction of hand preference by hand of performance ($F[1,46]=79.56$, $p < .001$). The main effects of hand preference and hand of performance were both non-significant. Left-handers performed this task faster with their left ($M= 32.75$) than right ($M= 42.79$) hand, while right-handers were faster with their right ($M= 30.84$) than left ($M= 39.47$) hand.

Table 1 presents the summary data from the three types of hand posture assessment measures. Self-classification of hand posture in left-handers revealed that 17 (71%) used an inverted writing posture while 7 (29%) used a non-inverted writing posture. Twenty-three (96%) right-handers used a non-inverted posture while one (4%) used an inverted writing posture. A Chi-Square test revealed that hand

Figure 2. Mean seconds to completion on the Target Test for left- and right-handers using their left and right hands.

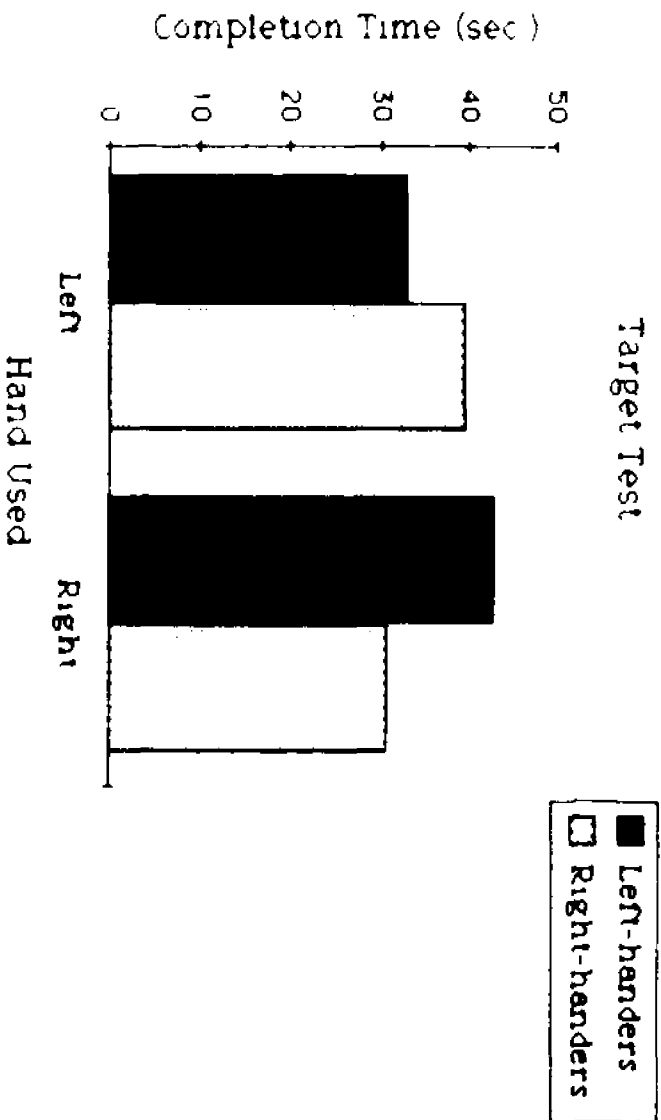


Table 1

Percent of subjects classified as having an inverted versus a non-inverted hand posture using a self and an experimenter classification questionnaire and picture designation of hand posture

	Self Classification	Experimenter Classification	Picture Left	Picture Right
<u>Inverter</u>				
<u>LH</u>	17 (71%)	22 (92%)	17 (71%)	11 (46%)
<u>RH</u>	1 (4%)	1 (4%)	13 (54%)	9 (38%)
<u>Non-inverter</u>				
<u>LH</u>	7 (29%)	2 (8%)	7 (29%)	13 (54%)
<u>RH</u>	23 (96%)	23 (96%)	11 (46%)	15 (62%)
$\chi^2=$	22.75	36.81	1.42	0.25
	p < .001	p < .001	n.s	n.s.

preference and writing hand posture were highly related ($\chi^2=22.75$, $df=1$, $p < .001$).

Experimenter evaluation of hand posture yielded similar results. Twenty-two (92%) left-handers used an inverted posture, while 23 (96%) right-handers used a non-inverted writing posture ($\chi^2=36.81$, $df=1$, $p < .001$). The differences between the subjects' self-classification and the experimenter's classification were not significant (left handers: $\chi^2=1.34$, $df=1$, n.s.; right handers: $\chi^2=0.0$, $df=1$, n.s.).

The picture designation data showed no significant differences between the left hand classification of inverted posture in left-($n=17$, 71%) and right-($n=13$; 54%) handers ($\chi^2=1.42$, $df=1$, n.s.), nor the right hand classification of inverted posture in left-($n=11$; 46%) and right-($n=9$, 38%) handers ($\chi^2=0.25$, $df=1$, n.s.).

The incidence of inverted hand posture in left-handers, using either picture designation (71%), self-report (71%), or experimenter (92%) evaluation, was not significantly different (picture-self: $\chi^2=0.0$; picture-experimenter: $\chi^2=3.42$; self-experimenter: $\chi^2=1.34$). There was no difference between self (4%) and experimenter (4%) evaluation of

inverted posture in right-handers. There were significant differences however, in the picture designation of inverted hand posture (38%) and either self (4%)- or experimenter (4%) classification of inverted posture in right-handers (picture-self: $\chi^2 = 8.08$, $df = 1$, $p < .01$; picture-experimenter: $\chi^2 = 8.08$, $df = 1$, $p < .01$). Contrary to left-handers, right-handers were more likely than the experimenter to classify their writing posture as inverted when using the picture designations of hand posture.

Summary of Sample Characteristics

The sample characteristics reveal several interesting similarities and differences between the self-classified left- and right-handers. There were no significant differences between handedness groups with respect to age or first degree familial sinistrality. The latter finding contrasts with Searleman, Tweedy, and Springer (1979) who found that their left-handers had a higher incidence of familial sinistrality.

As expected, the self-classified left- and right-handers responded differently on the Lateral Preference Inventory. Right-handers obtained positive ratio scores while left-handers had negative ratio scores. In

addition, the data from the Target Test revealed that self-classified left-handers were faster with their left hand while self-classified right-handers were faster with their right hand.

Handwriting posture in left- and right-handers was also significantly different in that left-handers primarily used an inverted writing posture, while right-handers primarily used a non-inverted writing posture. These results are consistent with those of Searleman et al., (1979). The picture designation data for right handers was less consistent, with a higher percentage of right-handers indicating an inverted posture. This may not be surprising in that the picture designations of hand posture have been criticized for measuring factors other than hand posture (e.g., paper orientation, wrist position) (Levy, 1984).

The foregoing results converge in their indication that the self-classified left-handers not only wrote with their left hand, but also demonstrated a left side preference and performance advantage, and that the self-classified right-handers demonstrated a right side preference and performance advantage on each variable.

General Experimental Procedure

The horizontal and vertical line stimuli, the horizontal and vertical arrow stimuli, and the two dimensional centering stimuli were combined and randomized into a single order. All 48 subjects completed the bisection and centering task booklet once with each hand, and the bisection discrimination task. The order of task presentation and hand used to perform the tasks were counterbalanced within subject groups.

Subjects were tested individually in a quiet room with only the experimenter present. The experimenter sat opposite the subject and presented all materials at the subjects' body midline. Subjects were given as much time as needed for all the tasks, and no feedback regarding accuracy was given.

Chapter 3

HORIZONTAL AND VERTICAL BISECTION

In order to examine the question of right hemisphere organization in left- and right-handers, a line bisection task was administered.

A line bisection task is often used to test for hemispatial neglect or inattention (Lezak, 1983; Schenkenberg et al., 1980). On this task, the subject is instructed to place a line through the center of a series of horizontal lines. Individuals with hemispatial neglect secondary to right hemisphere lesions tend to place their estimates of center to the right of true center (Ferro, Kertesz, & Black, 1987; Bisiach, Bulgarelli, Sterzi, & Vallar, 1983; Heilman & Valenstein, 1979; Schenkenberg et al., 1980). The effect is often marked, and as a result, line bisections are often used as a clinical test of neglect in brain-damaged individuals.

Relatively few studies have specifically examined the performance of normal subjects on a line bisection task. Bruyer (1984) suggests that this may be due to an assumption that normals perform flawlessly, or exhibit no systematic deviations to the left or right of center. The

studies which have examined normal subjects' performance indicate that systematic directional errors do exist, and that normal right-handers tend to bisect horizontal extents slightly to the left of true center (Bowers & Hellman, 1980; Bradshaw, Nettleton, Nathan, & Wilson, 1985; Bradshaw, Bradshaw, Nathan, Nettleton, & Wilson, 1986; Bradshaw et al., 1987; Ferro, et al., 1987; Schenkenberg, et. al., 1980). However, none of these studies have examined the contribution of hand preference or of differences in performance between the preferred and the non-preferred hand.

Scarisbrick et al., (1987) specifically examined the relationship between hand preference and hand of performance in left- and right-handers on a visual line bisection task. On horizontal lines they found that subjects' estimates of center tended to be left of veridical center, but were significantly left of center only when performed with the left hand, regardless of hand preference. In addition, left-handers using their left hand were significantly left of right-handers using their left hand. When bisecting vertical lines subjects' tended to place their estimates above objective center, regardless of the hand used or the

hand preferred. Bradshaw, Nettleton, Wilson, & Bradshaw (1987) found that right-handed children, ages 4-11, performed like adults, whereas left-handed children (especially those younger than 5 years) erred to the left of center with the left hand and to the right of center with the right hand. Bradshaw referred to this phenomenon as "symmetrical neglect" and noted that it decreased with increasing age.

The present study examined hand preference and hand of performance in left- and right-handers on a horizontal and vertical line bisection task. This experiment was an attempt to replicate Scarisbrick et al., (1987). It differs from the earlier study in that there is only one line per page and that line is always at the center of the page. In addition, more extensive measures of lateral preferences were obtained.

Methods

Stimuli

The stimuli consisted of black lines 2 mm. wide drawn on white pages (216 X 279 mm.) (See Figure 3). There was one line per page. The horizontal lines varied in lengths of 50, 100, and 200 mm., and the vertical lines varied in lengths of 51, 102, and 202 mm.¹ There were four

Figure 3. Examples of horizontal and vertical line bisection stimuli.

[REDACTED]

[REDACTED]

[REDACTED]

observations per line length for both horizontal and vertical lines, for a total of 24 line bisection trials. The stimuli were presented in a single randomized sequence for all subjects.

Procedure

The stimuli were presented at midline and directly in front of the subject. The subjects were instructed to : (i) place a small mark as close to the center of each figure as possible; (ii) not make more than one mark per line; and (iii) not to rotate the stimuli. Each subject completed the 24 transections twice, once with each hand. Order of hand used was counterbalanced within both left- and right-hand preference subjects.

The distance from the left side of horizontal lines and the bottom of vertical lines to the subjects' mark was measured to the nearest 0.5 mm. Percent deviation scores for each hand of performance and each type of stimulus were calculated using the formula from Schenkenberg et al., (1980) :

$$\text{Percent Deviation} = \frac{\text{measured distance (mm.)} - \text{objective center (mm.)}}{\text{objective center (mm.)}}$$

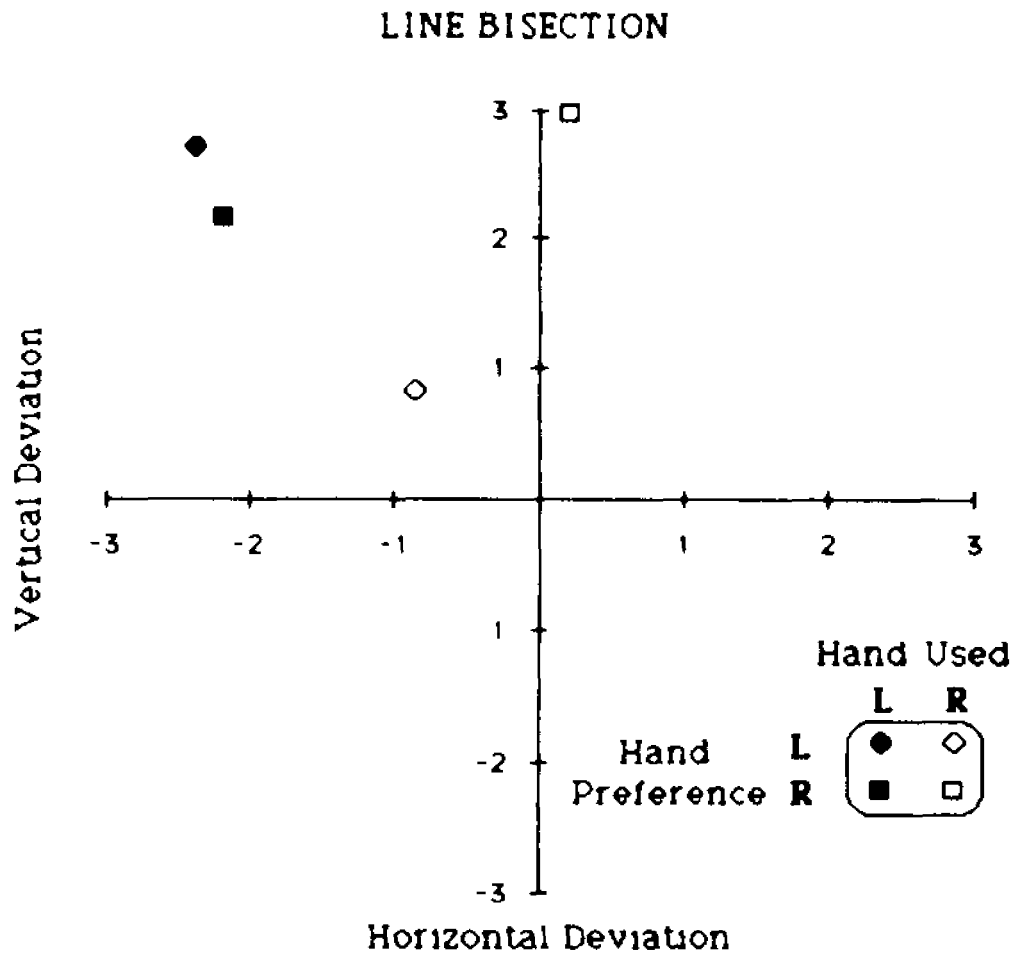
This expression yields negative values for deviations left or below center and positive values for deviations right or above center for horizontal and vertical bisections, respectively.

Results

Mean percent deviations were calculated for left- and right-handers using their left and right hands for both horizontal and vertical bisections. Figure 4 presents the mean percent deviations for left and right hand performances of left- and right-preference subjects. Each point represents the intersection of two obtained values : the mean percent deviation for horizontal bisections on the x axis, and the mean percent deviation for vertical bisections on the y axis. The origin represents veridical performances on both horizontal and vertical bisections. Overall, subjects' estimates were left of objective center on horizontal lines and above objective center on vertical lines.

Horizontal bisection - The left hand performances of left- ($M = -2.36$; $t[23] = -5.30$, $p < .001$) and right- ($M = -2.16$; $t[23] = -3.74$, $p < .002$) handers were significantly left of veridical center. The right hand performances of left- ($M = -0.84$; $t[23] = -1.57$,) and right- ($M = 0.24$;

Figure 4. Mean percent deviation for horizontal and vertical line bisections for left- and right-handed subjects using their left and right hands



$t(23) = -0.34$) handers were not significantly different from veridical center. When using their left hand, 83% of the left- and 83% of the right-handers produced mean percent deviations left of center. The corresponding values for right hand bisections were 67% and 37.5%, respectively (see Figures 5 and 6).

A 2 X 2 ANOVA, with hand preference as the between subjects variable and hand of performance as the within subjects variable, resulted in a significant main effect of hand of performance ($F(1,46) = 20.30, p < .001$). Left hand performances ($M = -2.26$) were significantly left of right hand ($M = -0.30$) performances. The main effect of hand preference ($F(1,46) = 0.85$) and the interaction of hand preference by hand of performance ($F(1,46) = 3.08$) were non-significant.

The effect of line length on horizontal line bisection performance was examined by a 2 X 2 X 3 ANOVA with hand preference as the between subjects variable and hand of performance and length of line as the within subjects variables. The main effect of line length was significant ($F(2,92) = 10.51, p < .01$)². The mean percent deviation for the short (50 mm.) lines was -1.62, for the medium (100 mm.) lines was

Figure 5. Cumulative percent of left-handers at each percent deviation for horizontal line bisections with their left and right hands.

CUMMULATIVE PERCENT OF LEFT-HANDERS
(Horizontal Line Bisection Data)

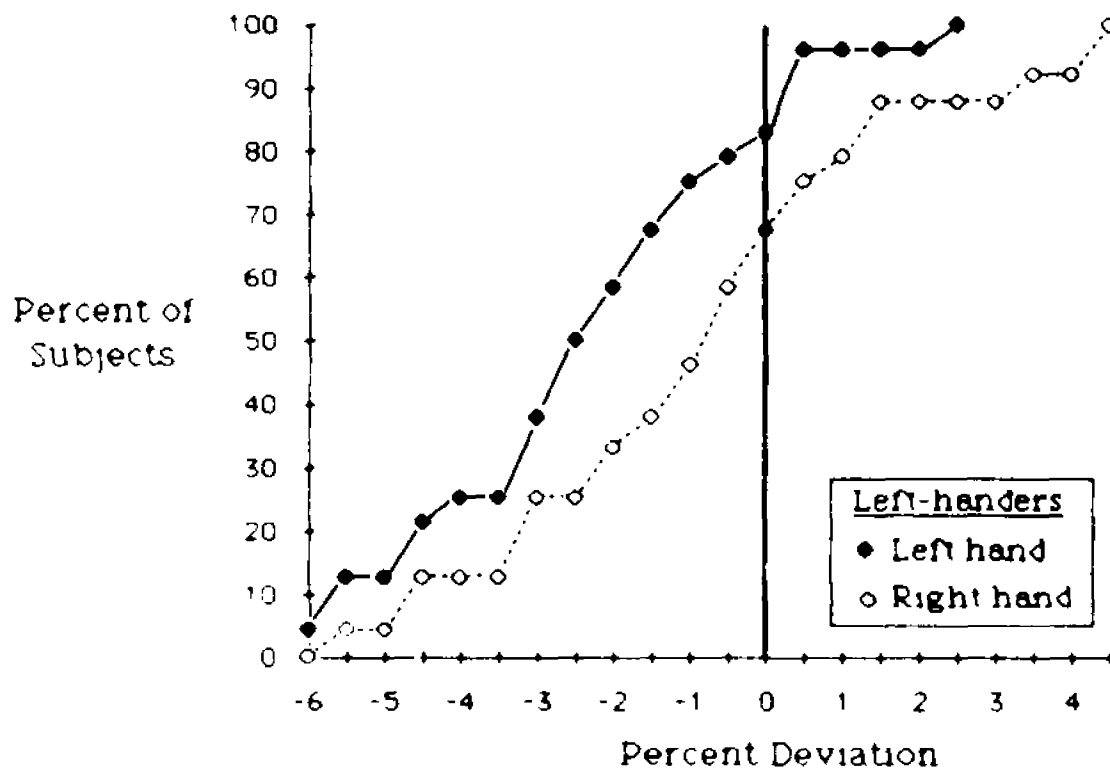
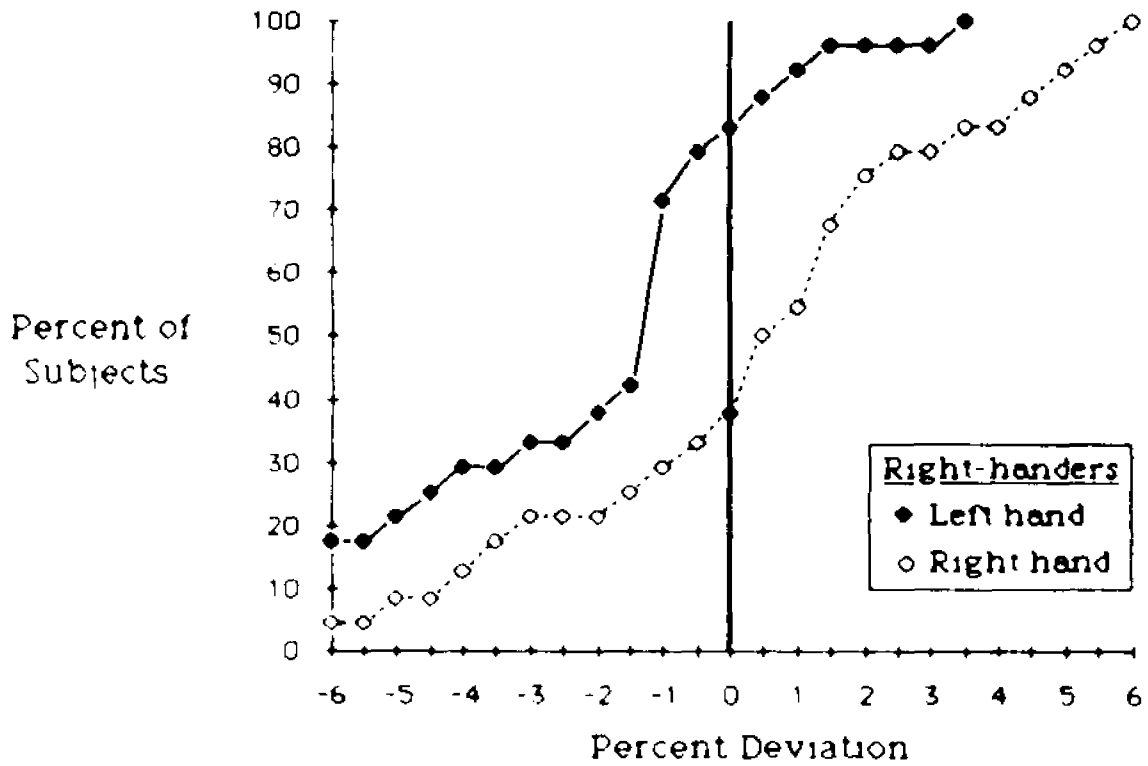


Figure 6. Cumulative percent of right-handers at each percent deviation for horizontal line bisections with their left and right hands.

CUMMULATIVE PERCENT OF RIGHT-HANDERS
(Horizontal Line Bisection Data)

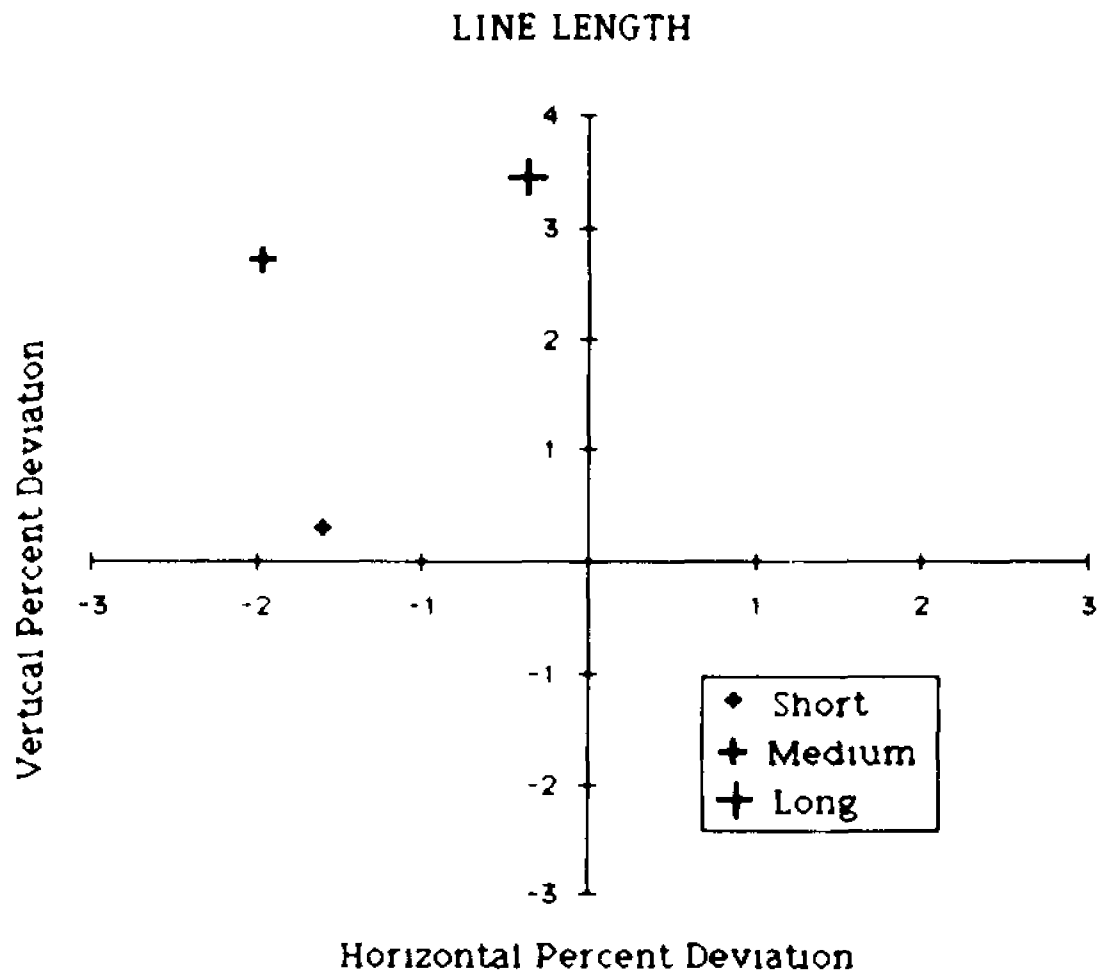


-1.94, and for the long (200 mm.) lines was -0.30. As expected, a significant main effect of hand of performance was obtained ($F[1,46]=20.15, p < .01$) with left hand performances being significantly left of right hand performances. Figure 7 presents the mean percent deviations for horizontal and vertical bisections of short, medium, and long lines. Post hoc pairwise contrasts revealed that the mean percent deviation of the short lines was not significantly different from that of the medium lines ($F[1,92]= 0.376$); however, the mean percent deviation of the long lines was significantly less than either the short ($F[1,92]= 6.01, p < .05$) or medium ($F[1,92]= 9.39, p < .01$) lines.

Vertical bisection - Left-handers performing with their left hand bisected significantly above center ($M= 2.70; t[23]= 2.97, p < .01$), whereas their right hand performance was not significantly above vertical center ($M= 0.80; t[23]= 1.17, n.s.$). Both the left ($M= 2.15; t[23]= 3.06, p < .01$) and right ($M= 2.98; t[23]= 5.18, p < .001$) hand performances of right-handers were significantly above center.

Seventy-five % of left- and 79% of right-handers obtained mean percent deviations above center when using the left hand. When using the

Figure 7. Mean percent deviation for short, medium and long horizontal and vertical line lengths.



right hand, 58% of left- and 79% of right-handers obtained mean percent deviations above center (See Figures 8 and 9).

A 2 X 2 ANOVA with hand preference as the between subjects variable and hand used as the within subjects variable revealed a significant interaction between hand preference and hand of performance ($F[1,46]=13.54, p < .001$). This interaction is due to the absence of a significant directional error of left-handers with their right hand, while all other performance deviations were significantly above center. The main effects of hand preference ($F[1,46]= 0.79, n.s.$) and hand of performance ($F[1,46]= 1.63, n.s.$) were non-significant.

The effect of line length upon vertical line bisection performance was examined by a 2 X 2 X 3 ANOVA with hand preference as the between subjects variable and hand of performance and length of line as the within subjects variables. The expected interaction of hand preference by hand of performance was significant ($F[1,46]= 10.87, p < .01$). The main effect of line length was also significant ($F[2,92]= 30.68, p < .01$)². Post hoc pairwise contrasts showed that the mean percent deviation of the short lines ($M=0.32$) was significantly different from the medium ($M=$

Figure 8. Cumulative percent of left-handers at each percent deviation for vertical line bisections with their left and right hands.

CUMMULATIVE PERCENT OF LEFT-HANDERS
(Vertical Line Bisection Data)

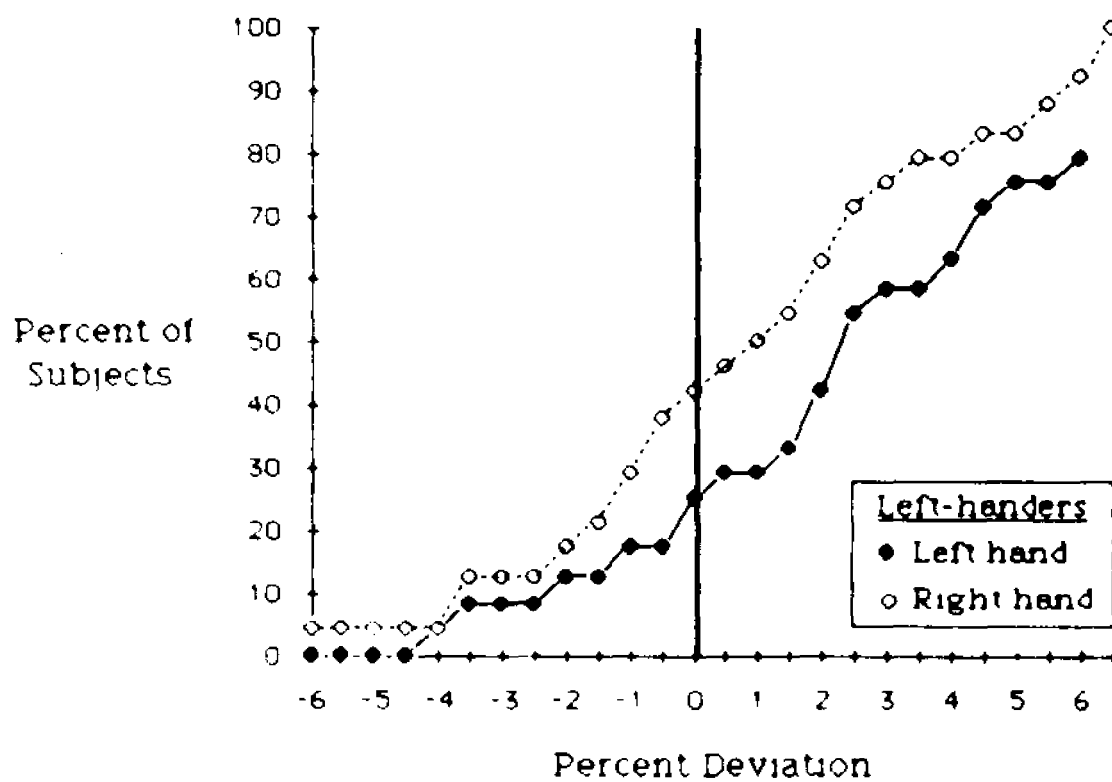
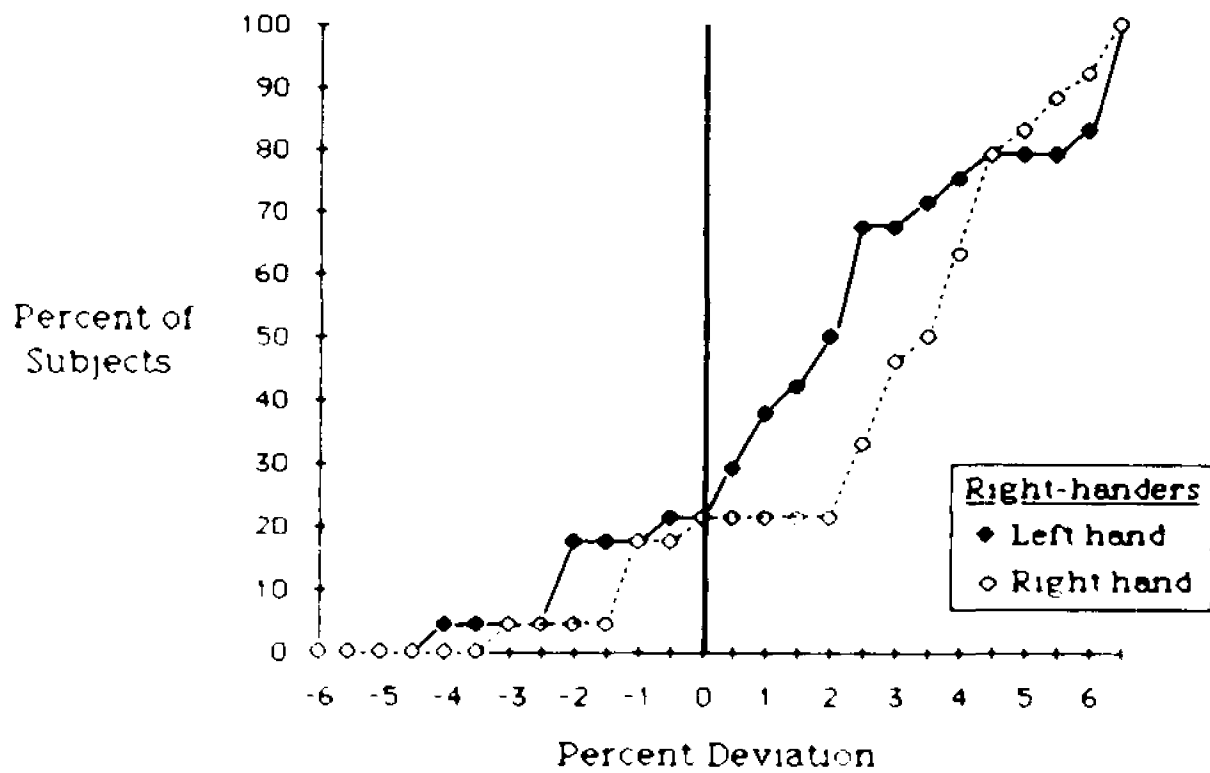


Figure 9. Cumulative percent of right-handers at each percent deviation for vertical line bisections with their left and right hands.

CUMMULATIVE PERCENT OF RIGHT-HANDERS
(Vertical Line Bisection Data)



2.71; $F[1,92]=16.29$, $p < .01$) and the long ($M= 3.46$; $F[1,92]= 28.10$, $p < .01$) lines. The mean percent deviations of the medium and long lines were not significantly different ($F[1,92]=1.60$, n.s.) from each other (see Figure 7). The interaction of hand preference by line length was also significant ($F[2,92]= 5.18$, $p < .01$). Post hoc comparisons revealed that left-handers' bisection of short vertical lines ($M= -0.69$) was significantly nearer to veridical center than their long lines ($M= 3.78$, $F[1,92]= 5.69$, $p < .05$), and right-handers' bisections of both medium ($M= 3.24$; $F[1,92]= 4.40$, $p < .05$) and long ($M= 3.13$; $F[1,92]= 4.15$, $p < .05$) lines. All other comparisons were non-significant.

Discussion

When bisecting horizontal lines, both left- and right-handers' left hand performances were significantly left of center. The right hand performances of left- and right-handers were not significantly different from veridical center. These results are in agreement with those of several earlier studies (e.g., Bowers & Heilman, 1980; Bradshaw et al., 1985; Scarisbrick et al., 1987).

The vertical line bisection findings revealed a generally upward

directional error. This upward deviation was significantly above center in right-handers, regardless of hand used, and in left-handers' left hand performances. The right (i.e., non-preferred) hand performance of left-handers was not significantly above center. These are essentially the same findings reported by Scarisbrick et al., (1987).

The effects of line length upon horizontal line bisection performance revealed that the greatest mean percent deviations occurred on the 50 and 100 mm. lines. On vertical line bisections, the mean percent deviations of 100 and 200 mm lines were significantly larger. Since both horizontal and vertical lines were measured in the same way, these results are not likely to be due to measurement error.

Upon examination of the results several explanations can be ruled out. One might argue that left hand deviations to the left of center on horizontal line bisections result from the subjects' failure to attend to a part of the line occluded by the left hand. This hypothesis fails to account for the right hand performances on horizontal lines, which were not significantly off center. In addition, performance on vertical line bisections produced deviations when the hand would not have occluded

part of the line.

The hypothesis that individuals are generally less accurate with their non-preferred hand might account for the results of the right-handers, but it fails to explain the consistent deviation to the left of center of left-handers using their left hands. It could be argued that the left-handers' performances are reconcilable with this hypothesis if the left-handers are actually right-handers masquerading as manifest left-handers (Satz, 1972; Satz, Orsini, Saslow, & Henry, 1985). This last hypothesis is inconsistent with the Target Test performance in which the left-handers were faster with their left hand and right-handers with their right hand.

The hand preference-hand performance interaction in the horizontal line bisection task requires an explanation which incorporates both hemispheric specialization and motor activation mechanisms. There is considerable evidence that the right hemisphere has an advantage in the appreciation of space (Bogen & Gazzaniga, 1965; DeRenzi, 1982; Nebes, 1971) and in attention (Heilman & Valenstein, 1979; Heilman & Van Den Abell, 1979; Mesulam, 1981). Tasks which involve the appreciation of

space may activate the right hemisphere more than the left, resulting in left visual field enhancement (Bowers & Heilman, 1980; Kinsbourne and Cook, 1971; Tartaglione, Cocito, Bino, Pizio, & Favale, 1983). An hypothesis that may account for the general leftwards deviation in this study would postulate that perceived center is slightly left of objective center. The larger leftward deviations of bisections performed with the left hand may be the result of increased right hemisphere activation through motor activation accompanying the use of the left hand (Joanette, Brouchon, Gauthier, & Samson, 1986; Kinsbourne, 1970; Kinsbourne & McMurray, 1975).

The differential effects of line length upon horizontal line bisections may be the result of subjects' ability to foveate the shorter lines (50 & 100 mm.), while the longer 200 mm. lines requires successive foveations. In support of this hypothesis, Gainotti, D'Erme, Monteleone, and Silveri (1986) examined unilateral spatial neglect in left- and right-hemisphere lesioned patients, using a searching for animals test on a large area (approximately 60 degrees of the visual field), and a much smaller area (approximately 20 degrees of the visual field) overlapping

figures test. They found that unilaterally lesioned subjects in general searched less often in the contralateral space on the large area search test. The main differences between groups arose in the small area search task where only right hemisphere lesioned patients neglected figures on the contralateral side of space. In addition, Bradshaw et al., (1985,1987) found that the leftwards error on rod bisection was stronger when subjects maintained fixation upon a central point, compared with a free scanning condition.

Errors on the vertical line bisections are extremely robust and reliable, and replicate Scarisbrick et al., (1987). There is little neuropsychological literature on any vertical attentional gradient in the visual fields. In a recent presentation (Rapcsak, Cimino, & Hellman, 1986), a patient with Balint's syndrome demonstrated altitudinal neglect on visual and tactile bisections of vertical rods (20 to 30 cm. in length). This patient consistently placed her mark above veridical center. The authors attributed this effect to bilateral damage to the parietal lobes. Although this result is intriguing, further research will be required to elucidate this effect.

Chapter 4

BISECTION DISCRIMINATION

The results of the preceding task demonstrated that left- and right-handers tend to transect horizontal lines left of veridical center. The effect is strongest when subjects used their left hand. It was hypothesized that these results may be due to a perceptual bias towards the left half of the line due to the right-hemisphere's specialization for the appreciation of space. To investigate the relative strength of the perceptual component versus the motor component on line bisection performance, a line bisection discrimination task was employed.

The hypothesis of a perceptual bias predicts similar errors on a recognition task as on the bisection task, in which subjects are required to judge whether or not an horizontal line is transected in the center or varying distances off center. Specifically, the perceptual bias hypothesis predicts the following: (i) subjects are more likely to judge a transection slightly left of center as being "on center" compared to a transection of equal distance right of center, and (ii) that if the

horizontal line is veridically bisected and subjects do not respond "center", they should be more likely to respond "right" than "left" of center.

Rosenberger (1974) examined the discriminative aspects of visual hemi-inattention in left and right hemisphere lesioned patients and in ten control subjects. The task tested an individual's ability to discriminate horizontal lines which were transected either to the left or right of veridical center from those transected at veridical center. The performance of normal subjects was virtually error free except at the smallest transection deviation of 0.46 (8% deviation). There was no evidence of a perceptual bias in the performance of normals. Errors were symmetric about center.

The Rosenberger (1974) study was concerned primarily with the patients' performance on this task. The failure to find any perceptual asymmetries in the controls may be the result of the procedure not being sufficiently sensitive. The smallest deviation used was eight percent, which is much greater than the percent deviation errors obtained on the horizontal bisection task reported in chapter 3.

The present experiment specifically evaluated the performance of normal left- and right-handers on a bisection discrimination task. In view of the Rosenberger (1974) results and the bisection performance results of the previous chapter, percent deviations of much less than 8% were specifically included.

Method

Stimuli

The stimuli consisted of black lines drawn on white pages (216 X 280 mm). There was one line per page and the lines were 2 mm. in width. The horizontal lines varied in lengths of 50, 100, and 200 mm and are referred to as short, medium, and long, respectively. A vertical transection line, 1 mm. wide and 10 mm. long, was placed through each horizontal line (See Figure 10). The transection line was placed either on center, or varying distances to the left or right of center. The fifty mm. lines had transections which differed by 0, 1, 2, 4, 6, 8, 16, and 24 mm. from center; On the one-hundred mm. lines, transections varied by 0, 1, 2, 4, 8, 12, 16, and 24 mm. from center; and the two-hundred mm. lines, had transections which varied by 0, 1, 2, 4, 8, 16, 24, and 32 mm. from

Figure 10. Example of line bisection discrimination stimuli.



center. These absolute deviations were chosen so that there were five proportional deviation comparisons (4,8,12,16 and 32%) across all three line lengths, five proportional deviation comparisons (2,4,8,16 and 24%) across 100 and 200 mm. lines, and five proportional comparisons (1,2,4,8 and 16%) across the 200 mm. lines, thus allowing analyses of progressively smaller deviations. Each line length appeared four times in each of the eight absolute deviations: two left and two right of center, and four on center. Thus, there were 32 observations for each of the three line lengths for a total of 96 trials. The stimuli were presented in a single randomized sequence for all subjects.

Procedure

Each stimulus was presented at the subject's midline, directly in front of the subject. The subjects were instructed to indicate, on each trial, whether the vertical transection line was on center, to the left of center, or to the right of center. Subjects were given no feedback and were allowed to proceed at their own pace.

Results

The statistical analyses examined the two possible types of errors

and their directions: (i) "center" responses when the transection was off center (referred to as "false alarms") and (ii) left or right responses when the transection line was on center (referred to as "misses.")

The "miss" data were subjected to a three-way ANOVA with hand preference (left vs right) as the between subjects variable, and line length (50, 100, or 200 mm.), and error direction (left vs right) the within subjects variables. A significant interaction of line length by error direction was obtained, which is shown in Figure 11 ($F[2,92]=12.50$; $p < .01$)². None of the other main effects or interactions were significant. The length by error direction interaction is due to subjects making more left misses with short lines and more right misses with long lines. Pairwise comparisons confirmed that there were significantly more left misses with short lines ($F[1,92]=13.80$, $p < .01$) and more right misses with long lines ($F[1,92]=11.21$, $p < .01$). There was no effect of error direction on medium lines. ($F[1,92]= 0.115$, n.s.).

Figures 12 and 13 present the left and right false alarm data at each percent deviation for left- and right-handed subjects. These data were entered into a four-way ANOVA, with hand preference as the between

Figure 11 Mean percent error ("miss") of short, medium and long lines on bisection discrimination task

LINE LENGTH BY ERROR DIRECTION
(“miss” Data)

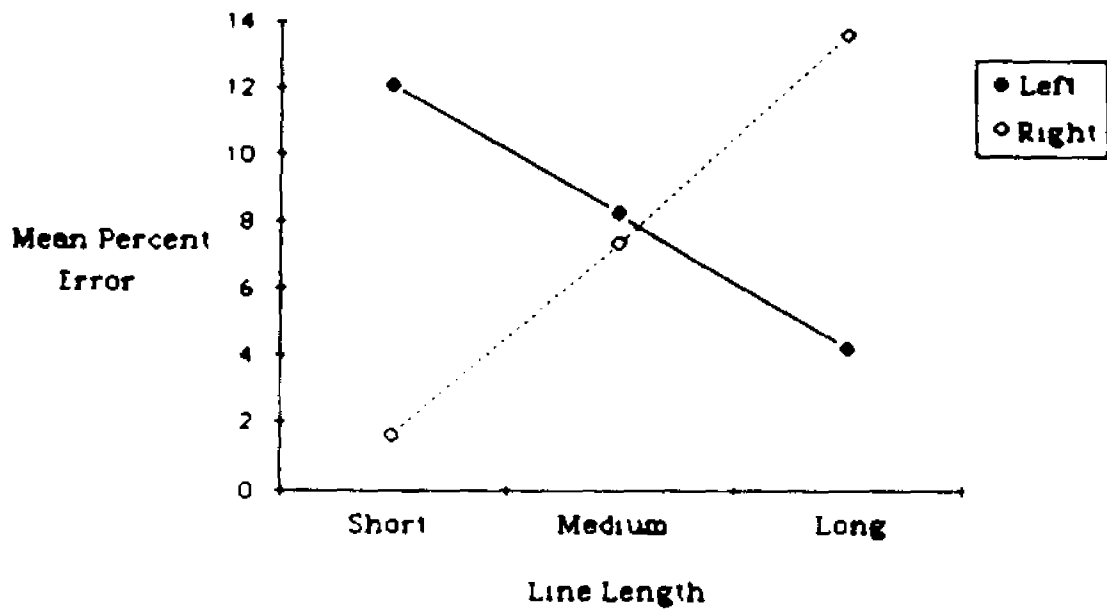


Figure 12. Mean percent of left and right "false alarms" at each percent deviation for left-handers.

BISECTION DISCRIMINATION TASK (false alarm Data)

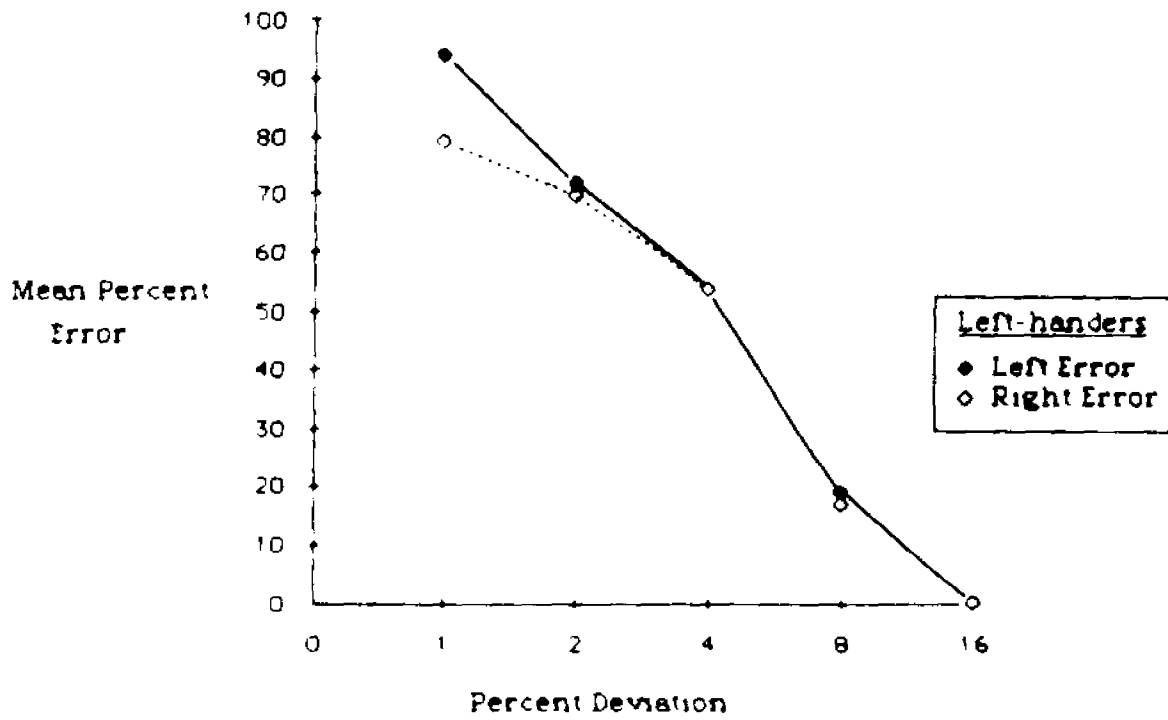
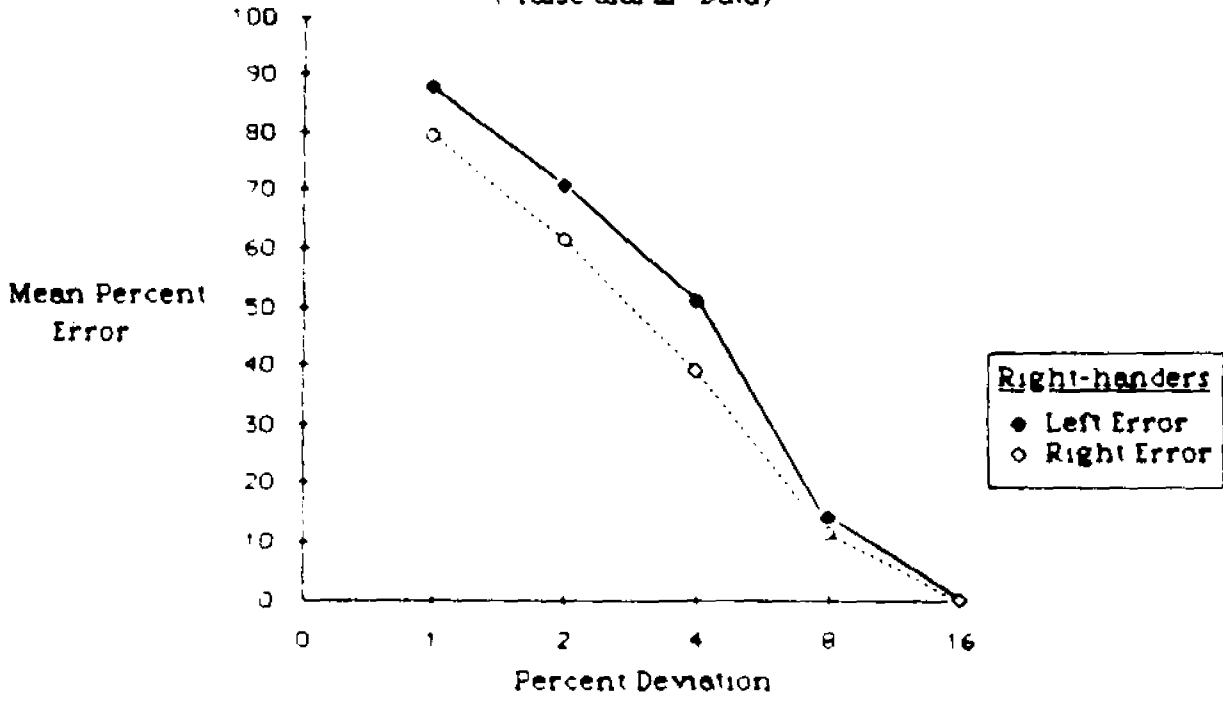


Figure 13. Mean percent of left and right "false alarms" at each percent deviation for right-handers.

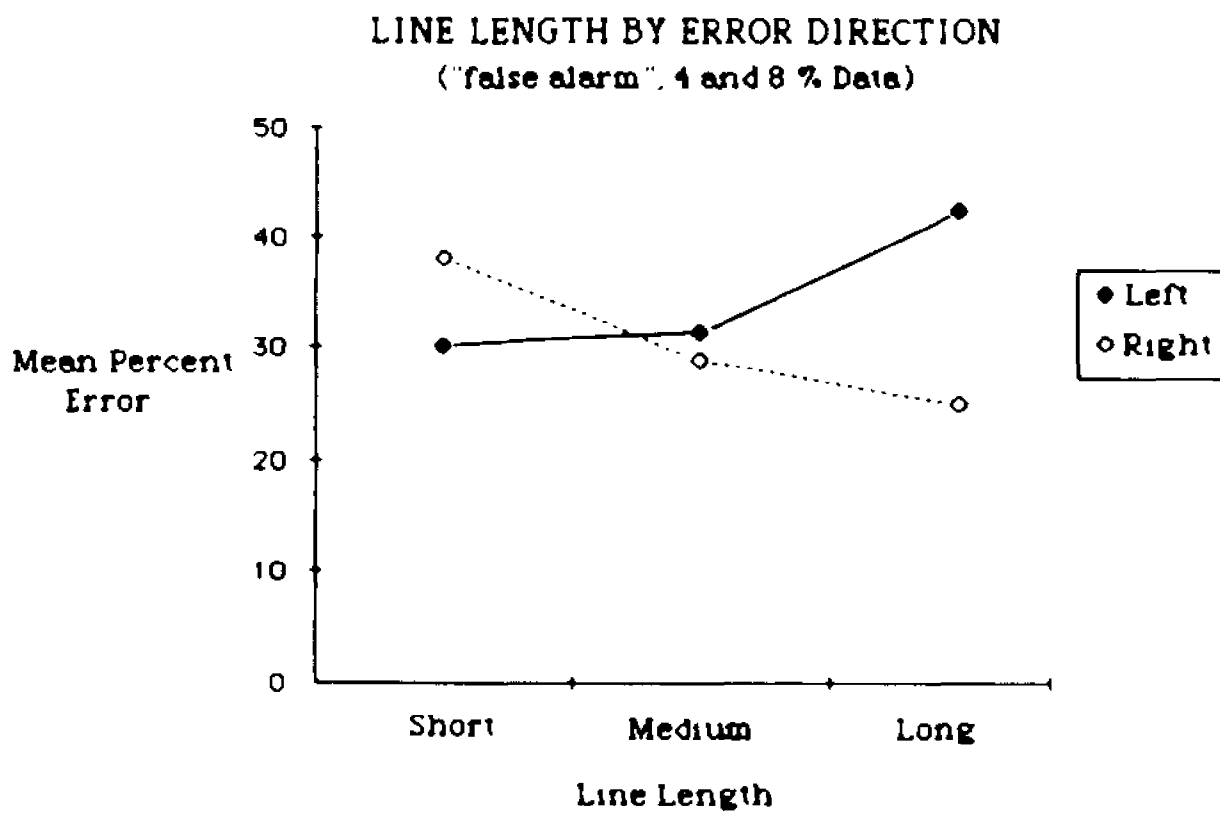
BISECTION DISCRIMINATION TASK ('false alarm' Data)



subjects variable, and line length (50, 100, or 200 mm.), error direction (left vs right) and percent deviation (4 vs 8%) as the repeated measures variables. The reason for restricting the analysis to the four and eight percent deviations was that no subject made a discrimination error on stimuli with an asymmetry greater than 8%. The interaction of line length by error direction was significant ($F[2,92]=11.36, p < .01$)². Examination of Figure 14 reveals that the significant interaction is due to subjects making more right false alarms on short lines and more left false alarms on long lines. Pairwise comparisons confirmed these observations, with subjects making significantly more right false alarms on short lines ($F[1,92]=4.79, p < .05$) and significantly more left false alarms on long lines ($F[1,92]=20.70, p < .01$). Again, there was no significant difference between left and right false alarms on medium length lines.

Not surprisingly, the main effect of percent deviation was significant ($F[1,46]=187.17, p < .001$). Subjects made significantly more errors on 4% ($M=49.3\%$) than on 8% ($M=15.45\%$) deviation trials. None of the other main effects or interactions were significant.

Figure 14. Mean percent of left and right "false alarms" for short, medium and long lines (Percent deviations of 4 and 8).



In order to examine the false alarms at smaller percent deviations, a four-way ANOVA with hand preference (left vs right) as the between groups variable, and line length (100 vs 200 mm.), error direction (left vs right), and percent deviation (2, 4, or 8%) as the repeated measures variables was performed. Again, the main effect of percent deviation was significant ($F[2,92]=164.19, p < .01$)². Subjects made significantly more errors at 2% ($M=68.6\%$) than 4% ($M=46.5\%$; $F[1,92]=14.7, p < .01$) and 8% ($M=16.5\%$; $F[1,92]=81.69, p < .01$) deviation trials. In addition, subjects made significantly more errors at 4 than 8% ($F[1,92]=27.08, p < .01$).

The interaction of line length by error direction was significant ($F[1,46]=17.02, p < .01$). Figure 15 demonstrates that subjects had no error bias, left vs right ($M=42.7\%$ vs 45.5%) on the 100 mm. lines ($F[1,46]=.18, n.s.$), but made significantly more left than right ($M=78.8\%$ vs 33.7%) false alarms on the 200 mm. lines ($F[1,46]=46.75, p < .01$).

The only other significant interaction involved line length, error direction, and percent deviation ($F[1,92]=4.99, p < .05$). Figure 16 shows that on the long (200 mm.) lines, subjects made significantly more left

Figure 15. Mean percent of left and right "false alarms" for medium and long lines (Percent deviations of 2, 4, and 8).

LINE LENGTH BY ERROR DIRECTION (“false alarm”, 2, 4, and 8 % Data)

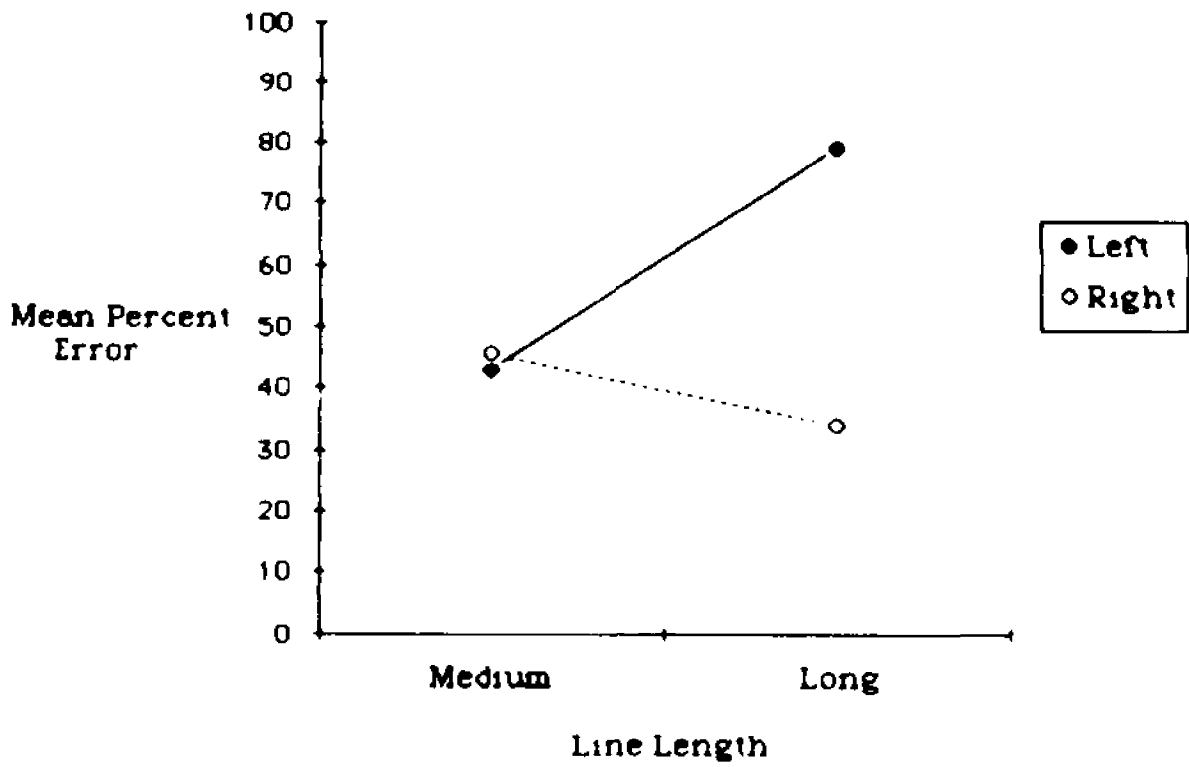
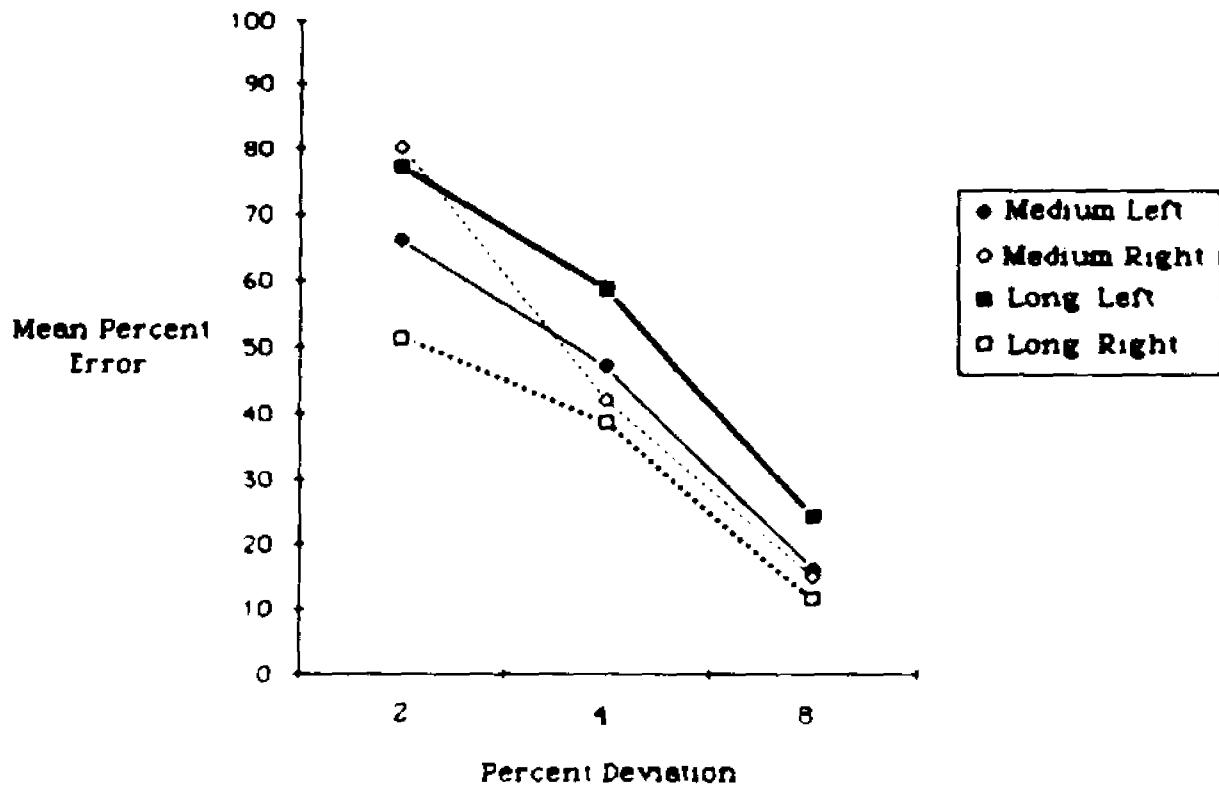


Figure 16. Mean percent of left and right "false alarms" for medium and long lines at deviations of 2, 4, and 8 percent.

LINE LENGTH BY ERROR DIRECTION BY PERCENT DEVIATION
("false alarm", 2, 4, and 8 % Data)



than right false alarms, regardless of percent deviation (2%: $F[1,92]=26.17, p < .01$; 4%: $F[1,92]=15.55, p < .01$; 8%: $F[1,92]=6.07, p < .05$). On medium lines (100 mm.), subjects made significantly more right than left false alarms on 2% deviation trials ($F[1,92]=8.23, p < .01$), whereas there were no significant left-right differences on 4% ($F[1,92]=1.07, n.s.$) and 8% deviation trials ($F[1,92]=0.67, n.s.$). All other main effects and interactions were non-significant.

The last analysis examined directional errors at deviations of 1,2,4, and 8% on the 200 mm. lines. Only 200 mm. line error data were used because this was the only line length which allowed percent deviations as small as one percent. A three-way ANOVA, with hand preference as the between subjects variable, and error direction (left vs right) and percent deviation (1,2,4, and 8%) as the within subjects variables was performed.

The main effect of error direction was significant ($F[1,46]=13.45, p < .01$). Subjects made more left than right ($M=62.5\%$ vs 44.75%) false alarms on the 200 mm. lines.

Not surprisingly, the main effect of percent deviation was also

significant ($F[3,138]= 99.97, p < .01$)². Subjects made significantly more errors on 1% ($x=85.0\%$) than on 2% ($M=64.0\%$; $F[1,138]= 13.53, p < .01$), 4% ($M=49.0\%$; $F[1,138]= 40.86, p < .01$) or 8% ($M=17.0\%$; $F[1,138]= 140.99, p < .01$) deviation trials. In addition, subjects made significantly more errors on 2% trials than on 4% ($F[1,138]= 7.37, p < .01$) and 8% ($F[1,138]= 67.17, p < .01$) trials, and significantly more errors at 4% than 8% deviation trials ($F[1,138]= 30.05, p < .01$).

Discussion

The bisection discrimination task examined subjects' ability to discriminate horizontal lines bisected on center from those transected with varying degrees of asymmetry. Subjects did not perform flawlessly, and demonstrated significant directional error tendencies.

The first finding was that as the actual deviation of the transection decreased, subjects' mean percent errors increased significantly. (See Figures 12 and 13). Thus, subjects are not perfect discriminators of line bisection (cf. Roseberger, 1974) when the relative asymmetry is small.

The second finding was that the direction of the error is a function of the line length. Subjects' are significantly more likely to make a left

miss on short lines and a right miss on long lines.

Subjects were also significantly more likely to make a right false alarm on short and medium lines, and a left false alarm on long lines.

The initial hypotheses generated from the horizontal line bisection performance results were that if a perceptual bias for the left side of the line exists, more left false alarms and more right misses would be expected. These were both confirmed, but only on trials involving the long stimuli.

In addition, since the production asymmetry effect was greatest on the short (50 mm.) and medium (100 mm.) horizontal lines, a similar prediction on the bisection discrimination task could be made. The results of the current study do not support this hypothesis. On short and medium length lines, at deviations of less than 4%, subjects' were significantly more likely to judge a transection slightly right of center as being on center, and a veridical bisection as being slightly left of center.

The results from the line bisection discrimination task on short and medium lines indicate that if a perceptual bias exists, it is slightly right

of veridical center. On the long (200 mm.) lines, the discrimination data are in accord with the hypotheses generated from the line bisection performance task. Subjects made more left false alarms and more right misses.

The results from this task and the prior line bisection task necessitate a re-evaluation of the hypotheses generated. It is possible that a perceptual bias (slightly right of center) exists, but that when subjects use their left hand it activates the right hemisphere with a resultant leftward shift. However, this explanation does not fully account for the right-hand production data which also tended to be slightly left of center. An experiment requiring subjects to perform a line bisection discrimination task while concurrently using either their left or right hands would resolve this issue (e.g., Kinsbourne, 1970).

Chapter 5

ARROW BISECTION

In the preceding task it was found that subjects exhibited a bias on a visual line bisection discrimination task. However, the observed bias was opposite to the predicted bias based upon line bisection performance data, at least for the shorter stimuli. It was hypothesized that when the motor component of the line bisection task was removed, it might diminish or reverse the bias (Ledoux, Wilson, & Gazzaniga, 1977). The present task examined if the perceptual bias could be experimentally exaggerated by changes in the stimuli used for bisection.

Bradshaw and colleagues (Bradshaw et al., 1986; Bradshaw et al., 1987) have specifically studied the differential effects of stimulus quality on the "left-side underestimation" effect on tactile rod and visual gap bisection. The central hypothesis guiding these studies was that if a hemispatial perceptual bias exists, such that the left extent is perceptually longer than the right, this effect can be manipulated through changes in stimulus salience on either the right or left side of

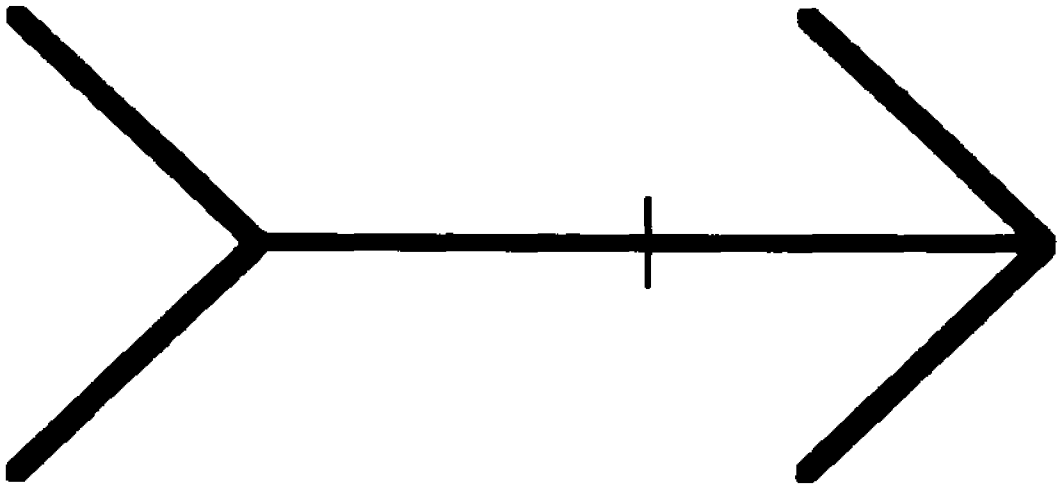
the bisected stimulus. In the gap bisection task (Bradshaw et al., 1986), subjects attempted to bisect the gap between two light emitting diodes (LED's). Hemispatial stimulus salience was manipulated by changes in brightness, stimulus duration, onset/offset asynchronies, and illumination constancy. They found that low salience, low intensity, and low contrast influenced the subjective midpoint. In addition, the effect was greater when the left as opposed to the right hand was used to signal a response.

On a rod bisection task (Bradshaw et al., 1987), hemispatial stimulus salience was manipulated by altering the contrast between the rod to be bisected and the corresponding background. An uniform black background with a white rod (or vice versa) were the high salience conditions. The low salience left and right hemispace conditions were achieved by using a background board which was half black and half white. The low salience hemispace conditions were defined as the trials in which the side of the board and the rod color were identical. For example, a low salience-left hemispace condition occurred when the left half of the background and the rod were both black, or both white. A high

saliency-right hemispace condition occurred when the right half of the background was white and a black bisection rod was used. The contrasting backgrounds and rod colors occurred on both sides of the hemispace equally often. Bradshaw et al. (1987) found the expected "left-side underestimation" in all the conditions. The effect was greatest when the low saliency condition occurred in the left hemispace. They postulated that these effects occur because subjects devoted greater attention in the low saliency conditions, and that there is a greater tendency to devote attention to the left hemispace because of the visuospatial nature of the task and/or because of the relatively greater visuospatial processing capacity of the right hemisphere.

In view of these studies, the present arrow bisection task was designed to address the issue of perceptual bias on visual line bisection. The stimuli used were modified versions of the Muller-Lyer Figure (see Figure 17, Holding, 1970; Morgan, 1969). This "arrow" figure was used to modulate the apparent location of objective center. On these stimuli, regardless of the arrow's direction, center is perceived as off-center in the direction of the head of the arrow. A small vertical transection line

Figure 17 Modified version of the Muller-Lyer Figure ("arrow") with a small vertical transection line on center.



has been placed in the center of Figure 17 to illustrate the effect.

Subjects' estimation of line center can be manipulated by the direction of the arrow. Arrows facing rightward should "pull" the subjects' center estimation left of center, resulting in negative deviation scores. Likewise, leftward facing arrows should "pull" the subjects' estimate right of center resulting in positive deviation scores.

One possible outcome is that although the estimates will depend upon the direction of the arrow, there will be no difference between the effect of leftward and rightward arrows. Such a result would argue for no difference in the perceptual salience of the left versus the right hemispace on this task. However, if there is a difference in perceptual salience or attention allocation to one hemispace, the absolute deviation of leftward and rightward arrows should differ, with rightward facing arrows eliciting a larger deviation. In addition, since bisection asymmetries are greater for the left than the right hand (Bradshaw et al., 1986; Scarisbrick et al., 1987), an interaction of the hand used and the arrow direction is predicted.

Methods

Stimuli

The stimuli consisted of black lines drawn on white pages (216 X 279 mm). There was one line per page and the lines were 2 mm. in width. The horizontal arrow stimuli were 50, 100, and 202 mm.¹, and the vertical were 51, 101, and 202 mm. in length. The fins of the arrows were approximately 20, 40, 60 mm. in length for the short, medium and long lines, respectively, and joined the shaft at an angle of 45 degrees. For each subject there were four observations per line length for both horizontal and vertical arrows, for a total of 24 trials. Half of the horizontal trials used leftward facing arrows, and the other half rightward facing arrows. Half of the vertical trials used downward facing arrows, and the other half upward facing arrows. The stimuli were presented in a single randomized sequence for all subjects.

Procedure

The stimuli were presented at midline and directly in front of the subject. The subjects were instructed to : (i) place a small mark as close as possible to the center of each figure; (ii) not make more than

one mark per stimulus, and (iii) not to rotate the stimulus materials. Each subject completed the 24 bisections twice, once with each hand. Order of hand of production was counterbalanced within both left- and right-preference subjects.

The distance from the left side of horizontal arrows and the bottom of vertical arrows to the subjects' mark was measured and analyzed according to the methods used in the horizontal and vertical line bisection task, using the Schenkenberg et al., (1980) formula.

Results

Mean percent deviations were calculated for left- and right-handers using their left and right hands for both leftward and rightward facing horizontal arrows, and upward and downward facing vertical arrows. The data from horizontal and vertical arrows were analyzed separately.

Horizontal arrow bisections: Figures 18 and 19 present the mean percent deviations for left and right hand performances of left- and right-hand preference subjects, respectively. The direction of the arrow affected the subjects' estimations in opposite directions. Rightward facing arrows pulled the subjects' estimate left of veridical center and

Figure 18. Mean percent deviations for leftward and rightward facing arrows for left-handers using their left and right hands.

LEFT-HANDERS

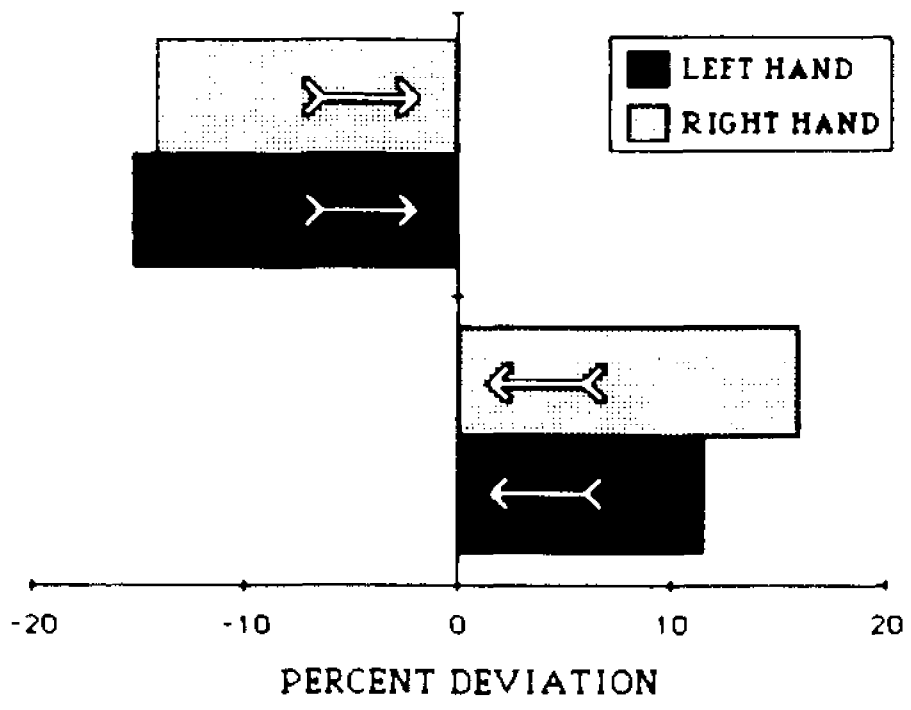
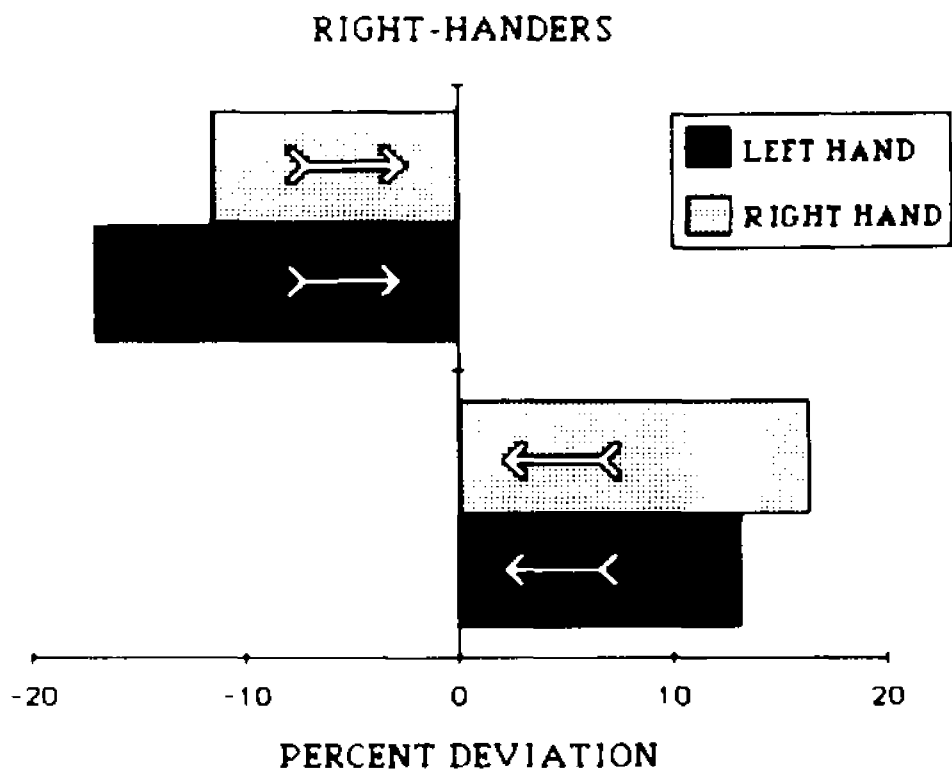


Figure 19. Mean percent deviations for leftward and rightward facing arrows for right-handers using their left and right hands.



leftward facing arrows pulled right of veridical center. However, regardless of the direction of the arrow's "pull", and the subject's hand preference, the deviation scores for the left hand performances were always left of the right hand. A four-way ANOVA, with hand preference as the between subjects factor and hand used (left vs right), arrow direction (left vs right) and arrow size (small, medium, or large) as the within subjects factors, resulted in significant main effects for hand used ($F[1,46]= 56.36, p < .001$) and arrow direction ($F[1,46]= 240.48, p < .001$). The deviation of left hand responses was left of center ($M= -1.82$), whereas that of the right hand was right of center ($M= 1.73$). The main effect of arrow direction is due to leftward facing arrows producing a positive deviation ($M= 14.35$), while rightward facing arrows produced a negative deviation ($M= -14.44$) of almost equal absolute magnitude.

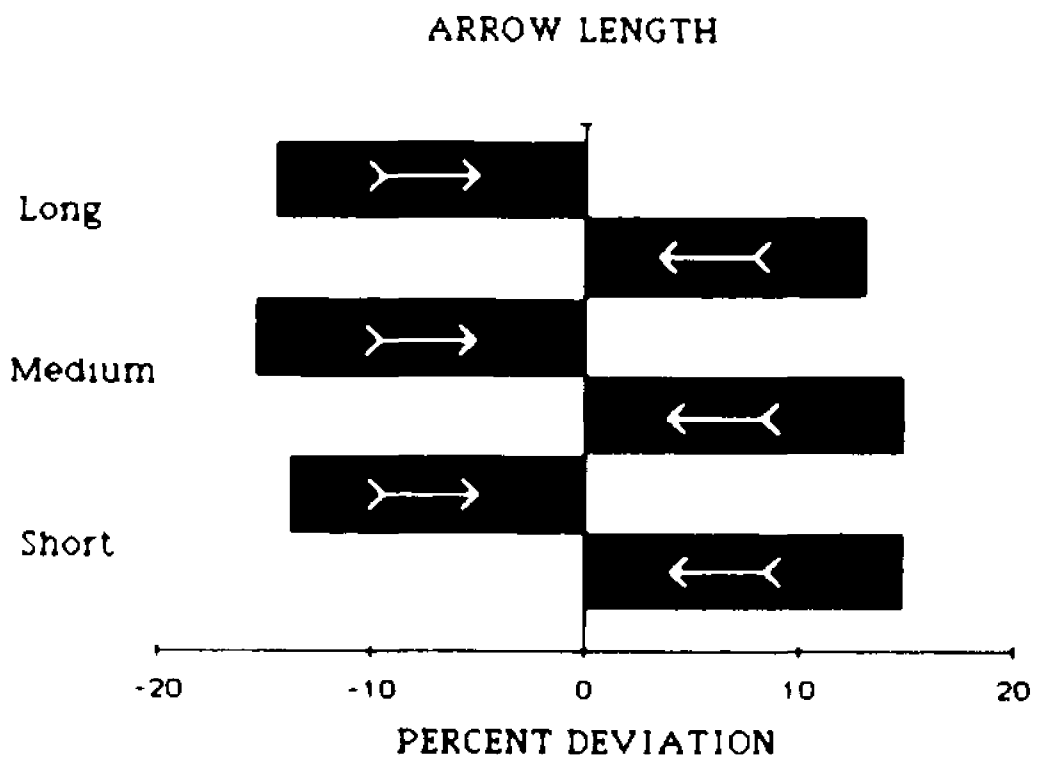
The interactions of hand preference, hand used, and arrow direction ($F[1,46]= 12.02, p < .01$), and of arrow direction and length ($F[2,92]= 4.31, p < .05$)³ were significant. None of the other main effects or interactions were significant. The interaction of hand preference, hand

used and arrow direction is somewhat complex. Figures 18 and 19 indicate that regardless of arrow direction and hand preference, left hand estimates were left of right hand estimates. However, post hoc comparisons revealed that the difference between left and right hand performances in left-handers on the rightward facing arrow was non-significant ($F[1,92]= 0.58$, n.s.). The three remaining comparisons of left and right hand performances were all significantly different (Left-handers-Left arrow- $F[1,92]= 9.51$, $p < .01$; Right-handers-Right arrow- $F[1,92]= 15.13$, $p < .01$; Right-handers-Left arrow- $F[1,92]= 4.87$, $p < .05$).

The significant interaction of arrow direction by line length resulted from the mean percent deviations of long stimuli ($M= 13.10$) being significantly less than either the medium ($M= 14.98$, $F[1,92]= 7.51$, $p < .01$) or short ($M= 14.97$, $F[1,92]= 7.43$, $p < .01$) leftward facing arrows, while only the short stimuli ($M= -13.72$) were significantly less than the medium ($M= -15.28$, $F[1,92]= 5.17$, $p < .05$) on rightward facing arrows (see Figure 20).

Vertical arrow bisections: Figures 21 and 22 present the mean

Figure 20 Mean percent deviations for leftward and rightward facing arrows of short, medium, and long length.



percent deviations for the vertical arrows for left- and right-handers. A four-way ANOVA resulted in the finding of significant main effects for arrow direction ($F[1,46]=235.02, p < .001$), and arrow length ($F[2,92]=21.12, p < .001$)². The mean percent deviation of downward facing arrows was significantly greater ($M=15.76$) than the upward facing ($M=-10.79$) arrows.

The main effect of line length indicates that long arrows produced a significantly greater mean percent deviation ($M=4.16$) than short arrows ($M=0.68, F[1,92]=10.52, p < .01$). There was no significant difference between medium ($M=2.6$) and long arrows ($F[1,92]=2.11, n.s.$).

Discussion

The present task attempted to elucidate if the perceptual bias could be experimentally exaggerated on a visual bisection task. Arrow stimuli were chosen because they promote an illusory percept of objective center as being off-center. From the results obtained, it is quite evident that the arrow stimuli resulted in the desired effect. Leftward facing arrows "pulled" subjects' estimates right of center, while rightward facing arrows "pulled" in the opposite direction (Figures 18 and 19).

Figure 21. Mean percent deviations for downward and upward facing arrows for left-handers using their left and right hands.

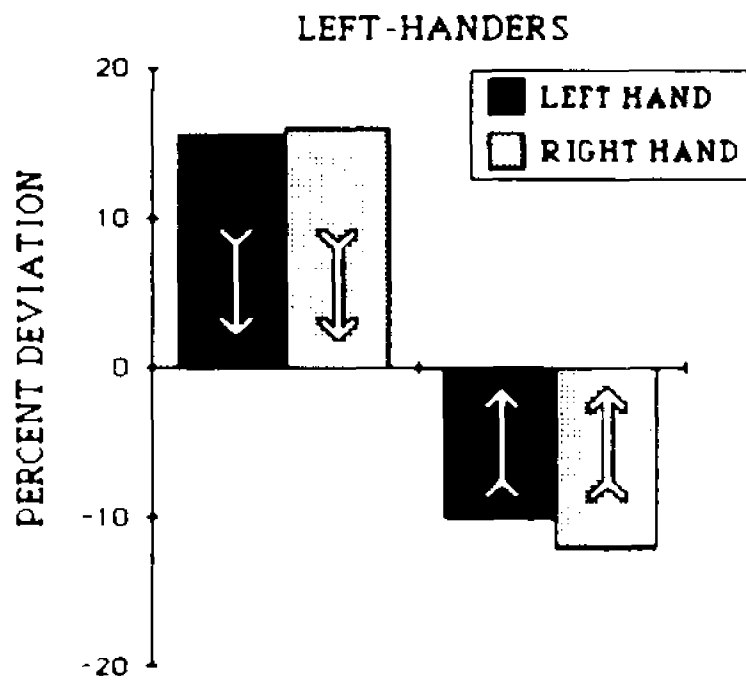
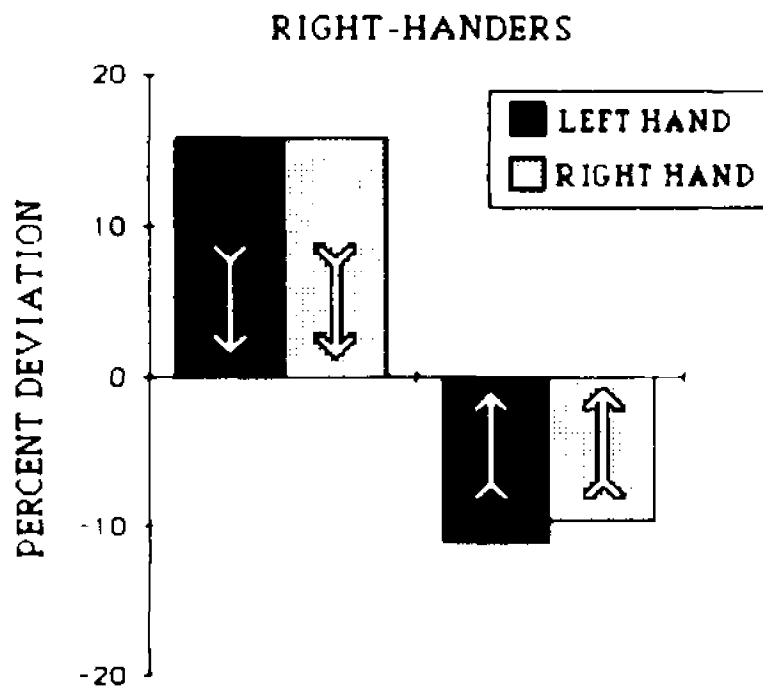


Figure 22. Mean percent deviations for downward and upward facing arrows for right-handers using their left and right hands.



Analogous effects were obtained with the vertical arrows (Figures 21 and 22).

In accordance with the prior line bisection results, left hand transections of horizontal arrows were left of right hand responses, regardless of arrow direction and hand preference. These results indicate that although the arrow stimuli were effective in changing subjects' estimates of center, the effect appears to be non-interactive with the proposed mechanisms for asymmetrical line bisection (cf. Bradshaw et al., 1986; Bradshaw et al., 1987). There was no difference in the magnitude of the "pull" in leftward and rightward facing horizontal arrows. The arrow stimuli effectively added or subtracted a constant error depending upon the arrow direction. Thus, the interaction of hand used and arrow direction was non-significant.

These findings do not rule out perceptual factors in asymmetrical line bisection performance, but rather indicate that the effects of the head and vanes of the arrow do not effectively interact with (i.e. asymmetrically manipulate) the factors which result in asymmetric bisection of the simple line stimuli used in the previous bisection tasks.

Chapter 6

TWO-DIMENSIONAL CENTERING

The results from several studies and from the present experiment (Chap. 3) have demonstrated that normal subjects transect horizontal lines left of center and vertical lines above center (Bradshaw et al., 1985, 1986; Scarisbrick et al., 1987). The question explored in the present task is the following: If subjects are required to locate the center of the two dimensions simultaneously, by marking the center of two-dimensional figures, are the observed deviations in the same directions as the horizontal and vertical line transections from uni-dimensional bisection tasks?

Several studies have specifically examined two-dimensional visual localization in unilateral brain injured patients (Faglioni, Scotti, & Spinnler, 1971; Hannay, Varney, & Benton, 1976; Ratcliff & Davies-Jones, 1972). The main focus of these studies was the effect of left versus right hemisphere damage on visual localization. The findings were that brain damage impairs performance relative to controls and

that right hemisphere damage disrupts performance significantly more than left hemisphere damage. These studies did not explicitly examine the performance of their controls for systematic directional errors and left-handers were specifically excluded.

Tartaglione and colleagues (Tartaglione et al., 1981; Tartaglione et al., 1981; Tartaglione et al., 1983) have specifically examined the performances of both right-handed normals and unilateral brain injured patients on a two-dimensional visual localization task which required the subject to reproduce the exact location of one or two crosses presented visually. The finding of import for the present study was that the control subjects produced systematic directional errors. In the horizontal domain, normal subjects showed a strong tendency to deviate leftwards when the target was on the left half of the page and to deviate slightly rightwards when the target was on the right half of the page. The direction of the vertical deviation scores was downward regardless of the position of the target. In the right-handed control subjects, hand of performance had no effect on the obtained deviations. Unfortunately, Tartaglione, et al., (1981a, 1981b, 1983) did not include a target directly

in the center of the page, so it is uncertain how subjects would perform under this condition with respect to any horizontal deviation. In view of the fact that the leftwards deviation was of overall greater magnitude than the corresponding rightwards deviation, a plausible horizontal deviation prediction for crosses in the center of the page might be a slight leftwards deviation. In the vertical direction, the results are much clearer in predicting a tendency towards a downward error in the centering task.

The present task examined left- and right-handers' performance on a two-dimensional centering task using both the left and right hand. If the subjects' performances are analagous to the combined performances of horizontal and vertical line bisections, the predicted error deviations would be to the left and above veridical center. If the two-dimensional nature of the task alters the observed deviations, the results of Tartaglione et al. (1981a, 1981b, 1983) would lead us to predict error deviations to the left and below veridical center.

Methods

Stimuli

The stimuli consisted of black figures drawn on a white background (216 X 279 mm.). There was one two-dimensional stimulus per page. The sizes of the stimuli were determined by each possible combination of the three line lengths (50, 100, 200 mm.). This resulted in three sizes of squares (i.e. 50, 100, 200 mm².), three sizes of circles (50, 100, 200 mm. in diameter) and six rectangles (i.e. 50 x 100, 50 x 200, 100 x 50, 100 x 200, 200 x 50, 200 x 100 mm.) (See Figures 23, 24, 25). There were two centerings for each of these 12 stimuli for a total of 24 trials. The stimuli were presented in a single randomized sequence, once for each hand.

Procedure

The stimuli were presented at midline and directly in front of the subject. The subjects were instructed to : (i) place a small mark as close to the center of each figure as possible; (ii) not make more than one mark per figure; and (iii) not to rotate the stimuli. Each subject completed the 24 centering responses twice, once with each hand. Order

Figure 23. Examples of square centering stimuli.

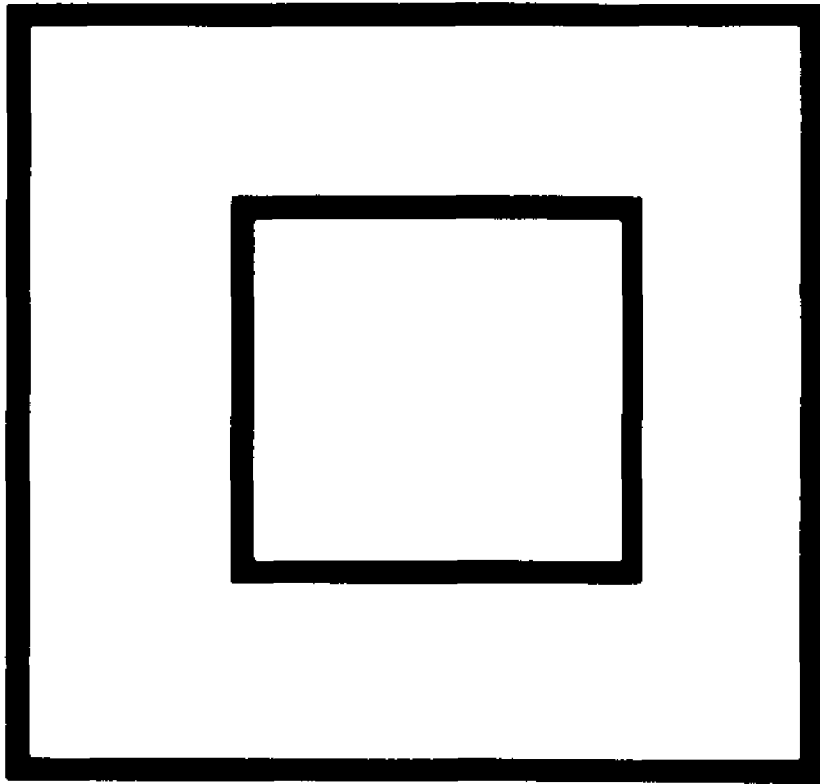


Figure 24. Examples of circle centering stimuli.

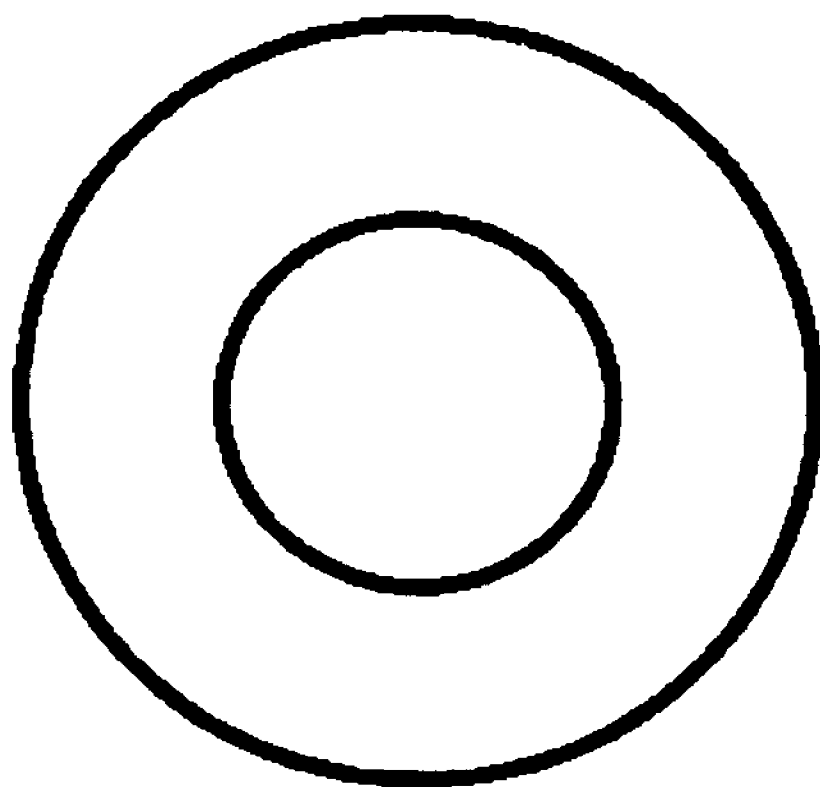
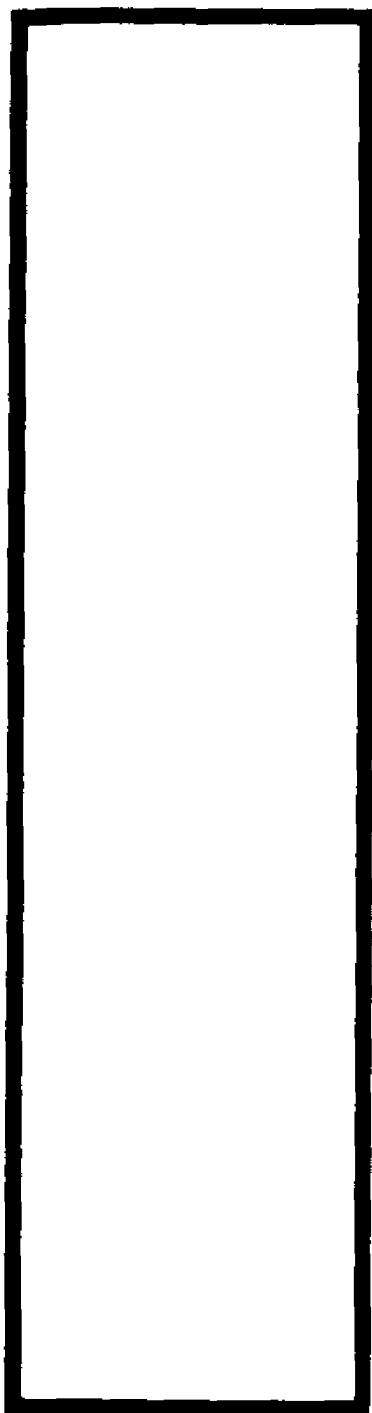


Figure 25. Examples of rectangle centering stimuli.



of hand was counterbalanced within both left- and right-preference subjects.

The distances from the left side of the figure to the subjects' mark and from the bottom of the figure to the subjects' mark were measured to the nearest 0.5 mm. These values represented the extent of horizontal deviation and vertical deviation, respectively. Percent deviation scores (hand preference x hand of performance x type of stimulus) were calculated using the formula of Schenkenberg et al. (1980).

Results

The results from the circles, squares, horizontal, and vertical rectangles were analyzed separately. Each stimulus type was analyzed using a four-way ANOVA with hand preference as the between subjects factor and hand used, size of stimulus (small, medium, or large), and coordinate direction (horizontal vs. vertical) as the within subjects factors. Table 2 presents the results of the ANOVAs. The significant factors are fairly similar across the stimulus types. The main effects of stimulus size (Size) and coordinate direction (Direction) were significant across stimulus types. The effect of coordinate direction

Table 2

Summary of ANOVA's for squares, circles, and horizontal and vertical rectangles.

Factor	Circles	Squares	Horizontal Rectangles	Vertical Rectangles
Hand Preference (P)				
Hand Used (U)				*
P X U				
Size	**	**		**
P X Size				
U X Size				
P X U X Size				
Direction (D)	**	**	**	**
P X D				
U X D	**	**		
P X U X D	**	*	**	**
Size X D		**	*	**
P X Size X D		*		
U X Size X D				
P X U X Size X D				

* $p < .05$

** $p < .01$

may be due to the Schenkenberg et al., (1980) formula which assigns negative values to leftwards horizontal deviations and positive values to upwards vertical deviations. The interactions of hand used x coordinate direction, hand preference x hand used x coordinate direction, and size x coordinate direction were also significant across most of the stimuli used.

Square Centering Data: The main effects of size of square ($F[2,92]=8.65, p < .01$)² and coordinate direction ($F[1,46]=57.45, p < .01$) were significant. The size effect is attributed to the mean percent deviation of the large square ($M=1.74$) being significantly greater than either the medium ($M=0.95; F[1,92]=4.19, p < .05$) or the small ($M=0.63; F[1,92]=8.15, p < .01$) squares. The mean percent deviation of small and medium squares were not significantly different from each other. The main effect of coordinate direction is due to the horizontal coordinate having a negative deviation ($M=-1.14$), while the vertical coordinate had a positive deviation ($M=3.35$).

The significant interaction of hand used by coordinate direction ($F[1,46]=7.37, p < .01$) is due to the left hand performances deviating

more negatively on the horizontal dimension and more positively in the vertical domain ($H = -1.67, V = 3.53$, difference = 5.2) than the analogous right hand performances ($H = -.61, V = 3.17$; difference = 3.78) (See Figure 26). The significant interaction of hand preference \times hand used \times coordinate direction ($F[1,92] = 5.69, p < .05$) is depicted in Figure 27. Examination of this figure reveals that left-handers using their right hands appeared to exhibit the most accurate centering performance, especially along the horizontal range. Pairwise comparisons indicated that, regardless of hand preference or hand used, none of the vertical deviations were significantly different from each other. However, examination of the mean horizontal deviations revealed that left-handers using their right hand ($M = 0.19$) were indeed significantly more accurate than with their left hand ($M = -1.32$; $F[1,92] = 4.66, p < .05$), and significantly more accurate than both the left ($M = -2.02$; $F[1,92] = 9.98, p < .01$) and right hand responses ($M = -1.41$; $F[1,92] = 5.23, p < .05$) of right-handers.

Figure 28 presents the interaction of square size \times coordinate direction ($F[2,92] = 14.91, p < .01$)². The mean center coordinate for each

Figure 26. Mean percent horizontal and vertical deviation for the left and right hand on the square stimuli

SQUARE CENTERING DATA

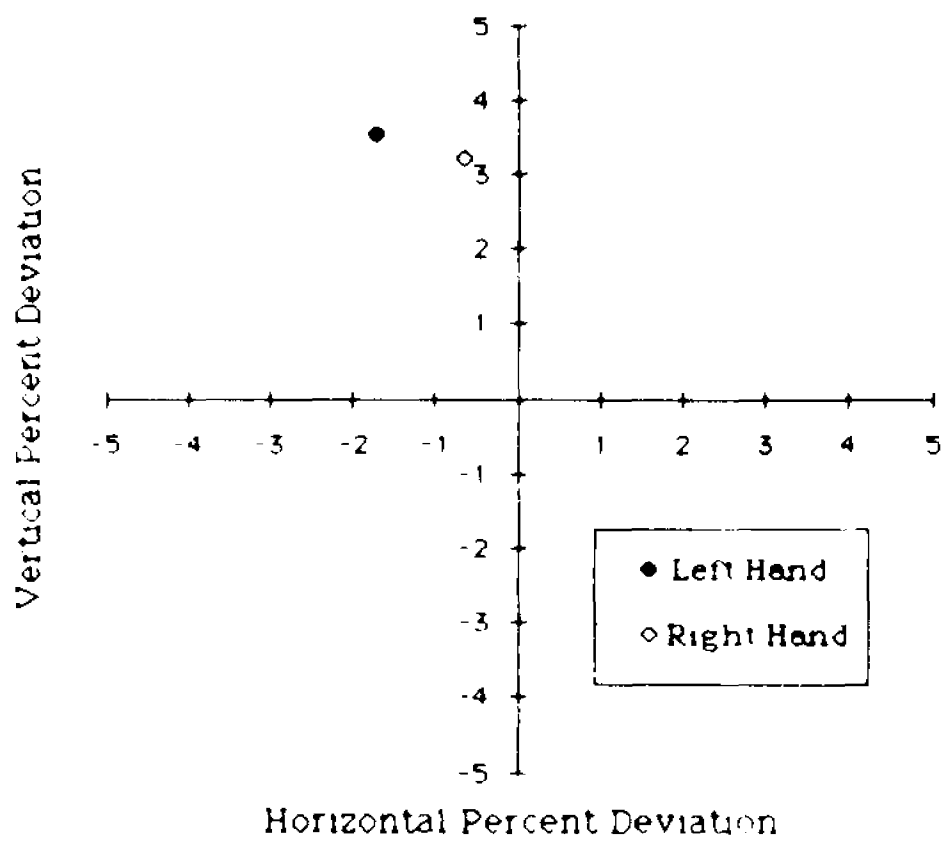


Figure 27. Mean percent horizontal and vertical deviation on the square centering task in left- and right-handers using their left and right hands.

SQUARE CENTERING DATA
(Hand Preference by Hand Used)

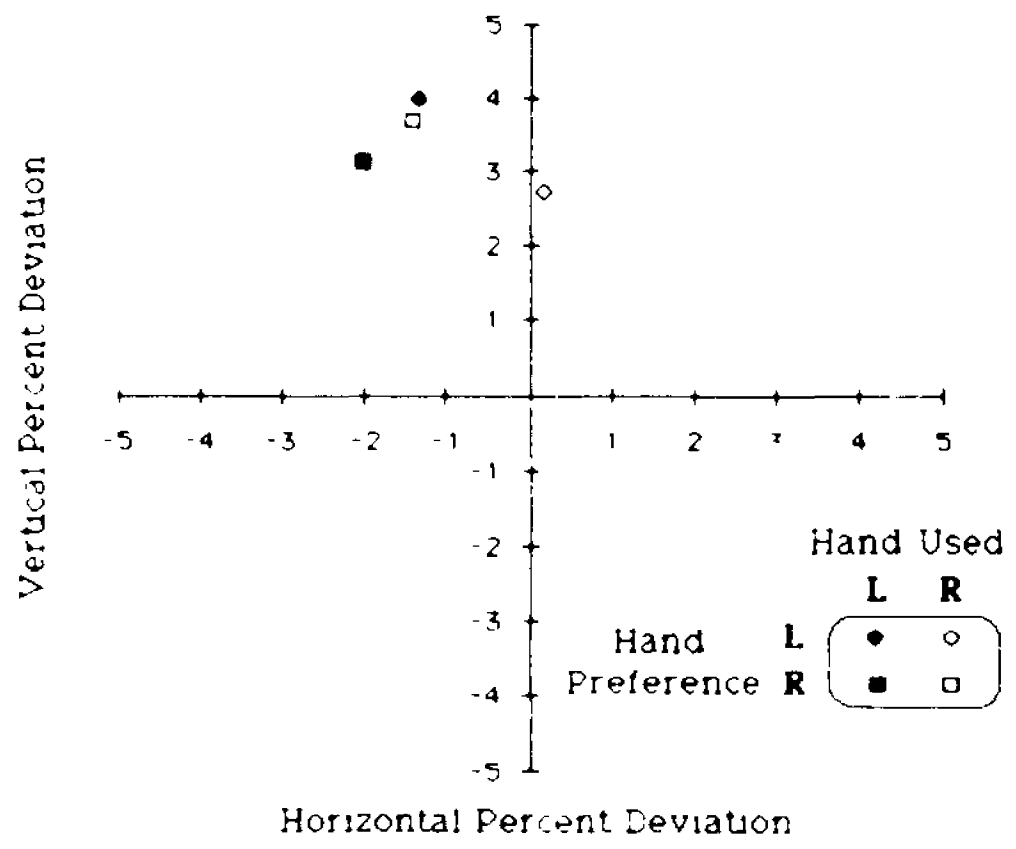
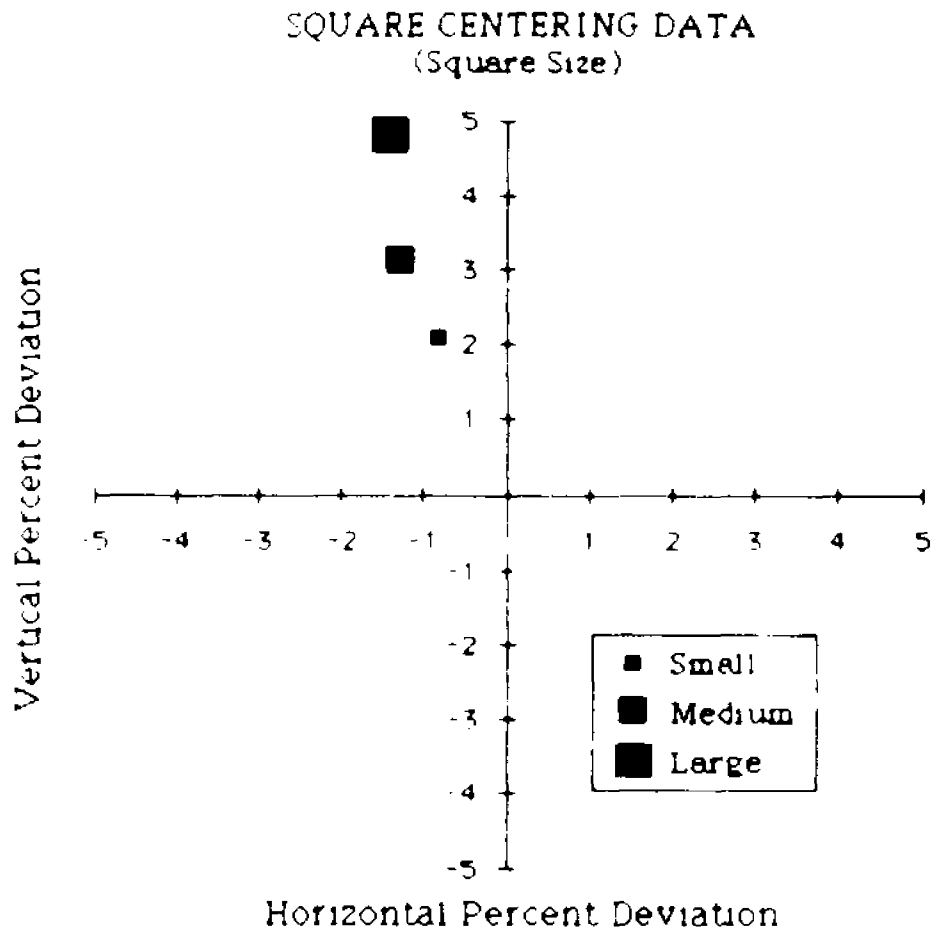


Figure 28. Mean percent horizontal and vertical deviation on small, medium and large squares.

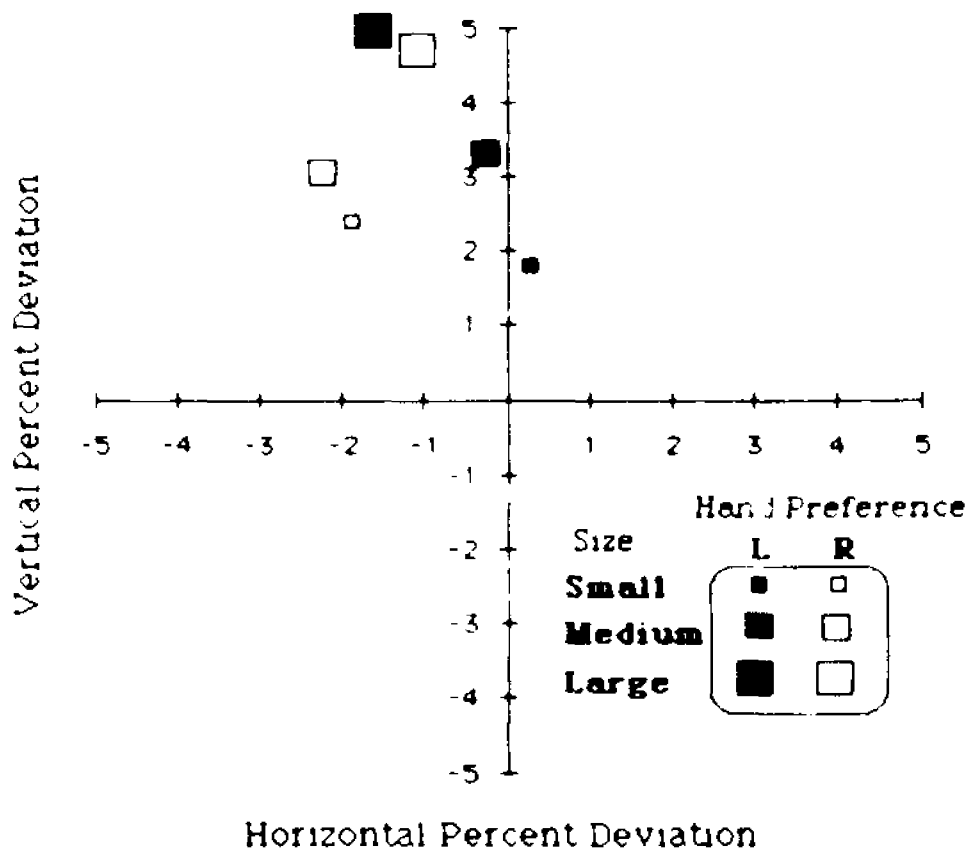


stimulus was left and above veridical center. Pairwise comparisons indicated that there were no significant differences between the different square sizes along the horizontal range, but that each was different from the other in the vertical domain (small vs medium $F[1,92]=6.21, p < .05$; small vs large $F[1,92]= 41.62, p < .01$; medium vs large $F[1,92]=15.67, p < .01$)

The significant interaction of hand preference x square size x coordinate direction ($F[2,92]=4.36, p < .05$) is presented in figure 29. Examination of the vertical coordinate of each of the points reveals an effect of size. The mean vertical percent deviation of the small squares was significantly smaller than either medium and large squares, and the mean percent deviation of the medium squares were significantly smaller than the large squares, regardless of hand preference. Left and right-handers were not significantly different. An examination of the horizontal percent deviations revealed an effect of hand preference wherein the mean percent horizontal deviations for left-handers on small and medium squares was significantly less than all the right-handers' responses and the left-handers large square responses.

Figure 29. Mean percent horizontal and vertical deviation on medium and large squares in left- and right-handers using their left and right hands.

SQUARE CENTERING DATA (Hand Preference by Size)



There was no significant difference between the small and medium squares in left-handers.

Circle Centering Data. The main effects of circle size ($F[2,92]=8.77, p < .01$)² and coordinate direction ($F[1,46]=15.10, p < .01$), and the interaction of hand preference X hand used X coordinate direction ($F[1,46]=8.89, p < .01$) were significant.

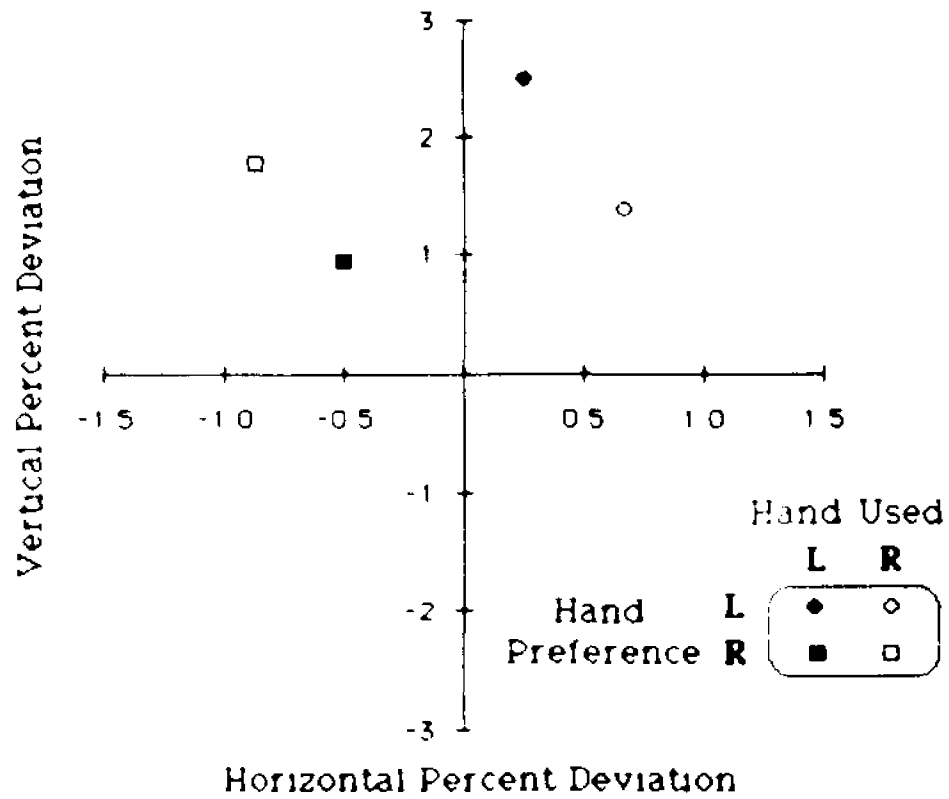
The size effect is attributable to the mean percent deviations of medium circles ($M=0.19$) being significantly smaller than either the small ($M=1.0$; $F[1,92]=5.71, p < .05$) or large ($M=1.11$; $F[1,92]=7.37, p < .01$) circles. There was no significant difference between small and large circles.

The main effect of coordinate direction is the result of the horizontal coordinate being negative ($M=-0.10$) while the vertical coordinate is positive ($M=1.64$).

The significant interaction can be seen in Figure 30. Pairwise comparisons indicate that in the vertical domain, the left hand performances of left- ($M=2.48$) and right- ($M=0.93$) handers are significantly different ($F[1,46]=7.63, p < .01$), while the corresponding

Figure 30 Mean percent horizontal and vertical deviation on the circle centering task in left- and right-handers using their left and right hands.

CIRCLE CENTERING DATA
(Hand Preference by Hand Used)



values for the right hand performances are not significantly different. In the horizontal dimension, the right hand performances of left- $(M=0.68)$ and right- $(M=-0.86)$ handers are significantly different ($F[1,46]=7.53, p < .01$), while the corresponding values for the left hand performances are not significantly different.

Horizontal Rectangle Centering Data: The main effect of coordinate direction is due to the negative mean horizontal value ($M=-1.15$) and the positive mean vertical value ($M=2.48$).

Figure 31 depicts the significant interaction of hand used X coordinate direction ($F[1,46]=13.61, p < .01$). Pairwise comparisons failed to reveal the nature of this interaction. The vertical values of the left ($M=3.03$) and right ($M=1.93$) hand deviations are not significantly different from each other ($F[1,46]=2.20, n.s.$). Likewise, the horizontal values of the left ($M=-1.61$) and right ($M=-0.68$) hand deviations are not significantly different from each other ($F[1,46]=1.57, n.s.$).

The significant three-way interaction of hand preference X hand used X coordinate direction ($F[1,46]=11.28, p < .01$) is shown in Figure 32. The obtained horizontal values are not significantly different from each

Figure 31. Mean percent horizontal and vertical deviation for the left and right hand on the horizontal rectangle stimuli.

HORIZONTAL RECTANGLE CENTERING DATA

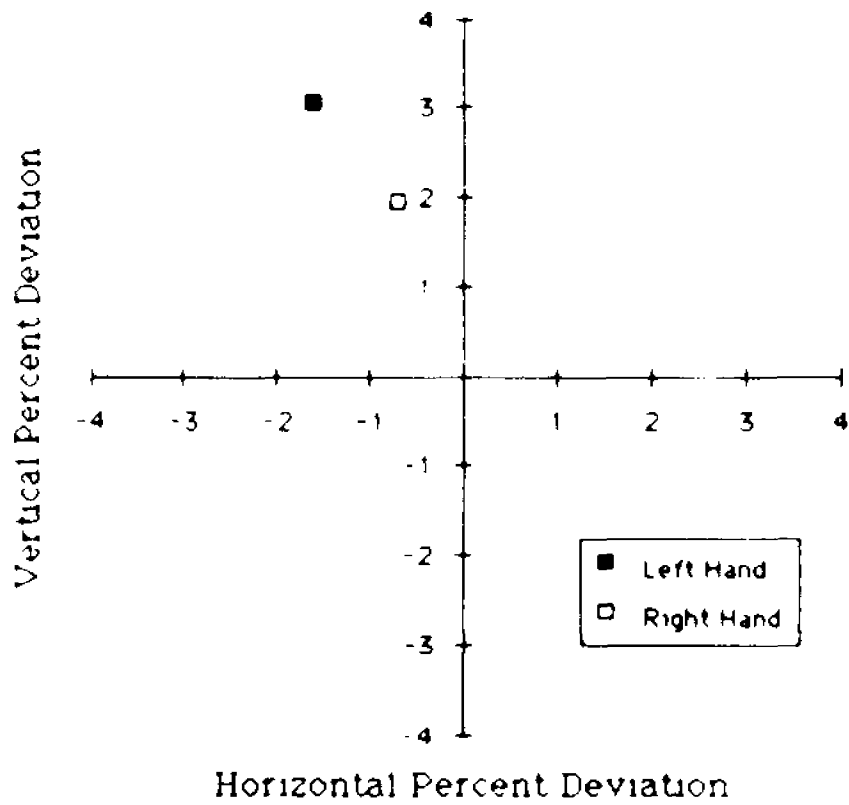
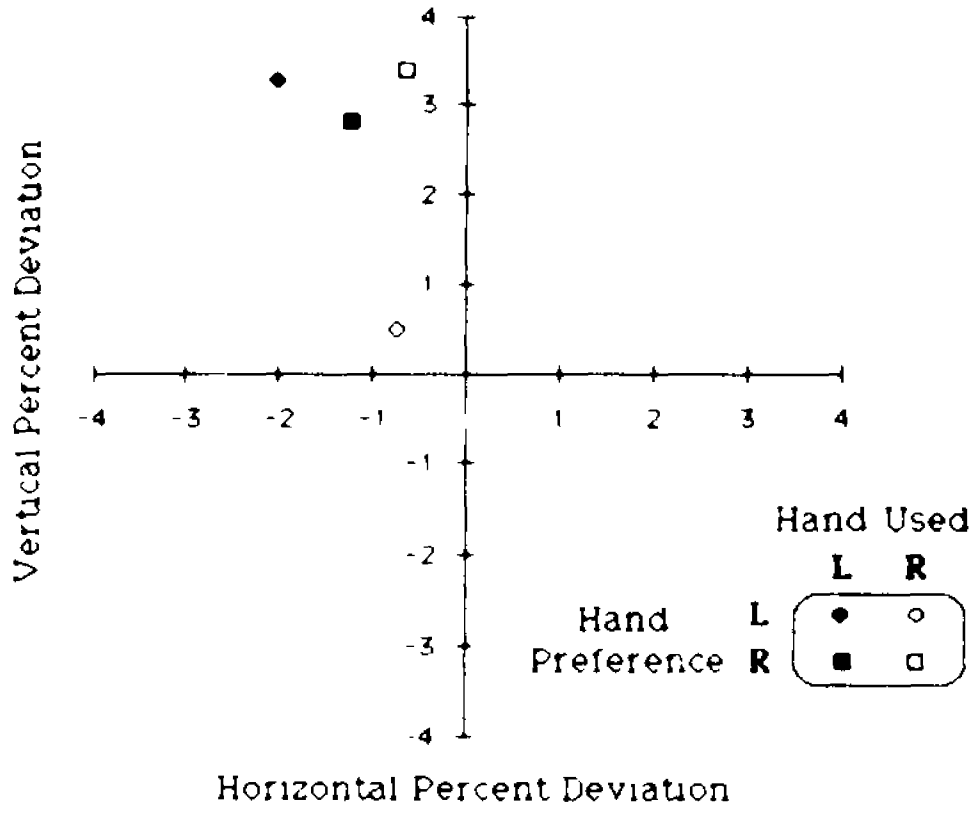


Figure 32 Mean percent horizontal and vertical deviation on the horizontal rectangle centering task in left- and right-handers using their left and right hands.

HORIZONTAL RECTANGLE CENTERING DATA
 (Hand Preference by Hand Used)



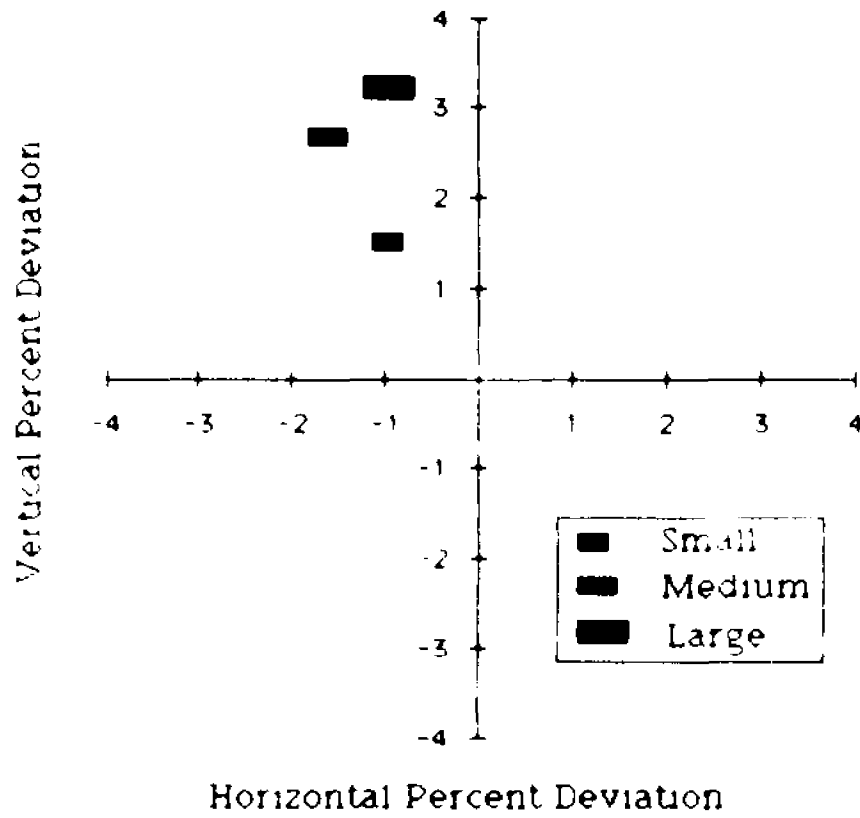
other. In the vertical domain, left-handers using their right hands ($M=0.47$) obtained significantly smaller percent deviations than their own left hand ($M=3.26$; $F[1,46]=14.17$, $p < .01$), and the left ($M=2.81$; $F[1,46]=9.97$, $p < .01$) and right ($M=3.39$, $F[1,46]=15.53$, $p < .01$) hands of right-handers.

Figure 33 shows the final interaction of rectangle size X coordinate direction ($F[2,92]=3.89$, $p < .05$). None of the horizontal values of the coordinates are significantly different from each other. Examination of the vertical values revealed that the small rectangles ($M=1.52$) were significantly less than both the medium ($M=2.68$; $F[1,92]=5.08$, $p < .05$) and the large ($M=3.25$; $F[1,92]=11.30$, $p < .01$) rectangles. The vertical coordinate values of medium and large rectangles were not significantly different from each other.

Vertical Rectangle Centering Data: The significant effect of hand used ($F[1,46]=4.48$, $p < .05$) was due to the mean percent deviation of the right hand ($M=1.40$) being larger than the left hand ($M=0.69$). The significant effect of size ($F[2,92]=10.16$, $p < .01$)² was attributable to the mean percent deviation of small rectangles ($M=0.38$) being

Figure 33. Mean percent horizontal and vertical deviation on small, medium and large horizontal rectangles.

HORIZONTAL RECTANGLE CENTERING DATA
(Size)



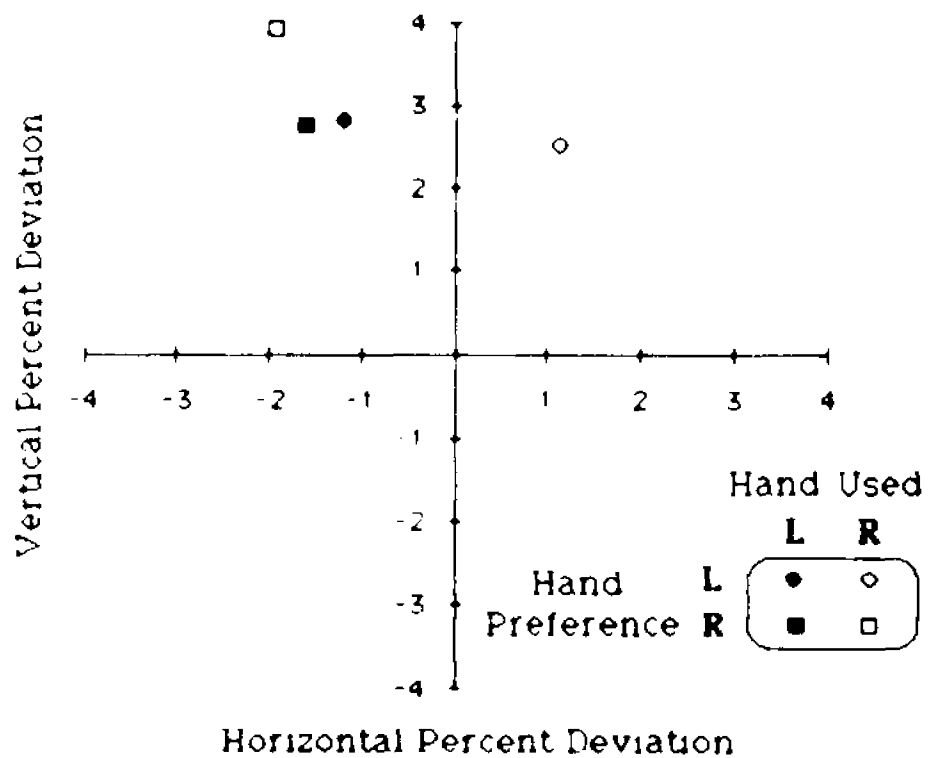
significantly smaller than medium ($M=1.75$) rectangles. There was no significant difference between medium and large ($M=1.0$) rectangles. The final significant main effect of coordinate direction was again due to a negative horizontal value ($M=-0.88$) and a positive vertical value ($M=2.97$).

The interaction of hand preference \times hand of performance \times coordinate direction ($F[1,46]=9.58, p < .01$) is shown on Figure 34. The most obvious point of this figure is the left-handers' right hand data point, which is above and to the right of veridical center. Pairwise comparisons on the vertical coordinate values resulted in no significant differences between groups or across hands. However, pairwise comparisons on the horizontal values revealed that the left-handers' right hand performance ($M=1.14$) was significantly different from their own left hand performance ($M=-1.19; F[1,46]=8.16, p < .01$) and from the left ($M=-1.58; F[1,46]=11.12, p < .01$) and right hand ($M=-1.90; F[1,46]=13.89, p < .01$) performances of right-handers.

The significant interaction of size \times coordinate direction ($F[2,92]=6.19, p < .01$)³ is due to medium rectangles having the smallest

Figure 34. Mean percent horizontal and vertical deviation on the vertical rectangle centering task in left- and right-handers using their left and right hands.

VERTICAL RECTANGLE CENTERING DATA
(Hand Preference by Hand Used)



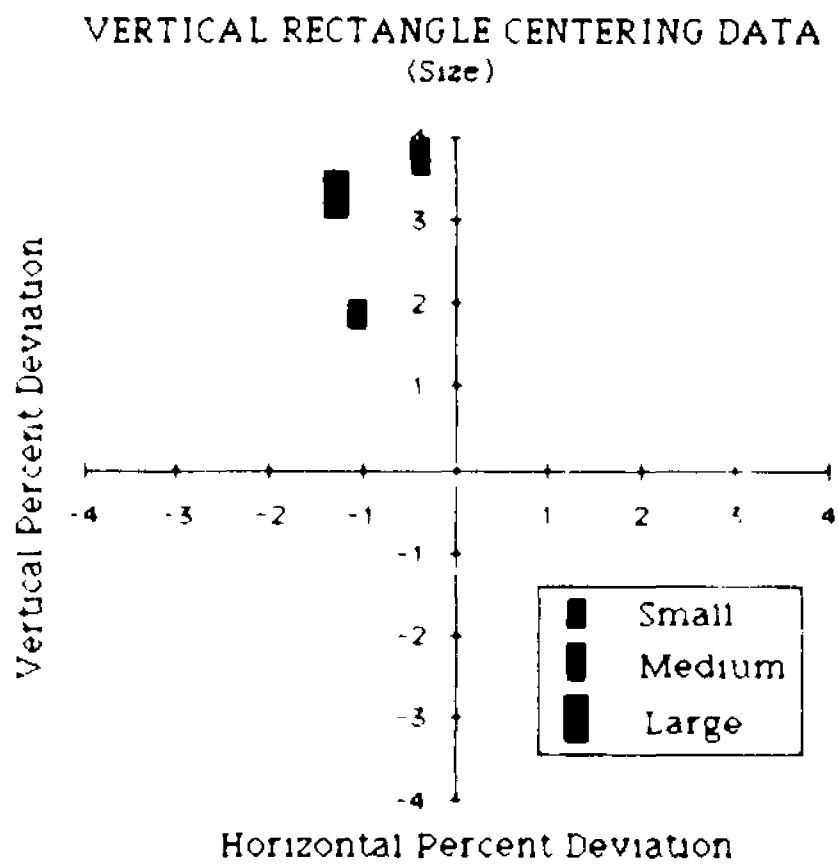
horizontal coordinate value, while small rectangles have the smallest vertical coordinate value (See Figure 35). Pairwise comparisons revealed that in the horizontal domain, the mean percent horizontal deviation for medium rectangles ($M=-0.31$) were significantly less than either small ($M=-1.04$; $F[1,92]=4.09$, $p < .05$) or large ($M=-1.29$; $F[1,92]=7.36$, $p < .01$) rectangles. Comparisons of the vertical percent deviation values revealed that the small rectangles ($M=1.81$) were significantly less than either the medium ($M=3.80$; $F[1,92]=30.36$, $p < .01$) or large ($M=3.30$, $F[1,92]=17.02$, $p < .01$) rectangles.

Discussion

The obtained results demonstrate that when individuals are required to estimate the center of two-dimensional figures, they make consistent directional errors to the left and above true center. These results are consistent with the results obtained in the study of bisection of horizontal and vertical lines (Bradshaw et al., 1985, 1986; Scarisbrick et al., 1987; and present results-Chap. 3).

Left- and right-handers' performances were similar in the general direction of the deviation scores. When handedness was a significant

Figure 35. Mean percent horizontal and vertical deviation on short, medium, and large vertical rectangles.



factor, this was due to the left-handers' right hand performance being different from the rest (see Figures 27,32,34). Left-handers using their right hand tended to be the closest to objective center. This finding is also similar to the results reported by Scarisbrick et al. (1987) on line bisections, and the results cited in Chapter 3 (see Figure 4).

The effects of stimulus size on the magnitude of the directional deviation are difficult to interpret. Vertical deviations tended to increase with increasing stimulus size (see Figures 28,33,35), while stimulus size appeared to exert no consistent effect on horizontal deviations. The effects of the vertical error and stimulus size are consistent with the results obtained from vertical line bisections discussed in Chapter 3 (see Figure 7).

The systematic deviations obtained on the current two-dimensional centering task are very similar to the deviations observed on the horizontal and vertical line bisection task, and this argues for a similar causal mechanism in the centering and transection tasks.

Chapter 7

DISCUSSION AND CONCLUSIONS

Summary of Results

This research examined several aspects of one- and two-dimensional space representation in left- and right-handers. The tasks chosen all evaluated the ability to estimate the center of various one- and two-dimensional stimuli. The subjects demonstrated systematic deviations in their estimates of center, and this study examined the possible mechanisms for this systematic bias. The study also systematically examined the relationships among bisection performance, hand preference, and hand used.

The results obtained on the horizontal and vertical line bisections (Chapter 3) replicated the results of many other studies in the literature (e.g., Bowers & Heilman, 1980; Bradshaw et al., 1986, 1987; Ferro et al., 1987; Scarisbrick et al., 1987). In general, both left- and right-handers placed their estimates left of center on horizontal lines and above center on vertical lines. The leftward deviation on horizontal line transections was statistically significant when the left hand was used, regardless of

hand preference. The upward deviation on vertical line transections was significantly above center in right-handers, regardless of hand used, and in the left-handers for left hand transections.

When subjects were required to estimate the center of two-dimensional stimuli (Chapter 6), they demonstrated systematic biases to the left and above objective center. These results are completely in accord with the subjects' performance on bisecting lines.

Asymmetric line bisection performance could result from a perceptual bias such that the two unequal extents to the left and right of the transection are perceived as equal. However, this might also reflect the motor factors involved in producing the line bisection. In an attempt to determine if purely perceptual factors could account for the systematic leftward deviations observed on horizontal line transections, a line bisection discrimination task was performed (Chapter 4). Both left- and right-handers demonstrated significant directional biases in their errors. However, the directional biases appeared to be a function of the length of the line. Subjects demonstrated a significant leftward bias on the 200 mm. lines, in accord with the horizontal line bisection

results. However, since a rightward bias was found on the 50 and 100 mm. lines, purely perceptual factors cannot fully account for horizontal transection results.

A second examination of the perceptual contribution to line bisections was undertaken using arrows as the figures to be bisected (Chapter 5). If a perceptual bias exists, perhaps it could be experimentally exaggerated by illusory manipulation of the apparent extent of the left and right sides of the stimuli. Arrows were chosen because of the illusory distortion of the center of the line (shaft of the arrow), created by the head and tail of the arrow. For these stimuli, the center of the shaft appears perceptually deviated toward the head of the arrow. These figures were quite effective in altering the subjects' estimate of center depending upon the direction of the arrow. However, the effect was of equal and opposite magnitude as the arrow direction changed. Thus the effect of arrow direction, while powerful, did not interact with the bias observed in bisections of simple horizontal lines. It should also be noted that regardless of the direction of the error, left hand responses were always left of right hand responses. This last

finding was found on all the production tasks in the current research, and suggests the existence of a motor activation component on bisection tasks.

In view of the differences obtained on horizontal and vertical transections, different mechanisms are likely to be involved. Thus the discussion which follows will treat the horizontal and vertical transection task results separately.

Possible Mechanisms for Asymmetrical Performances on Horizontal Bisection

One may postulate several different mechanisms to explain the observed systematic deviations on horizontal line bisections and on two-dimensional centering.

Visual Perceptual Hypothesis- The observed leftward deviations may result from an asymmetrical percept. When subjects estimate center left of center on horizontal lines, they may actually perceive this as center. Thus, if subjects were asked to bisect a line and then to judge

whether it was on or off center, subjects would respond on center. In view of the horizontal bisection results, perceptual center would be left of objective center. In the discrimination task, this prediction was consistent with the results on the 200 mm. lines, however, on the 50 and 100 mm. lines subjects made perceptual errors in the opposite direction. This indicates that perceptual factors alone can only partially explain the line bisection results and that some motor factor(s) may also be involved.

Motor Momentum Hypothesis- Errors on line bisection may be due to the momentum of the hand's movement from the starting position. If only the data on right hand performance were available, it could be argued that the slight leftwards deviation was an overshoot due to momentum from starting at the right side of the line. According to this hypothesis, we would expect a slight rightward deviation when using the left hand or starting from the left side. This is contrary to the results obtained in the current study of visual line bisection and the published data on rod bisection (Bradshaw et al., 1986; 1987), in which half of the trials are started from the left and half from the right side of the rod.

Thus, the motor momentum hypothesis cannot fully account for the transection performance results.

Hand Occlusion Hypothesis- If a subject partially occluded the line to be bisected with his hand and failed to take this into account, he might asymmetrically transect the line. Again, if only the data from right hand performances were available, the slight deviation to the left of center might be explained by part of the right side of the line being occluded, but this hypothesis would also predict errors to the right of center when using the left hand. As in the motor momentum hypothesis, this prediction is contrary to the obtained results in the present study and in the Bradshaw et al. (1987) study in which the hands were specifically placed away from the rods.

Motor Clumsiness Hypothesis - Subjects should be more accurate with their preferred hand and less accurate with the non-preferred hand. If only the right-handers' data had been examined, this would account of the greater accuracy of their right hand transections, although it does not account for the systematic leftwards errors obtained with their left hand. More importantly, since left-handers were more accurate with

their non-preferred hand on horizontal transections (and generally more accurate on the vertical line bisections), the motor clumsiness hypothesis is highly improbable.

Hemispheric Specialization and Motor Activation Hypothesis - The accumulated evidence (reviewed in Chapter 1) suggests that the right cerebral hemisphere is preferentially involved in the appreciation of space and in spatial relationships. The tasks used in the present experiment all involved the appreciation of space, which may have preferentially activated the right hemisphere. If this was in fact the case, a slight shift leftward on the horizontal bisections would have been expected. In fact, this was found in both the line bisection task results and the two-dimensional centering results. However, the fact that left hand performances were always left of right hand performances would necessitate the inclusion of an additional cerebral motor activation component (e.g., Kinsbourne, 1970). When subjects use their left hand, this effectively causes additional right hemisphere motor activation, resulting in a larger leftward deviation. This hemispheric specialization and motor activation hypothesis accounts for all of the

major findings of the production data in the present experiment. However, it cannot explain the horizontal line bisection discrimination data using short and medium lines in which a perceptual bias slightly right of center was found. This indicates that the hypothesis is inadequate as a general model of bisection performance, and suggests that the discrimination task may be qualitatively different from the production task and not governed by the same causal mechanism(s). The different results from the discrimination task and the production task could be attributed to either the proposed motor activation component on bisection production being large enough to mask the small resting asymmetries found on the bisection discrimination task, and/or to the possibility that the verbal response required on the discrimination task activated the left hemisphere, and that this tilted the balance of attention to the right.

In conclusion, the simple perceptual, motor momentum, hand occlusion, and motor clumsiness hypotheses fail to fully account for the present results. In contrast, the more complex hemispheric specialization/motor activation hypothesis accounted for most of the

present results. In agreement, Bradshaw et al. (1987) offered a similar explanation for their results on a rod bisection task.

Possible Mechanisms for Asymmetrical Performances on Vertical Bisection

The vertical line bisection task was originally included because it involved transection of space without regard to left or right personal hemisphere. However, virtually all subjects (Figures 8 and 9) demonstrated a significant deviation above objective center. Since difference in superior and inferior space was not the major thrust of the current study, the line bisection discrimination task did not include vertical lines.

The literature on systematic errors in the vertical dimension is small. Scarisbrick et al. (1987) found that left and right-handed subjects placed their estimates above veridical center on vertical lines. One recent presentation (Rapcsak et al., 1987) examined altitudinal neglect in a patient with Balint's syndrome. The patient, like the normal

subjects in the present study, placed his estimates above center on both line and rod bisections.

The implication of all of these results obtained on the vertical bisection task is that vertical space, like horizontal space, is mapped differentially in the brain, and/or that attention may be allocated differentially in superior and inferior vertical space, such that the superior half of the visual field is perceptually more salient.

Implications for Brain Organization in Left- and Right-Handers

In the General Introduction (Chapter 1), evidence concerning the similarities and differences in brain organization between left- and right-handers was reviewed. The majority of the studies favor a similar organization for left- and right-handers.

The results of the present experiment offer additional evidence for similarities in right-hemisphere spatial functions in left- and right-handers. Left- and right-handers performed very similarly on most

transection and centering tasks in this study, whereas, on a speeded task which involved motor dexterity (i.e., Target Test), left- and right-handers performed differently. This suggests that the neural systems responsible for motor dominance and visuo-spatial dominance are independent. If any group differences were recognizable on the spatial tasks, it appeared that many left-handers were more accurate with their right (i.e., non-dominant) hand than the right-handers with their right hand (i.e., preferred).

Clinical Implications

The present study makes two contributions to the use of line bisection tasks in patients with lateralized cerebral damage. First, this study provides some heretofore absent normative results on line bisection in both left- and right-handed adult males.

The second contribution is that clinical patients should be tested on line bisections with both hands. The prediction is that even though right hemisphere damaged patients bisect lines right of center with their

right hand, when they use their left hand, this may selectively activate the right hemisphere and decrease or even reverse the rightward error on line bisection. A similar leftward shift with the left hand would be expected in left hemisphere damaged patients.

Although the Schenkenberg et al., (1980) experiment was concerned with the frequency of neglect and the effectiveness of a line bisection task in identifying patients with unilateral cerebral disease, they obtained left and right hand line bisections on seven (35%) right and nine (45%) left hemisphere damaged patients. I calculated the difference between the left and right hand bisection scores for this subgroup of their patients. The right hemisphere damaged patients placed their estimates of center much further right of center (left hand = 9.35%; right hand= 14.64%) than the left hemisphere damaged patients' estimates (left hand= -3.96%; right hand= -0.14%). However, the point of major interest for the current discussion is the magnitude of the difference between the right and the left hand. In the right hemisphere damaged patients, a mean leftward shift of 4.19 % between the left and right hand productions was found. The left hemisphere damaged patients showed a

similar leftward shift of 3.83 %. The similar left vs. right hand difference in the left and right hemisphere damaged patients supports the argument that the results from these groups involve a similar mechanism at the level of production. The difference between the groups must occur at the level of where the subjective midpoint of a line is perceived. This equality also suggests that the extreme rightward shift in the right hemisphere damaged patients is not due to a generalized deficit associated with perhaps larger lesions. An experiment similar to the current one conducted on left and right brain-damaged patients would help to resolve this issue.

Footnotes

¹ Unusual lengths (e.g. 51, 102, and 202) were due to reprographic distortions.

² Significant at $p < .01$ when using the most conservative epsilon correction of $1/(k-1)$.

³ Significant at $p < .05$ when using the most conservative epsilon correction of $1/(k-1)$.

PLEASE NOTE

Copyrighted materials in this document have not been filmed at the request of the author. They are available for consultation, however, in the author's university library.

These consist of pages:

- 169, Lateral Preference Inventory
- 170, Familial Handedness Questionnaire
- 171, Handwriting-Posture Questionnaire
- 172-173, Directions for Target Test

UMI

QUEENS COLLEGE
of the City University of New York
Department of Psychology

Consent Form

I understand

that this experiment will involve sitting in a quiet room using a pencil to mark drawings in a booklet, and to fill out a questionnaire on which side of the body I prefer to use for various activities,

that this experiment will not be physically or psychologically harmful to me,

that participation is **voluntary** and my discontinuation at any time will incur **no penalty**,

that although the information gained from this experiment may be of little direct benefit to me, I realize that it may lead to a greater understanding of vision, cognition, and brain functioning,

I have been fully informed of the above described procedures and all of my questions have been answered. I know that David J. Scarisbrick will be available to answer any future questions I may have. I am free to withdraw this consent and discontinue participation at any time. I have received a copy of this form.

Signature

Witness

Date

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