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SEX DIFFERENCES IN HEMISPHERIC LATERALIZATION FOR THE  
PERCEPTION OF DIRECTIONALITY: THE ROLE OF VERBAL ANALYSIS

*City University of New York*

PH.D.

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THE PERCEPTION OF DIRECTIONALITY: THE ROLE OF VERBAL ANALYSIS

by

JOAN KAY CLAYTON

A dissertation submitted to the Graduate Faculty  
in Educational Psychology in partial fulfillment  
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This manuscript has been read and accepted for the Graduate Faculty in Educational Psychology in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

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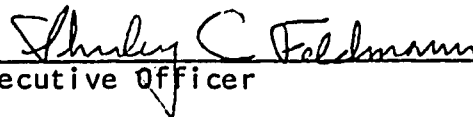
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## Abstract

### SEX DIFFERENCES IN HEMISPHERIC LATERALIZATION FOR THE PERCEPTION OF DIRECTIONALITY: THE ROLE OF VERBAL ANALYSIS

by

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Adviser: Professor Harry Beilin

A frequent finding in the area of cognitive development is the generally higher performance levels on spatial tasks in males than in females. One explanation for this performance discrepancy involves the possibility of greater hemispheric lateralization and specialization for spatial functions in males. It has also been suggested that the existence of less lateralization in females and/or a possible earlier maturational lead in language development may account for a "preference" in females to process all information--both verbal and spatial--in a verbal/linguistic form. Since spatial manipulations and transformations are relatively difficult to translate into linguistic structures, females face a loss in information processing efficiency when solving spatial tasks.

One corollary to the notion of greater lateralization in males is the possibility that the neural substrate underlying this specialization leads to a greater susceptibility for disruption or interference in hemispheric functions.

The current study examined the position that verbal mediation is the preferred cognitive strategy for females, and that males may demon-

strate an interference effect when using a cognitive strategy "non-native" to a given hemisphere, or when using two different strategies simultaneously at the level of single hemisphere processing.

Subjects consisted of fifth and ninth grade boys and girls. Half of the subjects were provided with a verbal strategy to describe lines of different orientations (e.g.,  $0^{\circ}$ ,  $30^{\circ}$ ,  $90^{\circ}$ ,  $135^{\circ}$ , etc.) by reference to the four directions of slant ("L" - left, "R" - right, "A" - across, "S" - straight). Lines were placed in two by two matrices and presented tachistoscopically to each lateral field. Subjects had to reproduce the direction of each line on answer sheets. Comparison of trained and untrained subjects indicated that with training, girls performed better than boys; and the left hemisphere of boys made fewer correct drawings with than without training, suggesting the possibility of the incompatibility of verbal and spatial strategies in the left hemisphere. For girls, however, the left hemisphere performed significantly better with than without training, suggesting that girls can and prefer to use verbal mediation for processing line directionality. These findings were repeated in a second experiment in which trained subjects were asked to compare letters and lines presented simultaneously to a single field (e.g., if the letter was "L" (left), the line should be to the left \). Overall, girls made significantly more correct comparison judgments than boys; girls demonstrated a left hemisphere bias; boys demonstrated a right hemisphere bias. Finally, the data indicated significantly better performance by ninth than by fifth graders on all tasks with some indication of greater laterality differences in the ninth than fifth graders.

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## CHAPTER I

### Introduction

Numerous books (e.g., Hutt, 1972; Maccoby & Jacklin, 1974; Ounsted & Taylor, 1972; Sherman, 1978) and review papers (e.g., Fairweather, 1976; Harris, 1978; Mischel, 1970) as well as hundreds of articles have examined sex differences in social and cognitive functioning. Within the area of cognition, attention has focused on the relative performance levels of males and females on both verbal as well as spatial tasks. While opinion varies as to whether sex differences (in favor of females) reliably exist on tests of verbal skills and reasoning, it is generally accepted that males usually perform better than females on problems containing a spatial component. In a recent review of the literature on sex differences in spatial abilities, Harris (1978) writes that "on a number of tests, only 20% to 25% of females exceed the average performance of males" (p. 405).

The specific types of "spatial" problems that have demonstrated male superiority are countless and have been the focus of investigation for decades (see Harris, 1978; Maccoby & Jacklin, 1974, for reviews). Among the areas investigated, males have been found to exceed the performance of females on the Embedded Figures Test (e.g., Schwartz & Karp, 1967; Witkin et al., 1967); problems involving three-dimensional kinetic imagery and rotation (Bennett et al., 1959; Hartlage, 1970); knowledge of geometrical principles--although not mathematical or algebraic knowledge (Smith, 1964); chess playing

(Chase & Simon, 1973); directional sense and orientation including mazes (Porteus, 1918, 1965), map reading (Money et al., 1965), pattern walking (Keogh, 1971), left-right discrimination (Bakan & Putnam, 1974), and complex coordinations (Shepard et al., 1962); the Rod-and-Frame Test (e.g., Morf et al., 1971; Witkin et al., 1967); geographical knowledge (e.g., Bettis, 1975); and several tests of Piagetian theory (e.g., Goldschmid, 1967; Tuddenham, 1971). Other tasks such as the tactile identification of shapes (Witelson, 1976) and the auditory perception of environmental sounds (Knox & Kimura, 1970) also contain "spatial" components and have shown some performance differences between males and females.

From just this brief listing it is clear that there is considerable variability in what qualifies as "spatial." Although not always obvious, however, the common element underlying most of the tasks above is some form of mental transformation, rotation, and/or orientation (see Eliot & Salkind, 1975, for a review of the meaning of "spatial," its historical perspective, and current research status). Harris (1978) has collected a sampling of definitions of spatial ability. Among these are the following:

To move, turn, twist, or rotate an object or objects and to recognize a new appearance or position after the prescribed manipulation has been performed (Guilford, 1947);  
to make discriminations as to the direction of motion such as up and down, left and right, and in and out (Guilford, 1947);  
to recognize the identity of an object when it is seen from different angles (Thurstone, 1950);  
to think about those spatial relations in which

the body orientation of the observer is an essential part of the problem (Thurstone, 1950); to perceive spatial patterns accurately and to compare them with each other (French, 1951) (in Harris, 1978, p. 405).

Implicit in most of these definitions is also the distinction Piaget and Inhelder (1971) have made between static imagery and kinetic imagery. It is this latter type that seems to be the least amenable to verbal description, and it is this fact, as discussed later, that has been offered as one explanation for sex differences on spatial tasks. That is, the possibility has been raised by some (e.g., Rudel et al., 1974) that females prefer verbal problem solving approaches for both verbal and spatial problems, and it is the relative inefficiency of verbal codes for spatial analysis that may account for the relatively lower performance of females as compared with males on spatial problems.

Over the years, various explanations other than the above have been offered to account for the discrepancy that exists between the performances of males and females on tests of spatial skills and ability. Today, it is assumed that a variety of factors play a role and that these are all necessary for a full expression of the trait. A summary statement encompassing the current thinking would include some combination of the following: Spatial ability is inherited through a recessive-sex-linked gene. In addition, various sex hormones, acting as releasing mechanisms, differentially influence the neural substrate of the cerebral hemispheres in males and females. Upon this foundation, environmental-experiential factors then play a role in the

enhancement or suppression of the actual manifestation of spatial skills. Of the three levels of analysis included in this summary view--genetic-hormonal, learning and experiential, and cerebral organization--only the latter (hemispheric structure and function) forms the major focus of the current paper.

### Hemispheric Functioning and Neuropsychology

Although interest in the workings of the mind has concerned researchers for thousands of years, much of modern neuropsychology dates from 1861 and the observation by Broca of language difficulties in an individual on whom a subsequent autopsy demonstrated a lesion in the posterior frontal area of the left hemisphere (Broca, 1960). Since then, knowledge of hemispheric functions has continued to accumulate from the study of individuals with a variety of cerebral insults including head trauma, lesions, and tumors. In the last 20 years, new procedures such as electrical stimulation of cortical regions (Penfield & Roberts, 1959); split-brain preparations (Gazzaniga, 1970); computerized axial topography (CAT scan); and evoked potentials have added to the literature on hemispheric functions (see Witelson, 1977b, for a complete review).

While the above involve the direct observation of brain damaged individuals or the direct use of "invasive" techniques with normal subjects, only in the last 15 years have "noninvasive" (and subsequently indirect) techniques for studying hemispheric functions been

possible (see Kimura, 1973, for a review). These procedures are largely based on the neuroanatomical cross-over of the visual, auditory, and somatosensory pathways. For instance, within the visual system, information perceived by the left half of each eye is sent to the right hemisphere while information perceived by the right half of each eye is sent to the left hemisphere. Thus, when investigating the visual system, the material to be viewed is rapidly flashed (tachistoscopically) to either the left or the right of the central fixation point while the subject looks only at the center. Since it takes approximately 200 msec for eye movement (Woodworth & Schlosberg, 1954), any material presented faster than this will be viewed exclusively by one hemisphere.

Although information is transmitted entirely to the contralateral hemisphere in the visual modality, there is some ipsilateral as well as contralateral transmission in the auditory and somesthetic modalities. In this case, the procedure involves presenting different information simultaneously to both lateral fields. In the auditory modality, two different sounds are presented simultaneously (dichotic listening)--one to each ear--producing competition in the neural pathways. This results in the contralateral information having some priority in reaching the hemispheres. Within the somesthetic (tactile) modality, simultaneous presentation of material to the left and to the right hand (dichaptic stimulation) (Witelson, 1974) is considered the equivalent of dichotic stimulation. However, because there is less cross-over in the somesthetic modality than in the auditory system,

successive tactile exploration with each hand separately (Rudel et al., 1974) is also used.

Other procedures that have been used to infer hemispheric functions have been described by Witelson (1977b) and include observing the direction of eye gaze on any particular cognitive task (e.g., Kinsbourne, 1972); hand predominance in the production of gestures associated with the act of speaking (Ingram, 1975b; Kimura, 1973); the simultaneous exercise of two modalities such as finger movements and speaking (Lomas & Kimura, 1976); and handwriting posture (Levy, 1977).

Based on knowledge obtained from the above techniques and procedures, a brief review of the organization and the functions of the cerebral hemispheres follows.

### The Cerebral Hemispheres

Over the years, data have been gathered showing the types of specific impairments resulting from brain injury and other cerebral trauma, and it is this data that have provided most of the descriptions of the hemispheric functions. In particular, damage to the left hemisphere (in right-handers) primarily disturbs language functions and depending on the site of the pathology may include one or all of the following: difficulties in language comprehension (often referred to as Wernicke's aphasia); difficulties in expressive speech (such as Broca's aphasia); word finding problems (anomia); writing difficulties (agraphia); reading difficulties (alexia); impairment in

mathematical functions (acalculia); and sensory/motor difficulties on the contralateral half of the body.

In contrast to the effects of left-sided injury, damage to the right hemisphere results in such deficits as: visual agnosia; somatognosia; unilateral neglect; prosopagnosia (nonrecognition of faces); and constructional apraxia. Specific research studies of right hemisphere functions in brain damaged individuals have found problems in the deduction of spatial relationships underlying a series of complex patterns (Carmon, 1978); difficulties in integrating fragmented shapes (Nebes, 1972); problems in detection of depth (Benton & Hécaen, 1970); poor recognition of abstract forms (Rubino, 1970); difficulties recognizing melodies and emotional, nonverbal human sounds (Carmon & Nachshon, 1971; Kimura, 1964; Shankweiler, 1966); failure to distinguish line orientation and directionality (Benton et al., 1973); and failure at maze learning (Corkin, 1965; Milner, 1965).

Although each hemisphere clearly has its own functions for which it is best suited, the right hemisphere has only recently been granted any significant status. Traditionally, the left cerebral hemisphere has held the predominant place in the theorizing and research in neuropsychology. This stems from the fact that at least 90 percent of the population is classified as being definitely right-handed and of this 90 percent, over 99 percent are strongly left hemisphere dominant for language (Benson & Geschwind, 1968). If damage to the left hemisphere should occur, language functions will be impaired causing

mild to severe forms of aphasia (errors in the receptive and/or expressive use and understanding of grammatical structure and word meaning). However, damage to the right hemisphere will essentially leave language functions intact, although right hemisphere damage will lead to visual/spatial deficits. A similar situation, however, does not exist for the left-hander. Of the 10 percent who are left-handed, around 40 percent are right hemisphere dominant for language and 60 percent have a left hemisphere dominance. In addition, left-handers do not show the same degree of dominance as right-handers since 80 percent of left-handers have mixed dominance-- language functions in both hemispheres (Gloning, I. et al., 1969; also see Rasmussen & Milner, 1977, for slightly different percentages). As a result, damage to either hemisphere in a left-handed individual produces some aphasia in 80 percent of all cases, although the aphasia will be less severe than that caused by a similar lesion in the left hemisphere of a right-handed person (Strub & Black, 1977). Since language has long been viewed as the basis of symbolic and representational thought, the left hemisphere subserving language functions has thus been considered the dominant hemisphere, erroneously implying that the right hemisphere must be the "minor" hemisphere or at least the less significant of the two.

This view persisted for years in spite of early studies showing distinctive impairment of functions with right hemisphere damage. In the 1870's, Jackson (cited in Taylor, 1958) documented the importance of the posterior right hemisphere in visual recognition and visual memory.

He also described the right hemisphere's role in visual orientation; the ability to recognize faces; and the ability to dress one's self. Sense of direction, route finding, and topographic memory were but a few of the impaired functions cited by Brain in 1941 in a paper suggesting an alternative view of the "minor" hemisphere. In spite of significant progress in the last 20 years in recognizing the unique nature of the right hemisphere, there is still a relative paucity of research pertaining to the right hemisphere. This is particularly true for developmental studies which consist of but a handful.

Today, the notion of dominance has been replaced by characterizing the left hemisphere as the one involved in verbal, linguistic, analytic, and sequential processing whereas the right hemisphere subsumes spatial, holistic, and parallel processing. Harris (1978) states:

It has been suggested that there are two distinct modes of coding operations, each specific to a single hemisphere: The left hemisphere operates in a more logical, analytical, computer-like fashion, analyzing stimulus information input sequentially, abstracting out the relevant details to which it attaches verbal labels; the right hemisphere is primarily a synthesizer, more concerned with the overall stimulus configuration, and organizes and processes information in terms of gestalts or wholes (Harris, 1978, pp. 462-463).

It should be cautioned that this discussion of hemispheric functions should not leave one with the impression of two separate and distinct "boxes" in the head--one for language and one for spatial analysis. Information is continuously passed back and forth between the hemispheres

through the corpus callosum (prior to the 1940's a structure assumed to have no significant function) and probably through some subcortical structures as well. In addition, this presentation suggests a rather sterile, compact view of the research in hemispheric functioning. In fact, many issues are currently being investigated including such questions as the specifics of intra- as well as inter-hemispheric transmission of data, and the issue of whether each hemisphere shifts in asserting control over the other from task to task (Gazzaniga & LeDoux, 1978).

#### Developmental Theories of Hemispheric Specialization

Although the above describes the functions of the hemispheres in the adult, there is a lack of consensus regarding whether specialization is present at birth or whether it develops over time (Witelson, 1977b).

Lenneberg (1967) has suggested that at least for the first two years of life, there is bilateral representation of language functions. Left hemisphere specialization then gradually sets in during the childhood years and by puberty, plasticity of the hemispheres to subsume the opposite hemisphere's functions is lost and primary language learning becomes impossible. To this extent, Witelson (1977b) has suggested that researchers and theorists in areas of cognitive development pinpoint adolescence as the time beyond which no new qualitative changes in general cognition occurs (e.g., Hebb, 1949; Piaget & Inhelder, 1969; Terman & Merrill, 1937). Lenneberg's (1967)

position also corresponds to the neuroanatomical evidence of final and complete myelination of the nerves by early puberty.

Krashen (1975) has proposed five years of age as the time at which hemispheric specialization is complete. The evidence for this view is the generally reported decrease after five years of age in the transferability of language functions to the right hemisphere following left-sided injury and the lower incidence of speech loss found with right hemisphere lesions also occurring after age five.

Kinsbourne (1975) has taken a different position and suggests that left hemisphere specialization is present at birth and that there are no further changes with development. Other researchers have qualified this view to include changes in specialization in some linguistic functions, but not all (Porter & Berlin, 1975).

Finally, others have suggested that although specialization in language is functional from the beginning, there are still increases in left hemisphere specialization with age (Bryden & Allard, 1978). This is based on reviews of dichotic listening studies in which the strength or degree of ear asymmetry is greater in older children.

Although the evidence shows that language can transfer to the right hemisphere in the early years, there do appear to be definite limitations to the kind of linguistic abilities that can be ultimately mediated by the right hemisphere. Generally, verbal comprehension remains intact as shown by measures of verbal IQ's; however, comprehension of complex, logically grammatical structures and syntactic features does appear to be more difficult (Dennis & Kohn, 1975;

Dennis & Whitaker, 1976).

One researcher has taken the position that the right hemisphere may be more specialized for its functions at an earlier age than the left hemisphere is for its functions. Lansdell (1969) has found that if damage occurs before five to the left hemisphere, both speech and spatial skills can be served by the right hemisphere; however, spatial functions are overall more impaired than verbal functions. The reverse is the case if the damage to the left hemisphere occurs after five. In this situation, verbal skills are more impaired than nonverbal skills. A similar hypothesis is that the right hemisphere is functionally more active or more mature than the left in the first few years of life. After the onset of speech, the reverse situation then occurs (Brown & Jaffe, 1975; Ounsted & Taylor, 1972).

As the above indicates, there are some considerable differences concerning the time at which specialization is completed or even begun. In an attempt to clarify this issue, Witelson (1977b) reviewed the various research studies conducted with normal or brain damaged children. She could only conclude that at least by three years of age the left hemisphere appears to play a greater role in linguistic functions, while at least by age six the right hemisphere has greater participation in visual/spatial, haptic, and nonverbal auditory perception.

Along these same lines, recent studies may provide evidence to extend these findings to infancy. Entus (1977) examined infants' responses to musical tones and consonant-vowel syllables. Twenty-four

boys and twenty-four girls, ages 1½-to 3-months old, comprised the subject population. In the music condition, 38 of 48 infants (79%) showed a left ear superiority, while in the verbal condition, 34 of 48 infants (71%) showed a right ear superiority for the speech sounds (i.e., /ma/, /da/). Although no sex differences were observed, this study suggests that as early as 40 days, infants show signs of left hemisphere language processing and right hemisphere processing of holistic, spatial information.

While knowledge of the overall development of specialization is important, the main interest of the present paper centers on differences in hemispheric functioning and how this may account for the differential performance of males and females on spatial tasks. It is not surprising that since there is little consensus on the general development of cerebral organization, there are also widely differing views on the lateralization of functions in the sexes. In addition, most of the studies to date have involved adults which leaves little opportunity for conclusions about developmental progress in males and females individually.

#### Neuropsychological Theories of Sex Differences

Two recent studies (Harris, 1978; Sherman, 1978) have reviewed the neuropsychological theories that examine sex differences in hemispheric specialization and that may account for the frequently reported male superiority on spatial tasks. Each author has suggested three major positions, although each of these three divisions is not

entirely equivalent. A closer examination leads to four theoretical statements--three of which differ along less controversial dimensions (Harshman & Remington, 1976; Levy, 1972; Witelson, 1976) while one presents a more radical departure from the others (Buffery & Gray, 1972).

#### Left Hemisphere Language Lateralization in Females and Bilateral Spatial Representation in Males

This view proposed by Buffery and Gray (1972) holds that the left hemisphere of girls develops more rapidly than the left hemisphere of boys. Since less lateralization occurs in males, the left hemisphere remains available to subsume some spatial functions. Thus, at maturity, males have the benefit of two hemispheres sharing in the processing of spatial information. This results in the observed superiority of males on spatial tasks and the frequently reported superiority of females on verbal tasks.

Buffery and Gray (1972) further speculate about the structural and processing demands of spatial and linguistic tasks:

...Linguistic skill, with its need for quick associations and serial ordering, probably demands fast and intricate neural mechanisms. Such mechanisms could benefit from being subserved by specific structures with a clearly lateralized and localized cerebral representation. This is apparently more likely in the female than male brain. Spatial skill, however, which is usually exercised in a three-dimensional and completely enclosing world, may benefit from a more bilateral cerebral representation. Thus, a consequence of the less well lateralized cerebral representation of linguistic skill in the male brain might be more bilateral cerebral representation of spatial skill than can be achieved in the female brain (Buffery & Gray, 1972, p. 144).

To a large extent, Buffery and Gray (1972) have derived their view from a long tradition of studies indicating earlier development of verbal abilities in girls. The literature (see Fairweather, 1976; Harris, 1978; Maccoby & Jacklin, 1974; Sherman, 1978, for reviews) is vast and contains a variety of findings including those that show that girls speak sooner, use more words (Nelson, 1973), and spontaneously babble and speak more than boys in infancy (Goldberg & Lewis, 1969). Fairweather (1976) cites several English studies including one (Winitz, 1969) that shows that girls more often outperform males than vice versa on tests of articulation. Many other studies report similar results but most authors (Fairweather, 1976; Maccoby & Jacklin, 1974; Sherman, 1978) place qualifying limitations on the studies purporting to show female verbal precociousness. Maccoby and Jacklin (1974) conclude that although there are findings pointing to earlier language development in girls than boys prior to age three, these studies are very old and must be reviewed critically for a number of methodological problems. The rest of the literature suggests that by three and up to adolescence, boys and girls perform equivalently. It is not until around 10 or 11 that some studies again show a female superiority on tests of verbal abilities.

The question of early female superiority in language functions has also failed to receive any definitive clarification from the neuropsychological literature (see Witelson, 1977b, for a review). Several dichotic listening studies have shown a greater right ear advantage (greater left hemisphere responding) in girls than in boys.

Kimura (1967) presented pairs of digits and found a right ear advantage for all five through eight year olds except in the one case of the five year old boys. Bryden and Allard (1978) reported on an earlier unpublished study by Bryden et al. (1973) in which pairs of consonant-vowel sounds were administered to kindergarteners, second, fourth, sixth, and eighth graders and found a right ear advantage by age nine for girls only. Most studies, however, have found no sex differences in degree of lateralization for verbal material in children (e.g., Bryden, 1970; Bryden & Allard, 1978; Kinsbourne & Hiscock, 1977; Knox & Kimura, 1970) or in infants (Entus, 1977). In addition, one study (Ingram, 1975a) reported a failure to find a right ear advantage for words in four-year-old girls. Finally, using tachistoscopic presentation of verbal material, no sex differences have been reported (e.g., Olson, 1973; Yeni-Komshian et al., 1975) except in one study (Marcel et al., 1974) in which seven-and eight-year-old boys showed a right visual field advantage on word and letter recognition.

The only evidence in favor of the second part of Buffery and Gray's (1972) position--bilateral spatial representation in males--has been reported by these same authors (Buffery, 1971; Buffery & Gray, 1972). In one study, information was presented intermodally using both tachistoscopic presentation and dichotic stimulation. In other words, visual material was presented to either the left or the right lateral fields and simultaneously the same or different corresponding word was presented to either the left or right ear. When the visual word and the auditory word were presented to the right hemisphere, processing was quite difficult for girls by age five, whereas the boys

did not show the same degree of difficulty until seven. Therefore, Buffery (1971) concluded that language functions lateralized earlier in the left hemisphere for girls than for boys.

In a second study (Buffery & Gray, 1972), children 3 to 11 years of age were asked to draw simultaneously with eyes closed a square with one hand and a circle with the other. Overall, all girls at all age levels showed left-hand (nonpreferred hand) superiority for drawing a square but the boys showed this left-hand superiority only after age seven. These results would seem to imply earlier right hemisphere specialization for spatial functions in females--the opposite of what is predicted by their theory. However, to Buffery and Gray (1972), since the left hemisphere subsumes linguistic functions at an earlier age in females than in males, the right hemisphere in females is more available for nonverbal functions. Thus, the left-hand, controlled by the right hemisphere, would be expected to do better on spatial tasks such as the drawing task.

In general, no other research can be cited to support bilateral representation of spatial functions in males. In fact, data to the contrary are widely used to support the opposite notion--that of greater lateralization for spatial functions in males.

The evidence for structural differences in the hemispheres for boys and girls is even less clear than the data on language development in the sexes. Harris (1978) reviewed the studies cited by Buffery and Gray (1972) and concluded that each study suffered from one or several flaws including the examination of a single age group

or the use of neurologically impaired individuals. In addition, the evidence in favor of structural differences in the left hemisphere of girls was mostly inferential and based on trends and not significant differences. What may be a more accepted finding, however, derives from the research showing that the planum temporale (part of the speech area) is generally longer in the left hemisphere than the right hemisphere (Geschwind & Levitsky, 1968; Wada et al., 1975; Witelson & Pallie, 1973). The support for possible sex differences in this asymmetry has been reported by Witelson and Pallie (1973) who found that of the brains of five infant boys and five infant girls, the left was significantly larger only in the infant girls.

#### Bilateral Representation of Verbal Functions in Females

Although the preceding theory argues that unilateral representation of verbal functions impairs spatial processes in females, the position formulated by Levy (1972) suggests that bilateral representation of verbal functions in females disrupts spatial functions. The basis for this is the speculation that each hemisphere with its different coding operations (linguistic processes in the left and spatial processes in the right) needs a "clear channel" for maximum operating efficiency (Levy-Agresti & Sperry, 1968; Semmes, 1968). Therefore, if the right hemisphere must subsume some portion of left hemisphere language functions, the result is a reduction in the processing capacity for the spatial functions of the right hemisphere. This is the exact situation found in a study (Milner, 1969) of early

brain injured individuals in which language had been lateralized in the right hemisphere. More impairment in nonverbal skills than verbal skills was found suggesting the incompatibility between spatial, synthetic right hemisphere processes, and linguistic, analytic left hemisphere processes.

Other evidence to support Levy's (1972) position comes from findings indicating that left-handers with left and right hemisphere representation of language functions frequently show impaired nonverbal skills (Miller, 1971) as compared with verbal skills. It is also this type of data that Levy (1972) relied upon to initially substantiate her theory. In a group of 10 left-handed and 15 right-handed males, she found that left-handers did more poorly on the Performance subtests of the Wechsler Adult Intelligence Scale (WAIS) than the right-handers. In terms of discrepancy scores, the left-handers had an average difference of 25 points between their Verbal IQ and Performance IQ, whereas right-handers had an average difference of only 8 points.

Levy (1972) hypothesized that left-handers and females share something in common--they both have language functions located in the left as well as in the right hemisphere. She writes:

It is interesting that the (spatial) perceptual deficit seen in left-handers is also present in females in general...It might be that female brains are similar to those of left-handers in having less hemispheric specialization than male right-hander's brains...It is hard to reject the notion that a spatial perceptual deficit in women is a sex-linked, genetically determined incapacity, an incapacity which possibly results from hemispheres less well laterally specialized than those of males (Levy, 1972, p. 174).

Although Levy (1972) based her view on her handedness study, not all other studies support her findings. Newcombe and Ratcliff (1973) and Fennell et al. (1978) have not confirmed that left handers are inferior on spatial tasks, while Nebes (1971), Silverman et al. (1966), and James et al. (1967) have.

In addition to the studies of handedness, data from individuals who have sustained brain damage later in life support the notion of bilaterality of verbal functions in females. One of the earliest referred to studies of the differential effects of brain damage to males and females was reported by Lansdell (1961). He noted that following left hemisphere temporal lobe operations, women's scores on an explanation-of-proverbs test were unaffected whereas men's scores dropped. This suggested to Lansdell that bilateral verbal functions existed in females but not males.

More recently, sex differences in the incidence and severity of aphasia in stroke victims and brain damaged individuals have been one of the most frequently cited sources for support of female bilaterality of verbal abilities. In a recent study (McGlone, 1977) of 55 men and 37 women who had sustained either left or right hemisphere lesions, aphasia associated with left hemisphere damage occurred three times more frequently in males than females. In contrast, with right hemisphere damage, women were the only group to show some decrease in verbal abilities relative to a normal control sample. Based on these data, McGlone (1977) concluded that "sex differences may exist in degree of bilateral

speech representation, and/or in regional specialization of verbal functions within the left hemisphere" (p. 787). Thus, the implication of these findings is that the right hemisphere of females has sufficient language representation to compensate for (or mask) damage sustained to left hemisphere speech areas, or that language functions are distributed differently in the left hemisphere of females.

Further evidence for bilateral representation of verbal functions in females comes from studies of neuropsychologically intact individuals. Harshman et al. (1976) pooled the data from previously reported dichotic listening studies and found a greater right ear advantage in males than females. Lake and Bryden (1976) have also found an overall significant sex difference with males as compared with females showing a greater right ear advantage for consonant-vowel syllables.

Hannay and Malone (1976) tachistoscopically presented a verbal memory task to both sexes and found no visual field differences in females but greater right visual field superiority in males. They concluded that in females "both hemispheres receive and retain verbal information equally well" (p. 203).

In a recent study (Bradshaw et al., 1977) of lexical decision making, words, illegal consonant strings (cvbn), and legal nonwords (sain) were presented tachistoscopically to either the left or right lateral fields and subjects had to indicate if the stimulus was or was not a real word. Results demonstrated that females showed

minimal field differences and responded faster than males who showed the typical asymmetry of response in favor of the left hemisphere. The authors noted that "this greater hemispheric equipotentiality in females at a lexical level may stem from a relatively greater lexical invasion of right-hemisphere space otherwise reserved for visuo-spatial and holistic processing" (p. 283). These findings were later confirmed in a follow-up study (Bradshaw & Gates, 1978).

Anatomical data are also available to suggest structural differences in the right hemisphere of men and women. Although the findings reported above showed a larger planum in the left hemisphere of infant girls but not infant boys, the reverse has been observed in adult brains. Wada et al. (1975) found that adult female brains upon autopsy were more likely to present with a relatively increased right hemisphere speech area than males, although the total incidence of such findings was small. If the right planum temporale can be shown to be larger in females than males, this would also imply that the posterior regions of the right hemisphere which are involved in visual/spatial functions are therefore smaller.

Overall, the evidence for bilateral representation of verbal functions is persuasive and hard to dismiss, although some (Fairweather, 1976; Sherman, 1978) have categorically concluded that all studies of bilateral verbal abilities have shown only minimal support for such a position and are subject to a variety of methodological and interpretational errors.

### Greater and Earlier Right Hemisphere Lateralization in Males

To a large extent, this position is the converse of Levy's (1972) theory; however, Levy did not focus on right hemisphere spatial functioning. That is, Levy (1972) assumed that language functions in females were in part located in the right hemisphere and that this therefore interfered with spatial holistic processing. Nothing specific regarding sex differences in lateralization of visual/spatial functions per se was hypothesized. Other researchers (Witelson, 1974, 1976), however, have looked only at the possibility that spatial functions are more lateralized in males with the possible implication of greater bilateral representation of spatial functions in females.

Clinical populations of individuals with brain damage, temporal lobectomies, and commissurotomies have provided much of the original evidence of greater male lateralization of spatial functions. Lansdell (1962) administered the Graves Design Judgment Test (a test measuring aesthetic and artistic appreciation) to men and women both before and after temporal lobe surgery. For patients who had had the operations on the language dominant hemisphere, scores increased on artistic judgment in men whereas scores for women decreased. The reverse occurred if the operation occurred on the spatial dominant hemisphere: women's scores increased and men's scores decreased. To Lansdell (1962) this suggested that females rely more on their left hemisphere for aesthetic judgment than males. He wrote: "Some physiological mechanism underlying artistic judgment and verbal ability may overlap in the female brain but are in opposite hemispheres

in the male" (p. 854). In later studies, Lansdell (1968a, 1968b) also reported that the lowest WAIS Performance scores (on Block Design and Object Assembly) were observed for males with right hemisphere operations. In addition, the greater the amount of tissue removal on the right side, the greater the drop in Performance scores for males but not for females.

Bogen and colleagues (1969, 1972) have investigated cognitive abilities in males and females following commissurotomies. The specific performance measures were the Street-Figure Completion Test (a spatial task) and the Similarities subtest of the WAIS (a verbal task). All tests were performed with the left hemisphere. Although there were only seven subjects in all (three male and four female), females achieved a higher score on the Street-Figure Completion Test than males, suggesting to the researchers that spatial functions were less lateralized in females prior to surgery.

McGlone and Kertesz (1973) examined 78 patients who had sustained either left or right hemisphere damage. These patients were administered tests of language functions and one test of visual/spatial reasoning--the Block Design subtest of the WAIS. Although the results were not statistically significant, there was a trend ( $p < .10$ ) in the direction of greater impairment of Block Design in males with right hemisphere lesions than in females with right hemisphere lesions. The authors also reported a significant correlation between the language test and the visual/spatial task for females with left-sided lesions. There was not, however, a significant correlation of

these two tests for females with right-sided damage or for males with either left- or right-sided damage. Thus, with left hemisphere impairment, and for females only, the greater the language deficit, the greater the visual/spatial deficit. Although this supports the notion of some spatial processes located in the right hemisphere, McGlone and Kertesz (1973) also feel these results support the view that females rely on some form of verbal mediation on tasks of spatial abilities. In a more recent study (McGlone, 1978), differences between WAIS Verbal IQ's and Performance IQ's were found in males but not in females. That is, for males, left-sided damage led to lower Verbal IQ scores and right-sided damage resulted in lower Performance IQ scores. No such discrepancies, regardless of size of lesion, were observed in females.

Studies of neurologically intact individuals using either lateral tachistoscopic or dichotic listening procedures have also contributed data supporting bilateralization of spatial functions in females. Kimura (1969) originally demonstrated a greater left visual field advantage for males than for females on a dot enumeration task presented tachistoscopically. McGlone and Davidson (1973) also investigated sex differences on verbal and nonverbal tasks and found support for bilateralization of spatial functions in females. In one experiment, 16- and 20-year-olds were given the WAIS Block Design subtest and Thurston's Primary Mental Abilities Spatial Relations Test as well as a dichotic listening procedure for word

recognition. The first finding was that males performed significantly better than females on the Spatial Relations Test. In addition, females who had higher left ear scores on the dichotic test (evidence of right hemisphere language abilities) had the lowest scores on Block Design. This was not the case for males. In a second experiment, females in contrast to males showed a stronger right visual field advantage on a dot enumeration task in support of greater male lateralization.

Other findings that indicate greater asymmetries (i.e., greater right hemisphere processing) in adult nonbrain damaged males than in females have come from studies of dot enumeration (Davidoff, 1977); the perception of directionality and line orientation (Sasanuma & Kobayashi, 1978); and the recognition of faces (Rizzolatti & Buchtel, 1977).

Within a different research paradigm, two studies (Ray et al., 1976; Tucker, 1976) have shown not only greater asymmetries in males for spatial tasks (more right hemisphere processing) but for verbal tasks (more left hemisphere processing) as well. Both studies relied upon electroencephalographic (EEG) analysis of brain activity as each subject performed a variety of tasks. In the first study, Tucker (1976) examined sex differences on two visual/spatial tasks and a vocabulary task. The visual/spatial tasks consisted of one that was assumed to require more perceptual analysis and understanding of part-whole relations (Gottschaldt Embedded Figures Test) and one that would require more synthetic processing by combining what looks like

nonsense designs into synthesized wholes (Mooney Closure Faces Test). There is some indication that the former may be more left hemisphere dependent and the latter more right hemisphere dependent.

The overall findings indicated that the females showed no differences in cortical activity between the hemispheres on the two spatial tasks. However, for males, there was significantly greater activity in the posterior region when performing the synthetic spatial task, although for the analytic spatial task, they relied as much on their left hemisphere. On the vocabulary task, sex differences also emerged. Males showed a greater tendency to use the left temporal region when speed of correct responding was the measure. Females showed no such tendency. Finally, males and females did not "use" the same regions within a hemisphere for solving the Gottschaldt or vocabulary tests. This corresponds to Kimura's (1966) and McGlone's (1977) suggestions of different intra-hemispheric (as well as inter-hemispheric) patterns for the sexes. In general, Tucker (1976) defends both the position that males are more lateralized for some spatial tasks and for some verbal tasks: "Apparently it is predominantly synthetic visuospatial functions for which the right hemisphere is specialized in males...and the left hemisphere is more specialized in males than females for at least some kinds of verbal processing" (p. 452).

Ray et al. (1976) also examined EEG recordings of males and females while they performed four left hemisphere activities (adding numbers, counting verbs in sentences, constructing sentences,

multiplication) and four right hemisphere activities (listening to two kinds of music, and visualizing two different tasks). Again, the results pointed to less lateralization in the female. Males showed greater use of the left hemisphere for left hemisphere tasks and greater activity of the right hemisphere for right hemisphere tasks; females did not show these asymmetries. This suggests differential usage of the hemispheres in females and in males.

All the above studies report findings for adult males and females. What evidence exists for lateralization of spatial functions in children is very scanty, although trends are in the direction of greater lateralization in boys.

In one of the few studies of spatial processing in the auditory modality, Knox and Kimura (1970) presented nonverbal environmental sounds (e.g., dog barking, phone dialing, water draining, power motor) dichotically to boys and girls (all right handers) between the ages of five and eight. Results indicated that more sounds were correctly identified from the left ear (right hemisphere) than from the right ear at each age and for each sex. When scores were examined for sex differences, the combined left ear score plus right ear score was greater for boys than girls at all four ages with the total score significantly greater for boys than girls. Although these findings do not specifically indicate greater right hemisphere lateralization in males, Knox and Kimura (1970) reasoned that these overall differences could not be explained in any way except "in terms of sex differences in neural functioning" (p. 236).

Bakker (1967) presented monaural sounds (each ear successively rather than simultaneously) of Morse-like patterns to 6-to 12-year-old boys and girls. The patterns consisted of three to five elements that were to be reproduced by a buzzer. Results indicated greater left ear scores in younger boys but not in girls, and by age 10 the left ear advantage no longer existed in males. Witelson (1977b), however, points out that Morse-like code sounds should perhaps be processed by the left hemisphere (right ear) because of the sequential nature of the task.

Two other studies that are unpublished (Anderson & Barry, 1976; McFarlane & Witelson, 1976) using dichotic presentation of sounds are reported by Witelson (1977b). In the former, no ear difference at any of four age levels (4, 5, 8, and 11) was observed for environmental sounds and no sex analysis was performed. In the latter study, the left ear advantage was obtained for boys only (ages 9 through 11).

Several studies employing electrophysiological measures have examined infants' responses to various nonverbal and verbal stimuli. Molfese, Freeman, and Palermo (1975) measured evoked potentials in 10 male and female infants with a mean age 5.8 months. Each infant showed a larger right hemisphere response to a burst of noise and to a C-Major piano chord. With older children, 4-to 11-years-old, the same authors (1975) found all 11 showing the greater right hemisphere potentials to the chord and 9 of the 11 to the noise stimulus. Gardiner and Walter (1976) also demonstrated in four six-month-old infants, right hemisphere changes in EEG's during presentation of music

segments. None of these studies, however, analyzed sex differences.

Tachistoscopic studies of spatial functions are equally few. Two studies have tachistoscopically presented a face recognition test, with findings in favor of a left visual field advantage. Marcel and Rajan (1975) demonstrated this for children aged seven to nine. Young and Ellis (1976) found the left field advantage in 5-, 7-, and 11-year olds. However, none of the above data were analyzed for sex differences. One recent study (Young & Bion, 1979) found greater overall accuracy in the left visual field for a dot enumeration task in 5-, 7-, and 11-year-olds. In addition, when the data were analyzed for sex differences, boys showed a greater degree of lateralization than girls.

The strongest evidence for greater lateralization in boys comes from studies of tactile exploration. Witelson (1974) designed a dichaptic shapes test in which 10 different shapes (meaningless and unfamiliar) were combined into five pairs. Boys, ages 6 to 14, examined (palpated) out of sight each pair simultaneously. This was followed by a visual recognition trial in which the two stimuli were presented with four other choices. Overall, there were more correct identifications for stimuli presented to the left hand (right hemisphere) than to the right hand.

In a follow-up study, Witelson (1976) presented the same nonsense shape task to 200 boys and girls between the ages of 6 and 13. Greater left hand scores were again observed but by boys only. The girls did not demonstrate any significant differences between hands.

Witelson (1976) concluded from these two studies that the right hemisphere is more specialized for spatial processing in boys than in girls as early as age 6 and at least through 13 years of age.

In a recent extension of Witelson's (1974, 1976, 1977b) work, Cioffi and Kandel (1979) presented pairs of (1) nonsense shapes; (2) two letter words such as TO - IT; WE - BE; and (3) consonant bigrams such as CM - GC; SV - VL to 6- and 14-year-olds. Each subject simultaneously explored one of the forms or letter combinations with their left hand and one with their right hand. Results showed that boys did better with their left hand on the bigrams but girls did better with their right hand on the bigrams. This suggests the possibility that girls prefer to code material through verbal (left hemisphere) processes. The authors themselves concluded that: "The brains of boys and girls may be differently organized for the cognitive processes involved in reading" (p. 1434).

A final study of sex differences in spatial skills used a Braille reading task (Rudel et al., 1974). In this study 80 children ranging from 7 to 14 learned six Braille letters with one hand and six different letters with the other hand. Half of the children learned with the left hand first and the right second; the other half reversed this order. (Braille is almost always "read" by the left hand.) The children's hands were placed behind a screen and the experimenter took each subject's hand and moved it across the Braille print while telling the subject the letter he was feeling. Following this, each Braille letter was presented to the left and

to the right hands individually and the subjects had to correctly identify which alphabetical letter the pattern of dots represented. In general, boys' left hand scores were greater than girls' left hand scores for all trials combined, indicating again a right hemisphere bias in males for spatial processing. In addition, it was also found that girls did very poorly when they first had to learn with their left hand, suggesting that not only may spatial processing in females be primarily a left hemisphere task, but also that females may "prefer" to process spatial patterns as a verbal task. Thus, as in the study by Cioffi and Kandel (1979), attaching a verbal component to an otherwise spatial task may facilitate right hemisphere processing in females.

Earlier Left Language Lateralization in Females But Subsequent Bilateralization of Language in Adulthood, Males More Lateralized in Adulthood

To some extent, this fourth position combines elements of the data described above but adds a developmental factor. Essentially, females are more lateralized for language functions in the early years because of maturational differences, but males eventually surpass females and by adulthood males are more lateralized for both verbal and spatial functions (Harshman & Remington, 1976). Following reasoning similar to Levy's (1972), greater asymmetries confer an advantage for solving spatial problems in males, while in females, bilateralization of language at adulthood confers a disadvantage.

This viewpoint, like Buffery and Gray's (1972), has attempted to consider the literature showing that females are more verbally precocious in early years, although there has not been universal support for this notion. In addition, little developmental literature within a neuropsychological framework exists to point to a shift in lateralization in girls or to support greater left hemisphere language functions in female infants or children as compared to male infants and preadolescents. In fact, the literature (e.g., Witelson, 1977b) in general points to a right ear advantage for verbal stimuli at all age levels with only some occasional trends toward a greater right ear advantage in females than males (e.g., Kimura, 1967). There is even less evidence in the lateral tachistoscopic studies using verbal material to support greater left hemisphere processing in girls as compared with boys in childhood. The rest of Harshman and Remington's (1976) position--greater lateralization in adult males--is supported by the data cited for Levy's position as well as the data cited for Witelson's (1976) view.

#### Summary of Lateralization Theories and Developmental Trends

In evaluation of the four theoretical statements, Buffery and Gray's (1972) view of bilateral spatial representation in males receives the least support. Their belief in greater female lateralization for verbal functions must also be met with caution since the literature is not conclusive as to whether there is earlier language usage in females. In addition, there is essentially no evidence that

girls as compared to boys show any significant left hemisphere advantage on dichotic listening tasks or tachistoscopic presentations. On the other hand, the remaining three positions merit more research: Harshman and Remington's (1976) view of greater lateralization of both hemispheres in adult males; Witelson's (1976) separate focus on greater right hemisphere specialization for spatial functions in males; and Levy's (1972) bias in favor of greater left hemisphere specialization for verbal functions in males.

When the data from all four positions are considered, little can be concluded regarding developmental trends in boys and girls. Because of the different ages and tasks, no specific patterns have emerged to date except for a probable right hemisphere advantage in males for spatial processes from early childhood on into adulthood. This conclusion, however, is based largely on dichaptic (tactile) tasks (e.g., Witelson, 1976) presented to children, and, therefore, must be considered tenuous.

### Sex Differences in Cognitive Strategies

#### Preference for Verbal Analysis in Females

Another approach for explaining the generally better performance of males on spatial tasks focuses not directly on lateralization differences, but on the possibility that males and females differ in terms of their preferred information processing strategies (Harris, 1978). This has been alluded to in the above literature review and what this suggests is that females may prefer verbal mediation for all

types of cognitive tasks--whether verbal or spatial. Males, however, may be more "differentiated" and rely only on verbal (left hemisphere) codes for verbal problems, and spatial (right hemisphere) codes for spatial problems. Thus, actual ability for spatial skills does not differ between the sexes, but, rather, the performance differences result from females attempting to use inappropriate verbal coding strategies. Females would thus be at a disadvantage when applying verbal analysis to spatial problems. The reason(s) for this "strategy" difference may stem from differences in hemispheric lateralization as described by the theories above; and/or different developmental learning experiences; and/or earlier verbal precociousness in females which predispose them to favor verbal analysis for all types of problem solving and information processing.

There is no doubt that information can be coded in memory either verbally or visually (e.g., Bower, 1972; Conrad, 1964; Paivio, 1969; Posner et al., 1969). Studies of hemispheric functions have also shown that the same information can be processed either through a left or right hemisphere channel depending on the presentation of the material (Bryden & Allard, 1976) or the instructions to the subject (Geffen et al., 1972; Seamon & Gazzaniga, 1973). Other researchers have stressed that verbal coding and verbal rule learning play an important part in general cognitive analysis (Beilin, 1971). The question, however, still remains as to whether verbal coding of complex spatial manipulations is a feasible alternative to direct

spatial processing per se (Cooper & Shepard, 1978; Huttenlocher & Presson, 1973; Metzler & Shepard, 1974).

Cooper and Shepard (1978) raise the question of what processes a subject engages in and the nature of the internal representations that are formed when trying to imagine how a three-dimensional line drawing of cubical blocks attached at different angles will look rotated in space. They write:

Are these representations the result of an analysis and recoding of the visual stimuli into some discrete lists of features, verbal descriptions, or other propositional structures, or are they the result of the internal formation of some sort of more holistic, isomorphic models of the corresponding physical stimuli? (Cooper & Shepard, 1978, p. 111).

Along these same lines, Metzler and Shepard (1974) had earlier suggested that subjects could possibly code these three-dimensional objects through a series of verbal descriptions (e.g., "a right-angle bend") and then use these codes to reconstruct the forms.

Although no direct tests of sex differences in strategy preferences are known, there are data that have been used to support the view that females are more "verbal" in their problem solving strategies. Harris (1978) has reviewed the literature and found some evidence to support the position that language ability is a more reliable predictor of intelligence in girls than in boys. Such findings occurred in a study by Cameron et al. (1967) in which vocalization scores between 5 and 13 months correlated with later Stanford-Binet IQ's obtained between 6 and 26 years for girls. Girls with high vocalization scores had high IQ's later in life while girls with

low vocalization scores had low IQ's. There was, however, no correlation for boys. Moore (1967) also found similar results for a group of boys and girls tested at 6 and 18 months and at 3, 5, and 8 years of age. Only the girls' scores on language tests (e.g., frequency of babbling, spontaneous talking) reliably predicted later intelligence scores.

Several of the earlier neuropsychological studies cited above have also been reevaluated (Harris, 1978) in terms of sex differences in strategy preferences. For instance, in the Lansdell (1962) study of aesthetic judgment, males performed better with an intact right hemisphere (for spatial evaluation) whereas females performed better with an intact left hemisphere (a verbal evaluation of a right hemisphere task). In other words, females may have preferred a left hemisphere verbal route in the solution of this type of spatial problem. This, therefore, would explain why they did poorly when the right hemisphere was "forced" (as a result of brain damage) to process this task.

In another study, McGlone and Kertesz (1973) suggested that their data "provide new evidence that verbal processes may play a significant role in 'nonverbal' activities, and that females make more use of such verbal mediation" (p. 318). In their study, Block Design scores correlated significantly with measures of verbal abilities for women with left-sided lesions. This was not the case for women with right-sided lesions or for males with either left- or right-sided damage. In other words, instead of implying that women

are bilateral in spatial representation, they "use" their left hemisphere and its analytic, sequential, linguistic mode for solving spatial problems as well as for solving obvious verbal problems. This, then, becomes the explanation for the inferior performance by females in contrast to males on various types of spatial problems-- particularly those spatial problems least amenable to verbal encoding.

The above studies suggest a greater correlation between verbal and spatial performances in females than in males, possibly inferring a "common" processing route for females. A more direct way of determining the possible validity of the notion of preferential cognitive modes would be to offer two different problem solving strategies (verbal and spatial) and then determine if one is more beneficial for men or for women. Although there appear to be no studies following this paradigm, one recent investigation suggests possible sex differences in the use of verbal and spatial codes. Seamon and Gazzaniga (1973) originally showed that more correct right hemisphere recognitions resulted from instructions to imagine an interaction between objects depicted by two words, while more correct left hemisphere recognitions resulted from instructions to verbally rehearse the words. Metzger and Antes (1976), by extending this work to include an analysis of sex differences, found an indication that males do better with imagery instructions while females do better with rehearsal strategies.

Another study has found possible differences between the type of information to which each sex attends. Kail and Siegel (1978) examined sex differences in the ability to remember position cues.

They tachistoscopically presented 3 X 3 matrices to each lateral field. Within each matrix, four digits (a verbal task) were randomly placed in four different cells (the position of the digits in the cells being the spatial right hemisphere task). With this simultaneous (both verbal and spatial) task, men recalled more information about spatial position while females recalled more information about digits.

#### Interference in Hemispheric Functioning in Males

The above study by Kail and Siegel (1978), although significant in showing recall preferences, is of equal interest for the possible implications for sex differences in availability of more than one cognitive strategy. Kail and Siegel (1978) reported that males' recall of positions did not differ reliably between the left and right hemispheres. One possible explanation for this finding (one would supposedly expect greater asymmetries for males on spatial tasks) involves an "interference" model. In other words, when both verbal and spatial information are presented simultaneously, the greater lateralization of functions in males creates "noise" in the processing system. Allard and Bryden (1979) have found some results in agreement with this possibility. When males were given a concurrent verbal task (list memorization) with a task of dot detectability, their scores for the usual left visual field superiority declined more than the scores of females, indicating what Allard and Bryden consider to be an interference effect between spatial and verbal tasks in males.

The notion of interference can also be applied to several studies discussed earlier that provided tasks with both a verbal and spatial component. Although these studies support the role of verbal analysis for females, they likewise suggest that whereas females may benefit from both types of analyses, males may not.

In the first study, Rudel et al. (1974) interpreted the results of their Braille study within the framework of sex differences in cognitive modes of analyses. In that study, the worse performance was in the group of girls who were first taught Braille with their left hand. However, the best performance occurred for girls receiving right hand training first. What can be postulated, therefore, is that the left hand (right spatial hemisphere) in females was inefficient at processing the Braille patterns until there had been experience with the right hand (left hemisphere) and thus verbal encoding. Rudel et al. (1974) suggested that "overtly or covertly, children may use language to codify the difficult discriminations..., and it may be that girls rely more heavily on such language strategies than do boys" (p. 737). Although they did not suggest how language may have been an aid for the girls, it is possible that the dot configurations could have been coded in the form of "two dots on the left, three on the right, etc."

This point can also be strengthened by extrapolating data from the charts and graphs appearing in the Rudel et al. (1974) study. Although they reported no overall analysis of accuracy scores for the sexes, the figures showed that the girls, but not the boys, had higher

average scores across all ages except in the one case in which the girls' left hands were trained first. Otherwise, girls exceeded the performance of males on what can be viewed as both a spatial and verbal task. Furthermore, at all age levels, average right hand scores (whether trained first or second) were always higher for the girls than the boys. In a similar vein, Witelson (1977c) reported data that seemed to show that girls outperformed boys on both the left and right hands on a dichaptic letters test. What the results of these findings point to is the possibility that males are at a disadvantage when a spatial task has a verbal component and when that task is processed exclusively by the left or right hemisphere.

Although the idea of interference between and within the hemispheres of either males or females has not been directly addressed in the literature, studies of learning disabilities have long inferred the possibility of an interference model for males. The high incidence of dyslexia in boys but not in girls has been attributed to atypical cerebral lateralization and processing of functions (Benton, 1975; Orton, 1937; Satz & Sparrow, 1970), and in particular to the fact that the neural substrate underlying the greater asymmetries of the male leave it more susceptible to disruption (Witelson, 1977a). In other words, the relatively high degree of "specialization" of the hemispheres in males: (1) increases the probability that should there be a dysfunction in the neural organization, it will be more readily manifested; and/or (2) decreases the flexibility in compensating for or adjusting to changes; handling an overload; and/or processing functions "non-native" to a given hemisphere.

## CHAPTER II

Rationale and Hypotheses

Based on the above literature review, two interrelated factors emerge that have been offered as explanations for why males, as compared with females, frequently perform at higher levels on spatial tasks. The first involves the observation of greater hemispheric lateralization and specialization in males for both verbal and spatial functions. The second involves the assumption that females "prefer" to code and process all information in a linguistic, verbal form. Since spatial information is not easily translated into a verbal descriptive system, females are at a disadvantage when performing spatial tasks. This preference for verbal analysis is assumed to stem from the relatively greater bilateralization of hemispheric functions in females and perhaps from an early maturational advantage in language development that predisposes them to favor language strategies in later years. In addition, a corollary to the differences in lateralization between males and females suggests that the greater hemispheric lateralization and specialization in males leads to a greater degree of "inflexibility" and a greater potential for "disruption" in each hemisphere's functioning. Females, however, because of the relative sharing of hemispheric functions, are less susceptible to interference from an incompatibility of verbal and spatial processes. Finally, the lateralization differences in males and females are assumed to follow a developmental course, although the exact nature of

this progress is unclear as there are virtually no investigations of the changes that occur from infancy to childhood.

This interpretation of the underlying basis for the performance differences between males and females on spatial tasks presumes that capacity for spatial functions does not differ between the sexes; rather, the cognitive approach for processing spatial information is assumed to differ. However, in the research to date, the notion that verbal mediation is the preferred cognitive strategy for females has only been inferred. No actual studies have attempted to change performance on spatial tasks by teaching a nonspatial or verbal solution. The other untested assumption is that males not only do not prefer verbal mediation, but that because of the greater degree of hemispheric specialization, the use of a "nonnatural" cognitive strategy (i.e., language for right hemisphere spatial problems) or the use of two different strategies simultaneously may actually hinder performance, particularly at the level of single hemisphere processing.

With this background, the following summarizes the specific questions addressed in the current study:

- (1) Can a verbal descriptive system applied to a spatial task raise the performance level of females; and does this differentially affect the processing of information in each hemisphere?
- (2) Will verbal labeling also aid the processing of spatial information in males or will it result in

an interference effect? Will there be a differential effect for each hemisphere?

- (3) Are there changes over the course of development in hemispheric lateralization and functions in males and females? Does verbal training have a parallel or different effect at different ages?

The specific spatial task selected for investigation involved the perception of directionality of lines in space. Research findings have demonstrated that directionality is primarily a right hemisphere "spatial" task (Benton et al., 1973, 1978; Fontenot & Benton, 1971; Kimura & Durnford, 1974); and, where sex differences have been examined, the findings have indicated right hemisphere processing in males but relatively greater bilateral processing in females (Susanuma & Kobayashi, 1978). If verbal description aids the processing of spatial information in females, then teaching girls to verbally label the direction of lines should facilitate their performance relative to males.

The verbal training procedure designed for this study involved teaching subjects that lines of different orientations could be described or labeled by reference to one of four basic words: left (↖), right (↗), across (—), straight (|). This procedure was used to determine the effects of verbal labeling as well as to study the question of whether males experience a disruption of hemispheric functioning when asked to make same/different comparisons between spatial information (lines) and their equivalent verbal

representations (the letter abbreviation for each word [e.g., "L" for left, etc.]).

To determine hemispheric lateralization, the spatial task (the perception of line orientation) was presented tachistoscopically to the left and right lateral visual fields. Stimuli seen by the left half of each eye (left lateral field) are sent to the right hemisphere and stimuli seen by the right half of each eye (right lateral field) are sent to the left hemisphere. Information presented in the center of the visual field projects to both hemispheres. The specific measures of laterality consisted of the number of correct line drawings or recognitions in each lateral field (and thus in each hemisphere), and the number of correct comparisons of verbal and spatial information presented in each lateral field.

In order to shed some light on the development of lateralization, two age groups--10- and 14-year-olds--served as the subject population. Ten years of age was chosen to insure that the task was not beyond a child's cognitive capability. The discrimination of directionality of lines is relatively difficult for children younger than seven or eight (Gibson, 1969). Piagetian literature (Piaget & Inhelder, 1971) also indicates that the ability to manipulate mental imagery and make spatial transformations emerges with the concrete operational age of development. Although the perception of the directionality of line slant does not involve transformations, it does involve the capacity to process coordinates in space.

Fourteen years of age was selected in light of research showing

this age as the time at which reliable sex differences appear on spatial tasks (Harris, 1978). In addition, research has suggested that sex differences on cognitive tasks may be influenced by maturational factors and the rate of emergence of adolescence (Petersen, 1976; Waber, 1977). Fourteen was thus felt to be beyond the main transitional period between childhood and adolescence for both boys and girls. The inclusion of these two age groups, therefore, was to permit a possible statement about changes in hemispheric lateralization during development for both boys and girls.

From the above literature review, the following hypotheses were proposed for the perception of directionality:

Without verbal training,

- (a) overall accuracy for boys and girls would not differ.

That is, combined left and right hemisphere responses for boys would be equivalent to combined left and right hemisphere responses for girls. This was based on several studies (e.g., Witelson, 1976) cited above in which no overall performance differences were observed,

- (b) boys, as compared with girls, would show a relatively greater degree of right hemisphere lateralization (more correct right hemisphere responses than left hemisphere responses). This was based on the greater lateralization of spatial functions in males,

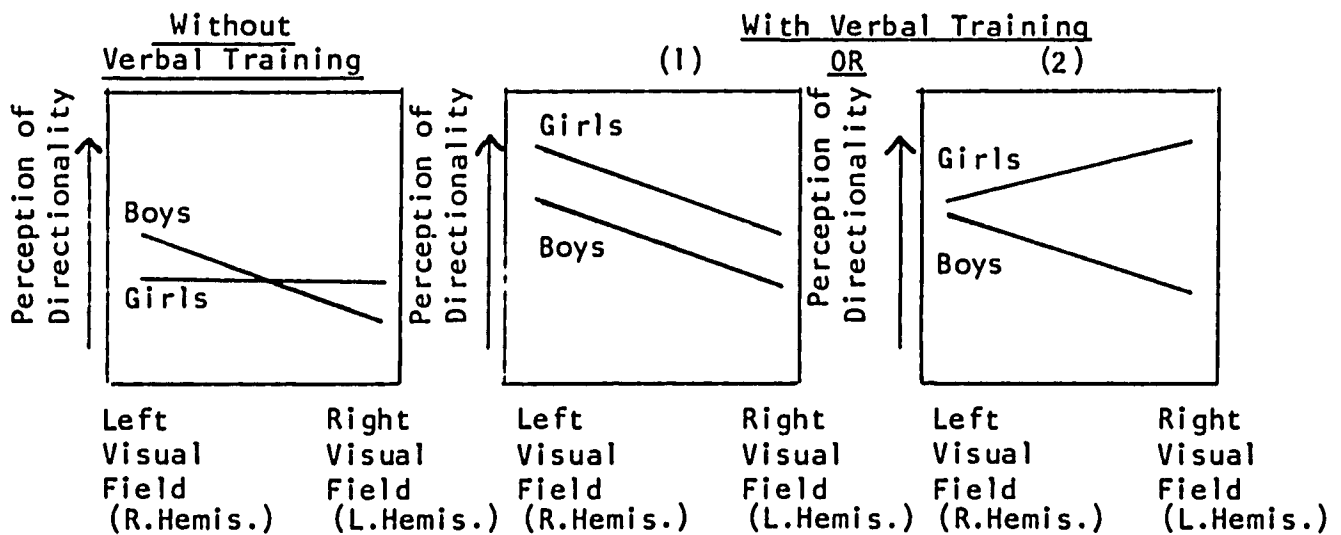
- (c) girls would demonstrate bilateral processing of directionality (left hemisphere responses would be equal to right hemisphere responses). This was based on the relatively greater bilateralization of functions in females.

Following verbal training,

- (d) overall accuracy for boys and girls would increase but girls would demonstrate relatively greater gains than boys. This was derived from the relatively greater bilateralization of verbal and spatial functions in girls, and the relatively greater lateralization of functions in males, and from a predicted relative inability in males of a single hemisphere to process both verbal and spatial information,
- (e) boys would still show greater right hemisphere than left hemisphere responding. This was based on the assumption that the left hemisphere cannot process spatial information because of the greater lateralization of functions in males,
- (f) girls were expected to demonstrate gains in both hemispheres, although the right hemisphere was expected to surpass the performance of the left. Right hemisphere gains were expected because of the initial relative "inefficiency" of the right

hemisphere to process spatial information without verbal cues. Left hemisphere gains were expected because the relative bilateralization of functions in females enables the left hemisphere to process both spatial and verbal information. (Greater left hemisphere gains could also be expected on the basis of Rudel et al.'s (1974) study and on the basis of the preference for verbal analysis.)

The following summarizes the above hypotheses:



- 1) Following verbal training, data supportive of (1) above would favor the view that girls prefer to solve spatial tasks through a right hemisphere channel (although language located within the right hemisphere may facilitate right hemisphere performance).

- 2) Following verbal training, data supportive of (2) above would offer evidence that girls prefer to process spatial tasks (if a verbal component is available) through a left hemisphere route.

As a result of requiring subjects to make comparisons of verbal and spatial material either successively or simultaneously,

- (g) boys, as compared to girls, were expected to demonstrate an interference effect in both hemispheres with overall accuracy for boys less than that for girls.

With reference to the course of development,

- (h) overall accuracy for the perception of directionality for boys and girls was expected to improve with age.
- (i) differences between left and right hemisphere performances would be more pronounced in the older age group.

To answer the above hypotheses, three experimental designs were followed. In Design 1, fifth and ninth grade boys and girls who had received no training (Control subjects) were given two conditions. One required them to reproduce (by free-hand drawing) lines of various orientations. The second required that they choose from several alternatives the lines that matched those just shown. Another group of fifth and ninth grade boys and girls received the verbal training procedure (Experimental subjects) and were asked to complete the above free drawing and recognition conditions. The Control subjects provided information to determine the performance levels of boys and girls at two age levels [Hypotheses (a), (b), (c), (h), and (i)]

while a comparison of the performances of the Control subjects and Experimental subjects examined the effects of training on perception of line directionality [Hypotheses (d), (e), and (f)].

Design II involved Experimental subjects only and looked at the relative abilities of boys and girls at two age levels to make correct judgments about the congruence or noncongruence of spatial stimuli (lines of different orientations) and verbal stimuli (the letter abbreviation of the words representing the lines--left, right, straight, across). Each subject received two conditions. One asked them to judge if letter abbreviations (e.g., "L") presented in the center field matched line orientations presented to the lateral fields (letter-to-line matching). The second asked subjects to judge if lines presented in the center field matched letters presented to the lateral fields (line-to-letter matching). Both of these conditions required successive matches of two different representations (lines and letter abbreviations) and examined the question of interference when shifting back and forth between two types of cognitive strategies [Hypothesis (g)].

Design III also involved Experimental subjects only and required that they make judgments regarding the congruence of lines and letter abbreviations presented simultaneously to a single lateral field. This condition looked at the possibility of interference when processing the two representations simultaneously [Hypothesis (g)].

## CHAPTER III

MethodDesign

The current study involved three research designs. Design I examined the perception of directionality in the left and right hemispheres as a function of sex, grade (fifth and ninth), and treatment (verbal training [Experimental] versus no verbal training [Control]). Design I was employed twice: once with responses from free drawing trials and once for responses from recognition trails. Design II examined the performance levels of the left and right hemispheres of trained subjects (Experimental group) only on two conditions (letter-to-line successive matches and line-to-letter successive matches) as a function of sex and grade. Design III examined the performance levels of the left and right hemispheres of Experimental subjects only on simultaneous letter-and-line matches as a function of sex and grade.

Subjects

Subjects consisted of 96 Caucasian students: 48 fifth graders enrolled in one New York City Public Elementary School and 48 ninth graders enrolled in one New York City Public High School. In general, both schools contained middle-class, achievement-oriented students. This was determined by the socioeconomic level of the surrounding neighborhood for the elementary school and by a special "selective" high school admission examination required by the high school. The fifth graders ranged in age from 10 years, 1 month to 10 years, 12

months (mean age, 10 years, 7 months), while the ninth graders ranged in age from 14 years, 2 months to 15 years, 3 months (mean age, 14 years, 6 months).

Within each grade, half (24) of the subjects were boys and half (24) were girls. Half (12) of the boys and half (12) of the girls at each grade level were randomly placed in the Control (no verbal training) group, while the remaining half of the boys and girls were placed in the Experimental (verbal training) group.

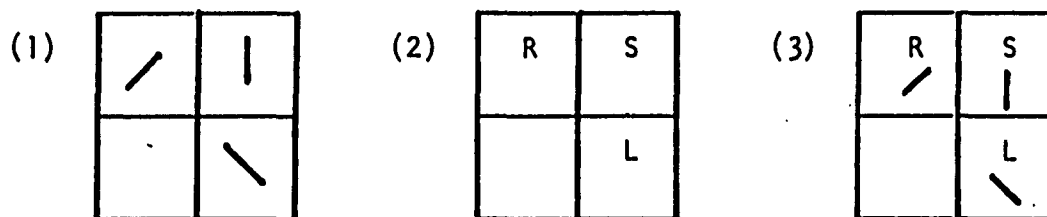
All subjects were right-handed as determined by the Harris (1955) Test of Laterality. In addition to right-handedness, all subjects were right-eyed. There is evidence (Denckla & Rudel, 1979) suggesting that mixed hand and eye dominance (e.g., left-eyed, right-handed) may be an indication of some degree of atypical organization of hemispheric functions.

### Apparatus

The testing equipment consisted of a Kodak Carousel 650H projector equipped with a tachistoscopic shutter mechanism and a Gerbrands "300" series digital millisecond timer to control the exposure duration of each slide. For viewing the slides, a rear projection screen was placed between the projector and the subject, approximately 1.63 m from the projector and approximately .61 m from the subject. To serve as the center fixation point for each slide presentation, a white dot (.64 cm in diameter) was placed in the center of the screen.

### Stimuli

For all conditions, the basic stimuli consisted of twelve 2 X 2 square matrices drawn in black ink on white paper. Within each matrix, one cell was always empty while the other three cells, depending on the particular treatment condition, contained one of the following specific types of information: (1) a single black line in each of the three cells drawn in one of 12 directions as represented by 15° intervals ranging from 0° to 165° (e.g., 0°, 15°, 30°, etc.); (2) a single black upper case letter ("R" for right, "L" for left, "A" for across, or "S" for straight); or (3) a single black line and a single letter.



The choice of the four words was based on the four types of line slant. Lines drawn at 15° to 75° were labeled "left" lines (e.g., \, \); lines drawn at 105° to 165° were labeled "right" lines (e.g., /, /); a line at 0° was an "across" line (e.g., —); and a line at 90° was a "straight" line (e.g., |).

The 12 standard matrices were constructed according to the following rules. The empty cell occurred equally among the four spaces; two of the three cells contained a line drawn at a "left" or "right" slant (e.g., 15°, 45°, 120°, etc.); the remaining third cell contained a line drawn at either 0° or 90°. Of the total 36 lines for the 12

matrices as a whole, 6 were  $0^{\circ}$ ; 6 were  $90^{\circ}$ ; 12 slanted to the left ( $\backslash$ ); and 12 slanted to the right ( $/$ ). The specific three cells that contained the lines varied randomly for each of the 12 matrices. The rationale for placing lines in only three of the four cells was based on the need to eliminate a linear display (e.g.,  $\backslash / \backslash$ ) which could have been subject to Gestalt principles of closure and thus more readily processed as a configuration. The literature suggests that simple pattern recognition seldom leads to significant hemisphere differences in accuracy (Umiltà et al., 1978). In addition, the unpredictability of the one empty space should have decreased the probability of left-right scanning tendencies.

The 12 "line" matrices served as the standards from which to construct the matrices containing letters and the matrices containing both lines and letters. Each of the 12 matrices was drawn twice--once to the left of center for presentation to the left visual field and once to the right of center for presentation to the right visual field. With one matrix presented per trial, there were thus 24 trials for each condition. The matrices were photographed with 135 mm Ektachrome slide film. Once projected onto the screen, the inside edge of the right matrix was  $2^{\circ}$  to the right of the center and the inside edge of the left matrix was  $2^{\circ}$  to the left of the center. The matrices were 6 mm square with each letter 1.25 cm high and each line 1.25 cm in length.

### Procedure

Each subject was tested individually and each subject was seen

one time only. For subjects in the Control group, the procedure lasted approximately 15 to 20 minutes. For those subjects in the Experimental group, training and testing took approximately 45 to 50 minutes. In general, fifth graders took about an additional 5 minutes per group. Each subject in both the Control and Experimental groups was first given tests for handedness and eyedness. The handedness test was taken from the Harris (1955) Test of Laterality and required that subjects demonstrate right-hand preference on 9 of 10 items composed of questions such as "With which hand do you write?, comb your hair?, cut?," etc. An additional requirement included right-eyedness as determined by asking each subject to look with one eye only through a paper telescope. Eight fifth graders and three ninth graders demonstrated mixed dominance and were given an abbreviated version of one of the treatment conditions and then excused.

In general, all subjects were told that the project required that they try to remember the direction in which lines were drawn. Variations of these instructions occurred for each of the five conditions. The only other general instruction given to all subjects stressed the importance of always attending to the center white dot. It was explained that since all information would be shown for 50 msec only (each subject was shown how fast 50 msec was), it would be very easy to miss something by looking away for an instant or by blinking. This point was further emphasized by explaining that the stimuli would sometimes occur to the left of center and sometimes to the right of center. Since it would not be possible to predict

which side would contain information on any one presentation, the best way to see everything was to focus in the center. To insure that subjects were indeed focusing on the center, one of three different types of information (the letter "M", the number "6", and a star) occurred in the center for 20 msec on random trials (4, 12, 17). Subjects were told that occasionally "something" would occur in the center and that they should be prepared to call out this center information.

Control subjects were administered two conditions: free drawing and recognition. In the free drawing condition, subjects were asked to draw each of the three lines as they appeared in each of the three matrix cells. In the recognition condition, subjects were asked to choose which one of four matrices was identical to the one just viewed on the screen.

All Experimental subjects were first given a training exercise in which they were taught: (a) to label lines by the direction of slant (either "L" for left; "R" for right; "S" for straight; or "A" for across); and (b) to illustrate letters by drawing lines corresponding to the direction the letters indicated. Following these exercises, subjects were administered five conditions: the first two (free drawing and recognition) were identical to the two received by the Control subjects and served to study the effects of training on the accuracy of line drawing and line recognition. The next three examined the ability to make rapid comparisons between letters and lines. In the letter-to-line condition, subjects were

shown a "letter" matrix in the central field and then asked if a "line" matrix presented to either the left or right field corresponded to the "letter" matrix. For instance, the center "letter" matrix

A	R
	L

does not match the "line" matrix

—	/
	/

presented to the lateral field because the lower right cells do not agree. That is, the letter "L" refers to the left, but the line "/" is pointing to the right. In the line-to-letter condition, the reverse procedure occurred. Subjects were shown a "line" matrix in the center and then a "letter" matrix in one of the two lateral fields and asked if each of the lines and letters matched in all three cells. In the letter-and-line condition, both the lines and letters were

shown simultaneously  $\left( \begin{array}{|c|c|} \hline A & R \\ \hline \text{—} & / \\ \hline & L \\ \hline & / \\ \hline \end{array} \right)$  in the same field and sub-

jects had to indicate if the line and letter in each cell matched. These three conditions attempted to answer the question of whether there are sex differences in hemispheric laterality for processing two types of information (spatial and verbal) successively (letter-to-line; line-to-letter) or simultaneously (letter-and-line).

All conditions were presented in the same order except for the two successive conditions in which half of the subjects received the

letter-to-line condition first while the other half received the line-to-letter condition first. Since these two conditions could be directly compared for possible differences in processing letters-to-lines and lines-to-letters, it was necessary to eliminate any practice effect that might accrue from giving one first followed always by the other one second.

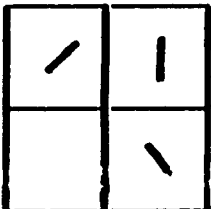
Each of the five conditions always involved 24 trials with 12 matrices randomly presented to the left and the same 12 randomly presented to the right. Each of the conditions for the Control and Experimental subjects was preceded by two practice trials to insure that subjects understood the basic task required of them.

All of the conditions for the Control and Experimental subjects are described more fully below.

### Control Group

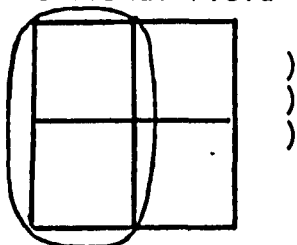
#### Free Drawing

The stimuli used in this condition consisted of the 12 "line"

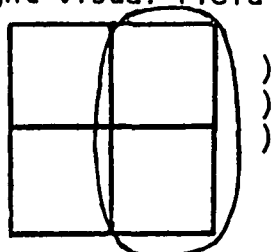
matrices (e.g.,  ) presented randomly one time to the

left and one time to the right for a total of 24 trials. Each matrix was shown on the viewing screen for 50 msec followed by a 5 second period during which the subject was to draw each of the three lines in the correct three cells. Immediately following this 5 second

period, a second matrix was shown for 50 msec and the same 5 second period was provided in which to draw the lines for this second matrix. Because the empty cell varied for each matrix, subjects were instructed to attend to both the direction of lines as well as to the position of the empty cell. For their drawings, each subject was provided an answer sheet consisting of 24 empty matrices. For scoring purposes, each line drawn was considered correct only if it was reproduced in the same orientation and in the same cell. Two independent scorers judged the "correctness" of the lines of the 48 ninth graders. Of the more than 3000 lines, disagreement occurred on less than 20. Two response measures were available from the free drawing procedure: (1) the total number of correct drawings in each lateral field; and (2) the total number of correct drawings only in the far left

two cells of matrices presented to the left (e.g.,  )

and in the far right two cells of matrices presented to the right

(e.g.,  ). Since four fifth graders and two ninth

graders failed to correctly identify the center fixation data, it was possible that attention was not always focused in the center. The inner cells were felt, therefore, to carry a higher probability of being

processed by a single lateral field. Subjects had also reported during pilot testing that it was easier "to see" the two inner most cells.

### Recognition

This condition also consisted of 24 trials (the same standard 12 matrices randomly presented once to the left and once to the right) with each matrix shown for 50 msec. Following this 50 msec presentation, each subject was given 5 seconds to select one of four matrices that matched the one just seen. These four choice matrices were drawn in a row on answer sheets and the subject had to mark his choice for each trial. This was then followed by a second matrix presented for 50 msec followed by a 5 second period to select the one that matched it. The four choice matrices were constructed according to the following rules: one matrix was identical to the one shown; one had one error (that is, one line in one cell was drawn in a different direction from that presented on the screen); one matrix had two errors; and one matrix had three errors (all three cells were different from that presented). An "error" for a left or right line was defined by a line pointing in the opposite orientation: a "left" line (↖) became a "right" line (↗) and a "right" line became a "left" line. "Straight" and "across" lines were shifted to the right or left depending on the overall configuration of the other lines in each particular matrix. In constructing error matrices, the object was to avoid an easily recognizable error configuration such as three lines in the same direction. The response measure for this condition consisted of the number of correct recognitions in the left visual

field and the number of correct recognitions in the right visual field.

### Experimental Group

All Experimental subjects first received two training exercises, followed by five treatment conditions. The training procedure and the individual conditions are described below.

#### Training

The training phase consisted of two activities to teach subjects to verbally label and describe line directionality. The first exercise consisted of demonstrating to subjects that lines fall into four basic types: lines that slant leftward ( $\backslash$ ); lines that slant to the right ( $/$ ); straight lines ( $|$ ); and across lines ( $-$ ). (Vertical and horizontal were not used since these are polysyllabic words--left and right are monosyllabic--and may also have been less familiar to fifth graders than to ninth graders.) Left and right lines were illustrated by placing arrowheads on the top of each line (left =  $\nwarrow$ ; right =  $\nearrow$ ). Subjects were then given an  $8\frac{1}{2}$  by 11 inch sheet of paper with 9 rows of 12 lines of various slants. Below each line was a space to enter the letter ("R" for right slant; "L" for left slant; "S" for straight line; and "A" for across line) that indicated the direction of the line. Subjects were given practice lines to code and then were administered a criterion test of 12 correct in 15 seconds.

Following this exercise, a second exercise was introduced in

which subjects were asked to code in reverse. That is, each subject was shown another 8½ in. by 11 in. practice sheet except this time there were nine rows of letters and subjects were asked to draw the appropriate line under each letter. Following practice trials a criterion test of 12 correct codings in 15 seconds was administered.

Immediately following the two training exercises, each subject was administered the following five conditions.

#### Free Drawing

This condition was identical to the one described above for the Control subjects, except that the instructions for the Experimental subjects stressed that the lines in each matrix might be more easily remembered by noting the direction (right, left, straight, or across) in which the lines were drawn.

#### Recognition

This condition was also identical to the one administered to the Control subjects with the addition that the instructions emphasized the verbal description of the lines as a memory aid.

#### Successive Letter-to-Line Matching

In this condition, subjects were required to determine if a "letter" matrix presented in the central field matched a "line" matrix presented to either the left or right fields. For instance,

if the "letter" matrix

S	R
	L

presented to the center field

was followed by the "line" matrix

	/
	/

presented to one or

the other lateral fields, the top two cells match (the letter and the line correspond) but the bottom cells do not match since the letter says "left" and the line points "rightward". This pair thus has one error.

Subjects were given answer sheets which contained 24 empty 2 X 2 matrices. Following each pairing (which constituted one trial), subjects were asked to place an "X" in the cell (or cells) in which the letter and line did not correspond. The matrices were constructed such that there were seven errors in the far left two cells

X	
X	

and seven errors in the far right two cells

	X
	X

Pilot data had shown that the far right two verti-

cal cells of matrices presented to the right and the far left two vertical cells of matrices presented to the left appeared to yield the more sensitive measure of laterality differences. Of the total 14 errors, 10 were "left" (5) and "right" (5), and 4 were either

"straight" or "across". (There were 28 errors in all since all matrices were presented once to the left and once to the right.) Pilot data had also shown that "straight" and "across" were more easily recognized and, therefore, not as sensitive to differences in left and right hemisphere functioning. To eliminate guessing, subjects were also told that a few (2) matrices contained no errors, although most contained one (6) or two (4) errors.

The center matrix was presented for 500 msec while the lateral matrices were presented for 50 msec. Before the 24 trials began, subjects were reminded to use the coding system. That is, after they saw the letters and then the lines, they should think of the letters that the lines represented to determine if they matched the letters originally presented in the central matrix.

Response measures were obtained for (a) total number of correctly identified "mismatches" of letters and lines in each field; and (b) total number of correctly identified "mismatches" of letters and lines in only the far left two cells of left visual field matrices and the far right two cells of right visual field matrices.

#### Successive Line-to-Letter Matching

This condition reversed the previous one in that the 24 trials consisted of presenting a "line" matrix in the center followed by a "letter" matrix to one or the other lateral field. Subjects were also told that when they saw the "letter" matrix they should think of the line direction that each letter represented in order to compare them with the lines shown originally in the center matrix.

The center matrix was shown for 500 msec followed by the lateral matrix for 50 msec. Following each trial, subjects were given 5 seconds to mark an "X" or "X's" on their answer sheets in the cell(s) in which information did not match. The response measures were the same as in the line-to-letter condition.

### Simultaneous Letter-and-Line Matching

This procedure combined the aspects of the two successive matching conditions by placing in one lateral field at a time both letters

and lines simultaneously ( 

S 	R /
	L /

 ). There were 24 trials

of 12 matrices presented randomly to the left and the same 12 randomly presented to the right. Two matrices contained no errors while six contained one error and four contained two errors. These 14 errors for the 12 matrices were distributed such that seven errors occurred in the far left two cells for left visual field matrices and the far right two cells for right visual field matrices. Thus a matrix such

as 

A —	R /
	L /

 contained one error, the bottom right cell, while

a matrix such as 

R /	L /
S 	

 contained no errors. Because of the

additional information presented in each matrix, exposure time was increased to 100 msec. Answer sheets consisted of 24 empty matrices and subjects were given 5 seconds following each matrix to place an "X" or "X's" in the cell or cells in which the spatial and verbal information did not match. Response measures consisted of (a) the total number of correctly identified cells with nonmatching letters and lines; and (b) the number of correctly identified far left two and far right two cells containing nonmatching letters and lines.

## CHAPTER IV

ResultsDesign 1 (Effects of Verbal Training on the Perception of Line Directionality)

Free drawing: full-frame responses. Table 1 presents the mean number of correct line drawings and the standard deviations for each lateral visual field with (Control) and without (Experimental) verbal training for boys and girls at the fifth and ninth grade levels. A mixed design 2 X 2 X 2 X 2 analysis of variance was computed with sex (male and female), grade (fifth and ninth), and treatment (Control and Experimental) as the between-subjects variables and field (left and right) as the within-subjects variable. The analysis yielded significant main effects for Treatment ( $F(1, 88) = 8.99$ ,  $p < .01$ ) and Grade ( $F(1, 88) = 78.43$ ,  $p < .01$ ), and a significant interaction of Sex by Field ( $F(1, 88) = 4.84$ ,  $p < .05$ ). No other main effects or interactions approached significance. An examination of Table 1 indicates that the Control subjects averaged 11.97 correct line drawings per field (of a possible 36) while the Experimental subjects averaged 13.76, an approximate difference of 2 correct responses. The significant Grade effect is clear by the means in Table 1 which indicate that fifth graders achieved an average of 10.22 correct responses per field while ninth graders performed at an average level of 15.51. Finally, the Sex by Field interaction is depicted in Figure 1. Across treatments and grades, girls demonstrated greater right (13.48) than left (12.65) visual field responding while

TABLE 1  
Means and Standard Deviations for Number of  
Correct Line Drawings for Free Drawing:  
Full-Frame Responses\*

	Control (No Verbal Training)				Experimental (Verbal Training)			
	Left Field (Right Hemisphere)		Right Field (Left Hemisphere)		Left Field (Right Hemisphere)		Right Field (Left Hemisphere)	
	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>
<u>Fifth Grade</u>								
Boys	3.75	(2.80)	8.25	(2.64)	11.75	(2.63)	10.83	(3.10)
Girls	9.42	(4.34)	9.33	(2.50)	11.00	(3.54)	12.33	(2.61)
<u>Ninth Grade</u>								
Boys	15.50	(2.97)	14.08	(4.54)	16.42	(3.45)	15.58	(5.89)
Girls	14.67	(3.00)	15.75	(3.06)	15.50	(2.68)	16.58	(4.58)

\*Total possible correct per field (with full-frames) = 36.

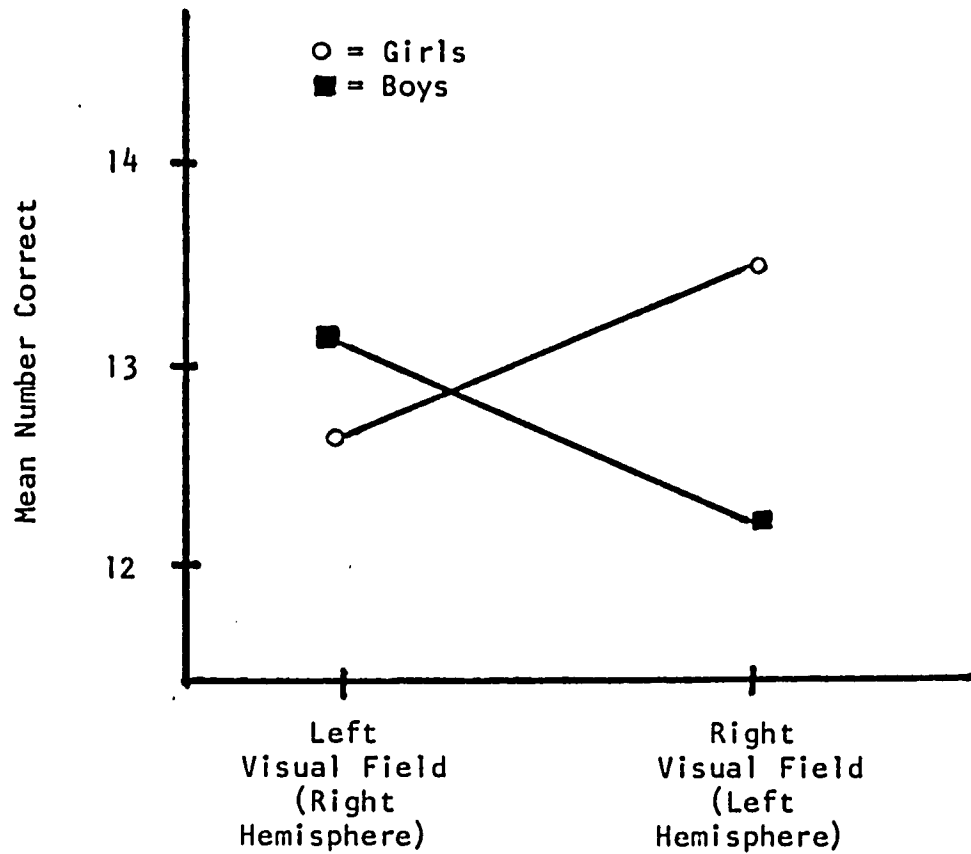


Fig. 1. Free Drawing: Full-Frame Responses. Mean number of correct line drawings in the left and right visual fields for girls and boys across grade (fifth and ninth) and treatment (Control and Experimental).

boys demonstrated greater left (13.13) than right (12.21) visual field responding. To further clarify this interaction (as well as all others reported below), pair-wise comparisons were computed using Dunn's method (Bonferroni  $t$  statistic). This method insured that all of the comparisons were simultaneously conducted at an alpha level of .05. That is, the probability of having made any Type I errors in the group of comparisons was less than .05. For the particular comparisons suggested by the Sex by Field interaction, no significant  $t$ 's resulted.

Free drawing: half-frame responses. The means used in the above analyses were based on all correct line drawings in all three cells of all matrices presented in each lateral field. The more reliable measure of field differences, however, was the number of correct reproductions in the far left two cells of matrices presented to the left visual field, and the far right two cells of matrices presented to the right field. These outer-most cells were more likely to be far enough off center to lie within a single lateral field. Table 2 presents the means and standard deviations using these half-frame responses. A comparison of this Table with Table 1 indicates that, in general, the far outside cells accounted for one-third to one-half of the total responses for each field. However, the data for full-frames and for half-frames were not totally comparable. The same four-factor mixed analysis of variance design used above in the full-frame analysis was repeated with the half-frame responses. The results of this analysis yielded both different as well as additional significant effects. A main effect for Grade was significant ( $F(1, 88) = 24.05, p < .01$ ),

TABLE 2  
 Means and Standard Deviations for Number of  
 Correct Line Drawings for Free Drawing:  
 Half-Frame Responses\*

	Control (No Verbal Training)				Experimental (Verbal Training)			
	Left Field (Right Hemisphere)		Right Field (Left Hemisphere)		Left Field (Right Hemisphere)		Right Field (Left Hemisphere)	
	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>
<u>Fifth Grade</u>								
Boys	4.00	(1.75)	4.75	(1.49)	4.83	(1.64)	3.67	(1.07)
Girls	4.67	(1.82)	5.00	(1.60)	6.00	(1.34)	6.50	(1.83)
<u>Ninth Grade</u>								
Boys	6.25	(1.48)	5.83	(2.08)	6.92	(2.31)	5.17	(2.66)
Girls	6.42	(1.88)	6.33	(2.35)	6.83	(2.37)	7.83	(2.13)

\*Total possible correct per field (with half-frames only) = 18.

indicating that averaging across treatment and sex, the fifth graders made an average of 4.94 correct drawings per field (total possible per field = 18) while the ninth graders achieved an average of 6.45 correct drawings per field. Sex was also significant ( $F(1, 88) = 11.21, p < .01$ ) with all boys across grade and treatment performing at an average of 5.18 correct responses per field, and girls at an average level of 6.21 per field.

Two two-way interactions were significant: Treatment by Sex ( $F(1, 88) = 3.98, p < .05$ ) and Sex by Field ( $F(1, 88) = 4.95, p < .05$ ). Figure 2 depicts the Treatment by Sex interaction. For boys, there were no differences in the number of correct line drawings with (5.15 per field) as opposed to without (5.21) verbal training. Girls, however, demonstrated more correct responses with training (6.79 per field) than without training (5.63 per field). Pair-wise comparisons (using the Bonferroni  $t$  statistic) indicated a significant difference between the boys with training (5.15) and the girls with training (6.79) ( $t(88) = 2.67, p < .05/4$ ). The significant Sex by Field interaction is shown in Figure 3. Across grade and treatment, girls had more correct drawings in the right than left visual field, while males performed better in the left than right field. Pair-wise comparisons indicated one significant result ( $t(88) = 3.61, p < .01/4$ ). Girls achieved significantly more correct line drawings in the right field (left hemisphere) (6.42) than boys achieved in the right field (4.85). Finally, a significant three-way interaction was obtained for Treatment by Sex by Field ( $F(1, 88) = 5.77, p < .05$ ). This is demonstrated in Figures 4 and 5. An inspection of these shows that girls and boys

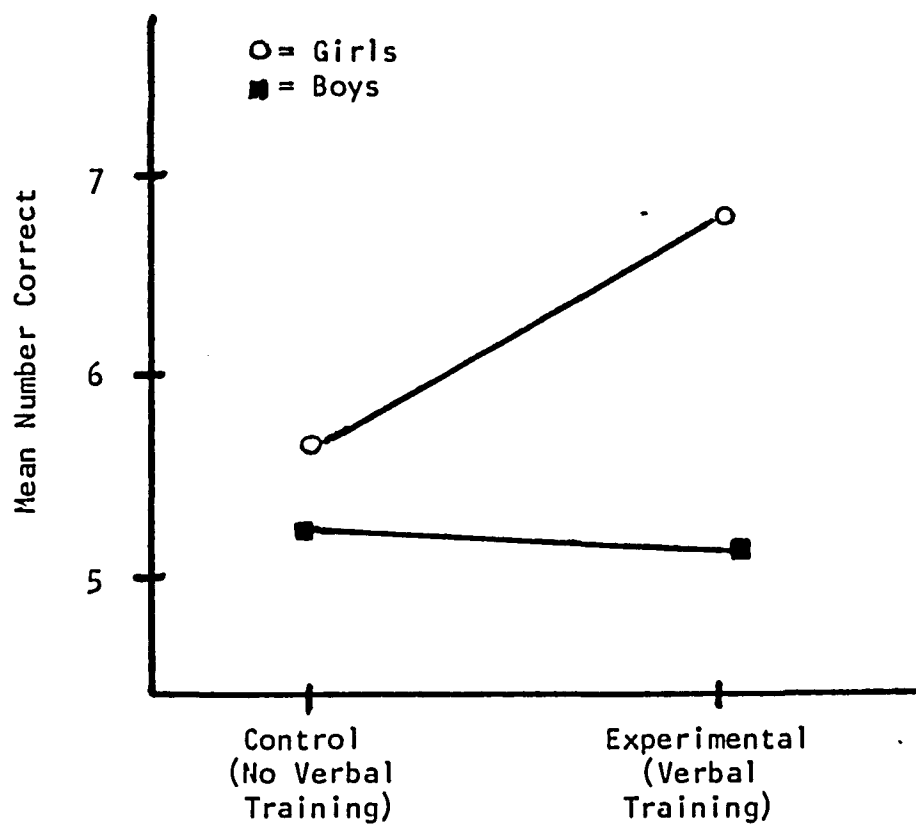


Fig. 2. Free Drawing: Half-Frame Responses. Mean number of correct line drawings for girls and boys in Control and Experimental treatments across grade (fifth and ninth) and field (left and right).

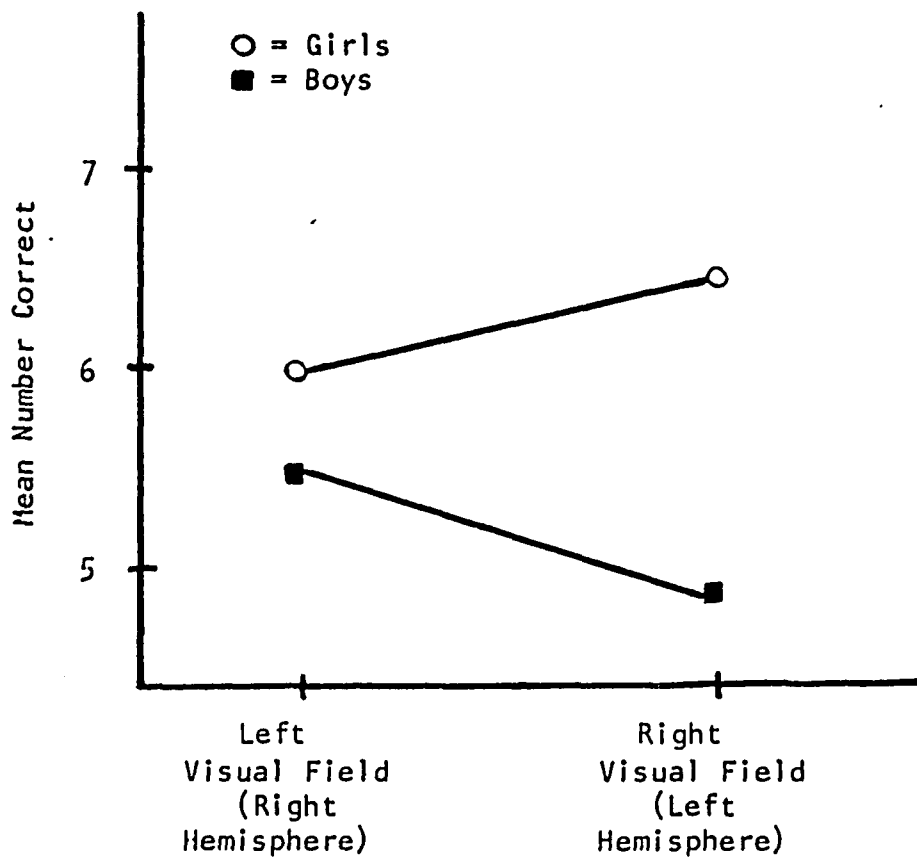


Fig. 3. Free Drawing: Half-Frame Responses. Mean number of correct line drawings for girls and boys in left and right lateral visual fields across grade (fifth and ninth) and treatment (Control and Experimental).

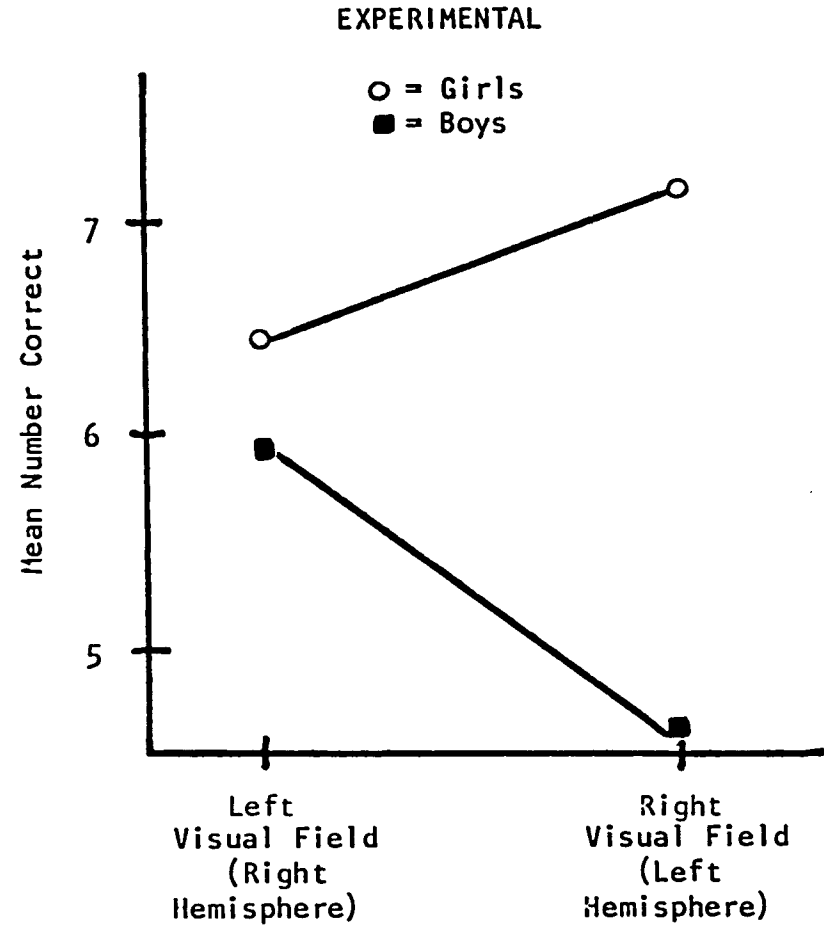
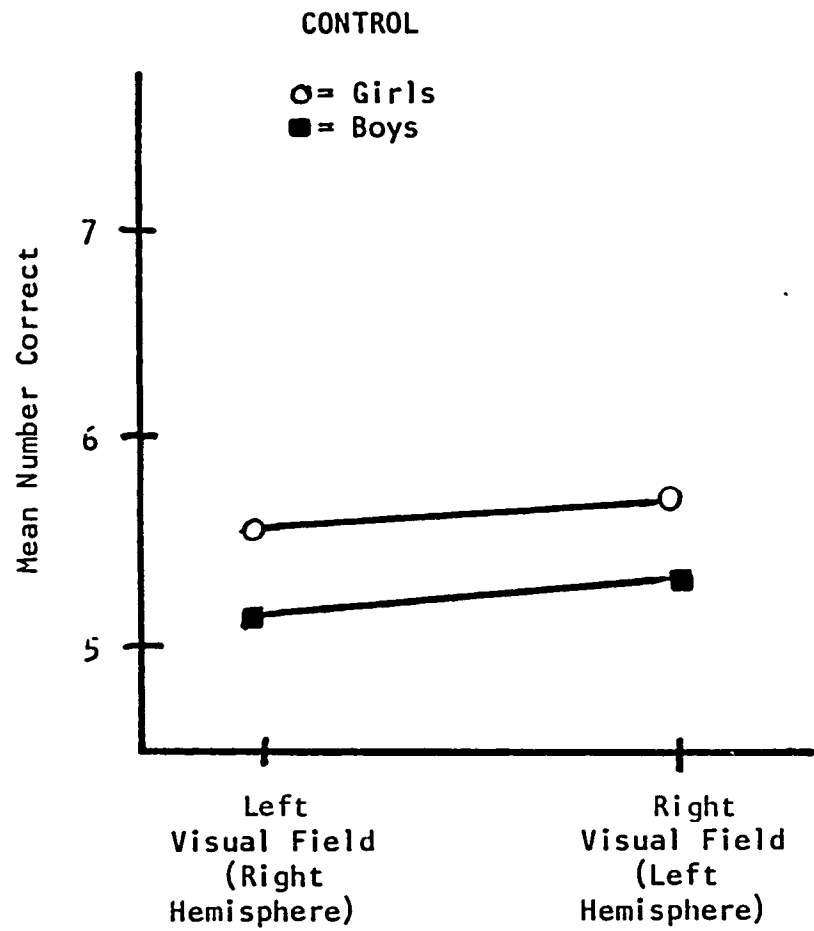


Fig. 4. Free Drawing: Half-Frame Responses. Mean number of correct line drawings for Experimental and Control boys and girls in left and right lateral visual fields across grade (fifth and ninth).



Fig. 5. Free Drawing: Half-Frame Responses. Mean number of correct line drawings for Experimental and Control boys and girls in left and right lateral visual fields across grade (fifth and ninth).

performed equally in the Control treatment (with more correct responses in the right field than in the left field for both boys and girls), although girls did demonstrate a slight advantage over boys in each field. With verbal training, however, boys and girls performed significantly different from each other. Although performance in the left field for both boys and girls was better with training than without training, this was not the case in the right field. Boys made fewer correct responses in the right field with training than without training. Girls, however, made more correct responses in the right field with training than without training. Pair-wise comparisons also indicated a significant difference between the right field performance of girls with training (7.17) and the right field performance of boys with training (4.42) ( $t(88) = 4.48, p < .01/16$ ). In addition, boys' left field performance (5.88) with training was significantly better than their right field performance (4.42) with training ( $t(23) = 3.48, p < .05/16$ ).

Recognition: full-frame responses. Table 3 presents the mean number of correct recognitions for each sex in each grade for each field in both Control and Experimental treatments. As can be seen, the recognition condition did not appear to provide a sensitive measure of the effects of verbal training on laterality differences for the perception of directionality. A mixed design  $2 \times 2 \times 2 \times 2$  analysis of variance was computed with sex, grade, and treatment the between-subjects variables and field the within-subjects variable. The only significant result was a main effect for Grade ( $F(1, 88) = 17.10, p < .01$ ). Fifth graders achieved an average of 5.10 correct recognitions per field (total possible per field = 12), whereas ninth graders

TABLE 3  
Means and Standard Deviations for Number of  
Correct Line Recognitions for Recognition:  
Full-Frame Responses \*

	Control (No Verbal Training)				Experimental (Verbal Training)			
	Left Field (Right Hemisphere)		Right Field (Left Hemisphere)		Left Field (Right Hemisphere)		Right Field (Left Hemisphere)	
	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>
<u>Fifth Grade</u>								
Boys	5.42	(1.67)	4.58	(2.11)	5.00	(2.00)	5.25	(1.76)
Girls	5.17	(2.08)	4.92	(1.93)	5.17	(1.19)	5.33	(1.37)
<u>Ninth Grade</u>								
Boys	6.58	(1.50)	5.17	(1.59)	6.50	(1.67)	5.83	(1.85)
Girls	6.58	(1.44)	6.33	(1.88)	6.42	(1.62)	6.50	(2.15)

\*Total possible correct per field (with full-frames) = 12.

performed at an average level of 6.24.

### Results of Design I for Proposed Hypotheses

The following hypotheses applied to Control (no training) subjects only:

Hypothesis (a)--overall accuracy for the perception of directionality for boys and girls would not differ without training. Results of the above three analyses indicated that there were no significant performance differences between "untrained" (Control) boys and girls.

Hypothesis (b)--boys would show a relatively greater degree of right hemisphere lateralization for directionality. None of the above analyses yielded significantly better right hemisphere as compared to left hemisphere performance in boys without training. In addition, none of the above three analyses led to any significant result indicating greater right hemisphere performance in Control boys as compared to Control girls.

Hypothesis (c)--girls would demonstrate bilateral processing of directionality. All the above analyses indicated that left and right hemisphere performances of girls did not differ.

The following hypotheses were proposed for the effects of verbal training (Experimental subjects):

Hypothesis (d)--overall accuracy for directionality for boys and girls would increase with verbal training but girls would demonstrate relatively greater gains than boys. The significant two-way interaction of Treatment by Sex obtained with the free drawing: half-

frame responses and the significant three-way interaction of Treatment and Sex and Field (free drawing: half-frame) both indicated that accuracy for the perception of directionality in the outermost cells was greater for the Experimental girls than the Experimental boys. This greater accuracy for girls was a combination of more correct responses in both fields. For boys, however, only the right hemisphere responses were greater with than without verbal training, while the left hemisphere performed at a lower level with training. In addition, however, the failure to obtain greater accuracy in girls in the analysis of full-frame responses suggests that whereas, overall, training improved performance for both boys and girls, the left and right hemispheres were not equally able to profit with training when a more sensitive measure (half-frame responses) was employed. The results of the two pair-wise comparisons also indicated that girls with training performed significantly better than boys with training, and the left hemisphere performance was greater in Experimental girls than boys.

Hypothesis (e)--boys' right hemisphere performance would be greater than their left hemisphere performance in both Control and Experimental treatments. The interaction of Sex by Field by Treatment in the free drawing: half-frame analysis indicated that although the left and right hemispheres performed equally for the boys in the Control treatment, the right hemisphere clearly performed significantly better than the left hemisphere following verbal training.

Hypothesis (f)--girls would demonstrate better perception of directionality in both hemispheres with than without verbal training. However, if performance was more accurate with training in the right hemisphere than left hemisphere, a preference for right hemisphere spatial processing would be indicated. If performance was more accurate in the left hemisphere, a preference for left hemisphere spatial processing would be indicated. The Treatment by Sex by Field interaction (for free drawing: half-frames) clearly demonstrated that with verbal training girls performed better than boys. However, for girls, more accurate performance did not occur primarily in the right hemisphere but rather in the left hemisphere; and the girls' left hemisphere performance with training was significantly better than boys' left hemisphere performance with training.

With reference to the course of development, the following hypotheses were proposed:

Hypothesis (h)--ninth graders would have higher overall performance levels for the perception of directionality than fifth graders. The main effect of Grade was significant for all of the above three analyses, indicating significantly better performance for ninth graders than fifth graders.

Hypothesis (i)--differences between left and right hemisphere performances would be more pronounced in ninth graders. None of the above three analyses yielded a significant Grade by Field inter-

action to indicate more pronounced field differences in ninth than in fifth graders. An examination of the means in Tables 1, 2, and 3 indicate that for Control subjects there was, however, on the average, greater absolute field differences in ninth graders than in fifth graders.

Design 11 (Letter-to-Line and Line-to-Letter Successive Comparisons - A Test for Interference)

Letter-to-line and line-to-letter comparisons: full-frame responses. Table 4 provides the means and standard deviations for the number of correct identifications of nonmatching verbal and spatial information in each field for both fifth and ninth grade boys and girls under the two conditions of letter-to-line and line-to-letter comparisons. A 2 X 2 X 2 X 2 mixed design analysis of variance with sex and grade the between-subjects variables and field and condition the within-subjects variables demonstrated a significant main effect for Grade ( $F(1, 44) = 11.84, p < .01$ ). The average number of correctly identified mismatches for fifth graders was 6.17 per field (total possible per field = 14), whereas the average performance of ninth graders was 7.69. A significant main effect was also obtained for Condition ( $F(1, 44) = 6.71, p < .05$ ). The average number of correctly identified mismatches for all subjects administered the letter-to-line condition was 7.28 per field, while the correctly identified

TABLE 4  
Means and Standard Deviations for Number of  
Correct Comparisons for Letter-to-Line  
Matches and Line-to-Letter Matches:  
Full-Frame Responses\*

	Letter-to-Line				Line-to-Letter			
	Left Field (Right Hemisphere)		Right Field (Left Hemisphere)		Left Field (Right Hemisphere)		Right Field (Left Hemisphere)	
	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>
<u>Fifth Grade</u>								
Boys	6.83	(2.02)	5.92	(2.23)	6.75	(1.76)	5.67	(2.15)
Girls	6.00	(1.86)	6.25	(2.49)	5.75	(2.45)	6.08	(2.11)
<u>Ninth Grade</u>								
Boys	3.67	(1.97)	7.83	(1.95)	7.17	(1.90)	7.33	(2.53)
Girls	8.08	(1.88)	8.58	(2.40)	6.33	(2.53)	7.50	(1.93)

\*Total possible correct per field (with full-frames) = 14.

mismatches for the line-to-letter condition was 6.57 per field.

The only other significant effect was that of a Sex by Field interaction ( $F(1, 44) = 4.82, p < .05$ ). Figure 6 illustrates this interaction. Combining conditions and grades, girls demonstrated more correct responses in the right field (7.10) than in the left field (6.54), whereas boys demonstrated more correct responses in the left field (7.38) than in the right field (6.69).

Letter-to-line and line-to-letter comparisons: half-frame responses. The same four-factor (sex, grade, field, condition) mixed analysis of variance design (repeated measures on field and condition) used in the full-frame analysis above was computed using only the correctly identified mismatches in the far half-frames (the outer-most vertical cells in each field). Table 5 presents the means and standard deviations for the half-frame judgments for both fifth and ninth grade boys and girls in the two conditions of letter-to-line and line-to-letter comparisons. A significant main effect for Grade ( $F(1, 44) = 5.94, p < .05$ ) occurred with fifth grade boys and girls averaging 3.26 correctly identified mismatches per field (total possible per field = 7) while ninth graders averaged 3.89 correct responses per field. The main effect of Condition was also significant ( $F(1, 44) = 8.17, p < .01$ ) with the letter-to-line condition easier (3.83 per field) than the line-to-letter condition (3.31 per field). The Grade by Condition interaction also proved significant ( $F(1, 44) = 7.53,$

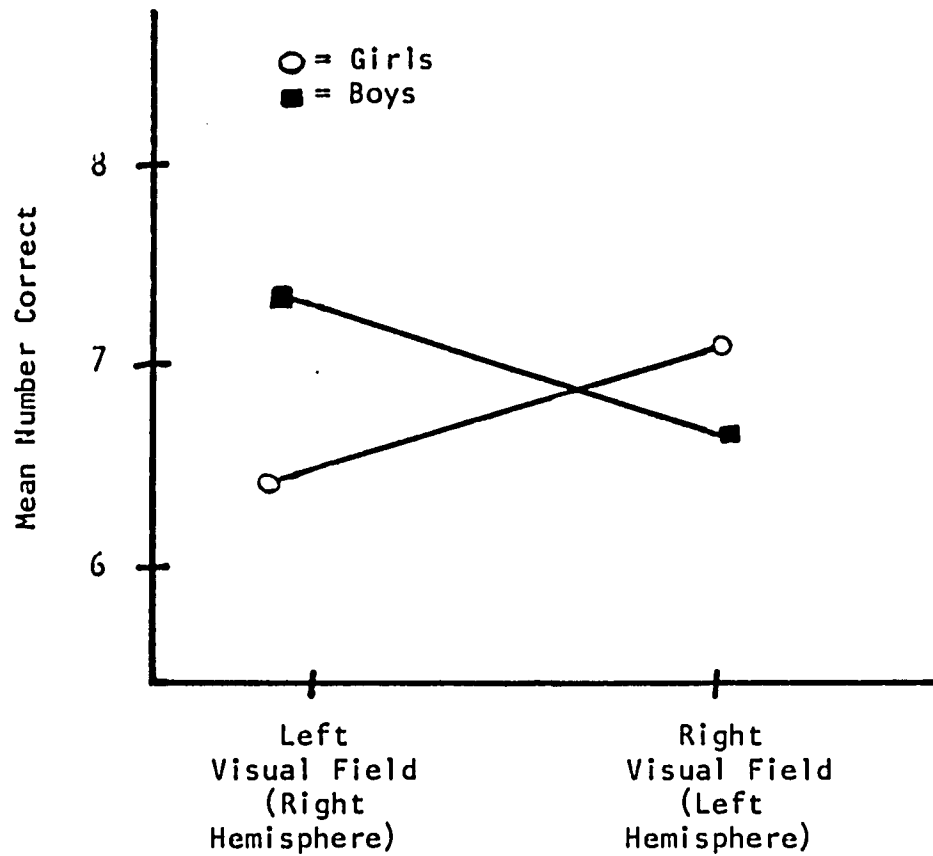


Fig. 6. Letter-to-Line and Line-to-Letter Matches: Full-Frame Responses. Mean number of correct matches for girls and boys in left and right visual fields across grade (fifth and ninth) and condition (letter-to-line and line-to-letter).

TABLE 5  
Means and Standard Deviations for Number of  
Correct Comparisons for Letter-to-Line  
Matches and Line-to-Letter Matches:  
Half-Frame Responses\*

	Letter-to-Line				Line-to-Letter			
	Left Field (Right Hemisphere)		Right Field (Left Hemisphere)		Left Field (Right Hemisphere)		Right Field (Left Hemisphere)	
	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>
<u>Fifth Grade</u>								
Boys	3.58	(1.24)	2.83	(1.64)	3.17	(1.19)	3.08	(1.38)
Girls	3.08	(1.16)	3.58	(1.08)	3.33	(1.68)	3.42	(1.38)
<u>Ninth Grade</u>								
Boys	4.75	(1.13)	3.92	(1.83)	3.25	(1.71)	3.58	(1.24)
Girls	4.08	(1.37)	4.83	(1.47)	3.17	(1.64)	3.50	(1.67)

\*Total possible correct per field (with half-frames only) = 7.

$p < .01$ ) and this is illustrated in Figure 7. Fifth grade boys and girls performed identically in each of the two conditions, whereas the ninth grade boys and girls made fewer correct responses in the line-to-letter condition than the letter-to-line condition.

#### Results of Design II for Proposed Hypotheses

Hypothesis (g)--boys would demonstrate an interference effect in both hemispheres; overall accuracy for verbal (letter) and spatial (line) comparisons would be lower for boys than girls.

Combining responses for both grades and both conditions, an examination of the means for the full-frame Sex by Field analysis indicated that boys and girls performed almost equivalently (girls = 6.82, boys = 7.03), although girls showed a somewhat lower performance level. When half-frame scores were considered in the analysis, once again performance was equivalent (3.62 for girls; 3.52 for boys). Thus, for the two conditions involving successive comparisons, there was no indication of lower accuracy for boys. However, the data highlighted field differences for girls and boys with girls showing a left hemisphere bias and boys demonstrating a right hemisphere bias. This would suggest that girls prefer left hemisphere language strategies whereas boys prefer right hemisphere spatial strategies.

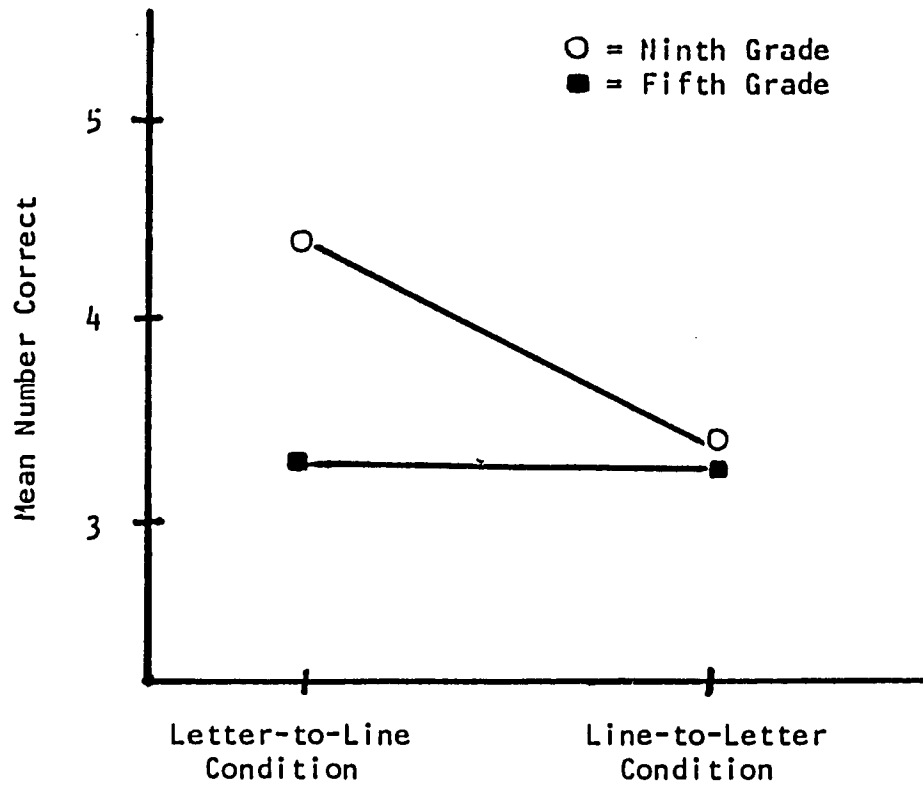


Fig. 7. Letter-to-Line and Line-to-Letter Matches: Half-Frame Responses. Mean number of correct matches for letter-to-line and line-to-letter conditions for fifth and ninth graders across sex and field (left and right).

Design III--(Letter-and Line Simultaneous Comparisons- A Test for Interference)

Letter-and-line matches: full-frame responses. Table 6 presents the means and standard deviations for the number of correctly identified letter and line mismatches presented simultaneously to each field for both fifth and ninth grade boys and girls. The results of a 2 X 2 X 2 mixed design analysis of variance with grade and sex the between-subjects variables and field the within-subjects variable indicated a significant main effect for Grade ( $F(1, 44) = 21.47, p < .01$ ) with all fifth graders achieving fewer correct responses per field (4.73) than all ninth graders (6.73) (total possible per field = 14). The only other significant result occurred for the Sex by Field interaction ( $F(1, 44) = 7.66, p < .01$ ) which is depicted in Figure 8. Boys and girls performed identically in the right hemisphere but girls as compared with boys achieved more correct responses in the left hemisphere (girls = 6.63; boys = 5.17).

Letter-and-line-matches: half-frame responses. Means and standard deviations for the number of correct simultaneous comparisons in the half-frame (Table 7) were computed and used in a two between-subjects (sex, grade) and one within-subjects (field) mixed design analysis of variance. The effect of processing both letters and lines simultaneously is more clearly seen in the half-frame analysis as compared to the analysis using full-frame responses. A significant main effect for Grade ( $F(1, 44) = 4.92, p < .05$ ) and a significant main effect for

TABLE 6  
Means and Standard Deviations for Number of  
Correct Comparisons for Simultaneous  
Letter-and-Line Matches:  
Full-Frame Responses\*

	Left Field (Right Hemisphere)		Right Field (Left Hemisphere)	
	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>
<u>Fifth Grade</u>				
Boys	4.75	(.97)	4.33	(1.61)
Girls	4.83	(1.59)	5.00	(1.41)
<u>Ninth Grade</u>				
Boys	6.25	(2.41)	6.00	(2.71)
Girls	6.42	(1.73)	8.25	(1.36)

\*Total possible correct per field (with full-frames) = 14.

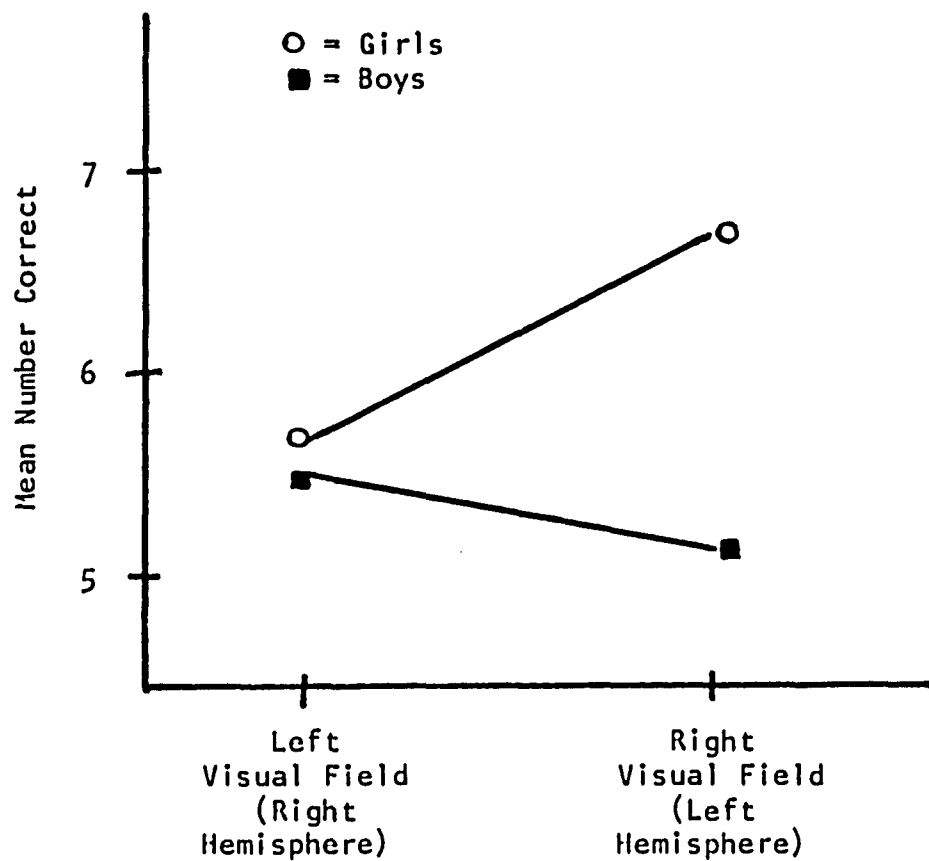


Fig. 8. Letter-and-Line Matches: Full-Frame Responses. Mean number of correct matches for boys and girls in left and right visual fields across grade (fifth and ninth).

TABLE 7  
Means and Standard Deviations for Number of  
Correct Comparisons for Simultaneous  
Letter-and-Line Matches:  
Half-Frame Responses\*

	Left Field (Right Hemisphere)		Right Field (Left Hemisphere)	
	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>
<u>Fifth Grade</u>				
Boys	2.25	(1.06)	2.00	( .74)
Girls	2.58	(1.24)	2.67	(1.07)
<u>Ninth Grade</u>				
Boys	2.83	(1.70)	2.00	(1.04)
Girls	2.92	(1.08)	4.25	(1.21)

\*Total possible correct per field (with half-frames only) = 7.

Sex ( $F(1, 44) = 8.74, p < .01$ ) were obtained. Ninth graders made more correct responses per field (3.0) than fifth graders (2.38) (total possible per field = 7); and girls performed better in each field (3.10) than boys (2.27). A significant Sex by Field interaction also appeared ( $F(1, 44) = 11.22, p < .01$ ) with this interaction shown in Figure 9. There were more correct responses in the right visual field for girls (3.46) than boys (2.00) although the left field performance did not differ between the two sexes (girls = 2.75; boys = 2.54). Tests of pair-wise comparisons indicated a significant difference between girls' right field performance and boys' right field performance ( $t(44) = 3.67, p < .01/4$ ). Finally, a significant Grade by Sex by Field interaction was present ( $F(1, 44) = 6.04, p < .05$ ). There was little difference between fifth grade girls and boys in either field, but a large difference occurred between ninth grade boys and girls in the right field (girls = 4.25; boys = 2.00), although there was no difference in the left field (girls = 2.92; boys = 2.83). Figures 10 and 11 illustrate these results. A comparison of ninth grade girls' right field performance with ninth grade boys' right field performance indicated a significant difference ( $t(44) = 3.99, p < .01/16$ ). In addition, ninth grade girls' performance in the right field was significantly better than their performance in the left field ( $t(11) = 3.75, p < .05/16$ ).

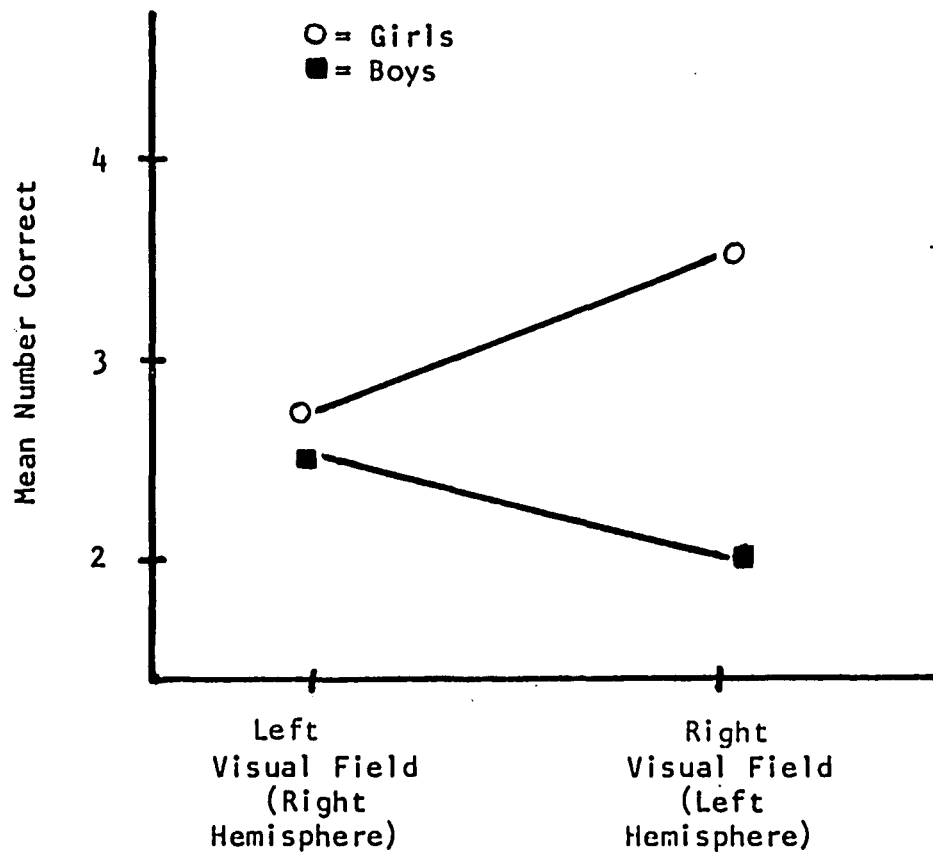


Fig. 9. Letter-and-Line Matches: Half-Frame Responses. Mean number of correct matches for girls and boys in left and right lateral visual fields across grade (fifth and ninth).

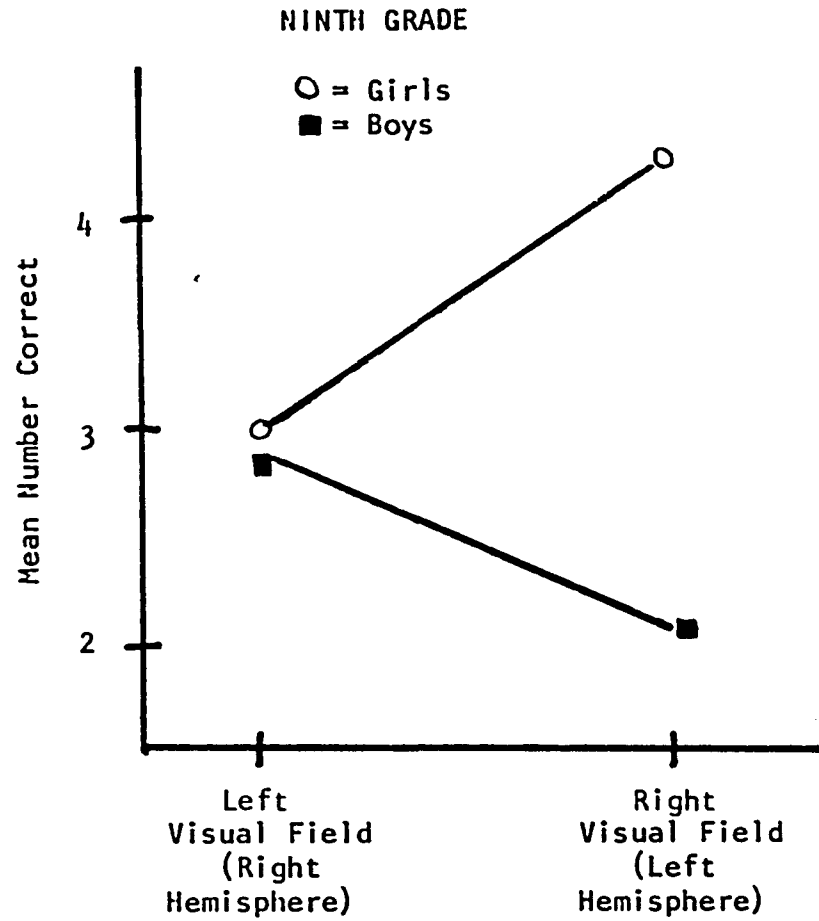
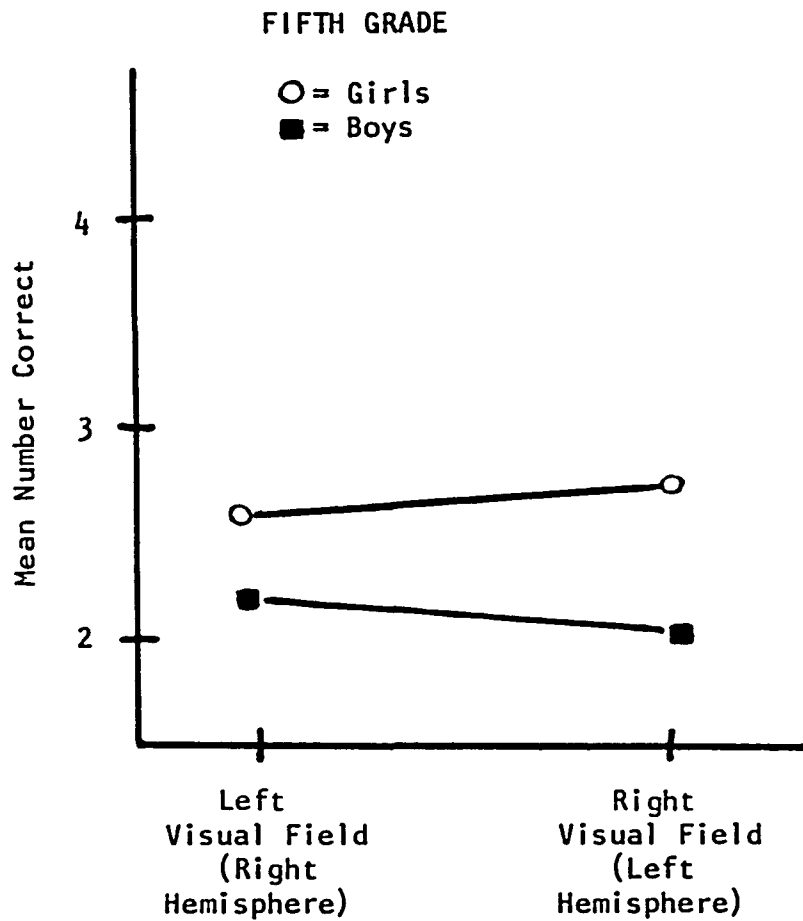


Fig. 10. Letter-and-Line Matches: Half-Frame Responses. Mean number of correct matches for fifth and ninth grade girls and boys in left and right lateral visual fields.

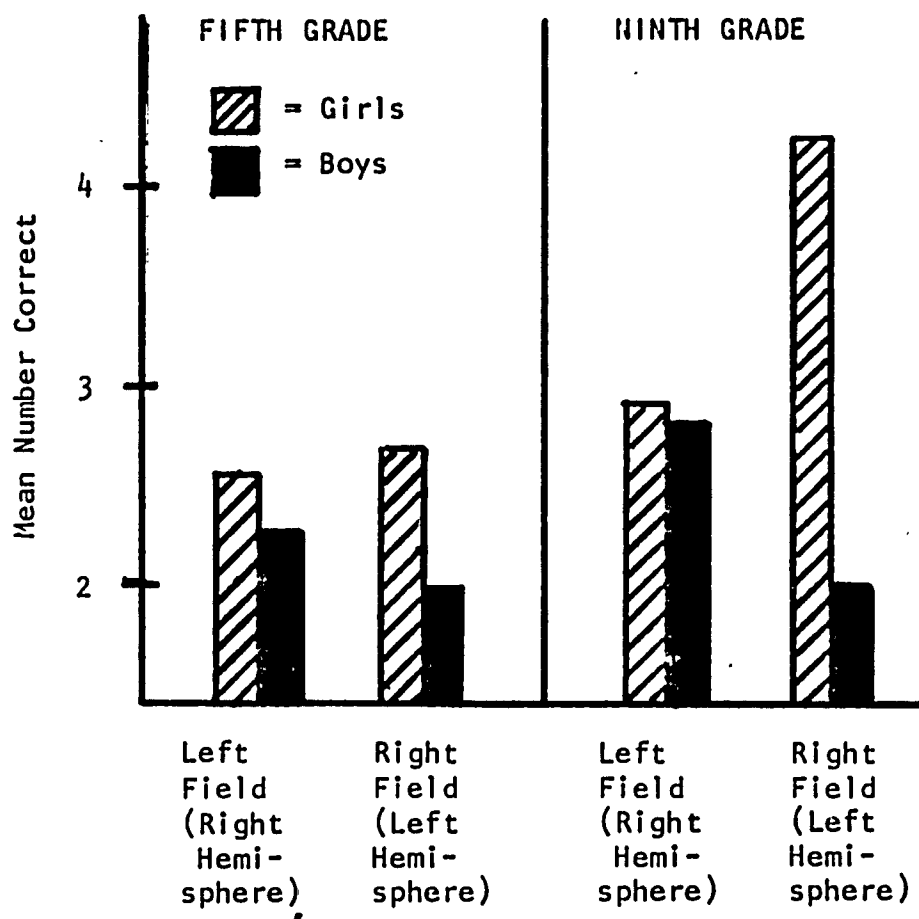


Fig. 11. Letter-and-Line Matches: Half-Frame Responses. Mean number of correct matches for fifth and ninth grade girls and boys in left and right lateral visual fields.

### Results of Design III for Proposed Hypotheses

Hypothesis (g)--boys would demonstrate an interference effect in both hemispheres; overall accuracy for verbal (letter) and spatial (line) comparisons would be lower for boys than girls. Although Design II examined the ability to make comparisons between verbal (letters) and spatial (lines) information presented successively, Design III examined the ability of boys and girls to make comparisons of spatial and verbal information presented simultaneously. A clear difference between males and females was evident from the significant main effect for Sex for half-frame responses; the significant interaction of Sex by Field for full-frame responses and for half-frame responses; and the significant Grade by Sex by Field interaction for half-frame scores. Combining responses in both fields and both grades, girls exceeded the performance of boys, with the most significant difference between boys and girls appearing at the ninth grade level. Thus, although successive letter-to-line and line-to-letter comparisons did not produce sex differences in hemispheric processing, the requirement of simultaneous comparisons clearly indicated the possibility of an interference effect in boys. This was more pronounced in the right as compared to the left field in boys, and more evident in ninth grade boys as compared to fifth grade boys.

### The Recognition of Position

#### Full-Frame Responses from Free Drawing

In addition to the data on line perception, the free drawing

condition permitted an analysis of the ability to correctly process "position." Since the one empty cell varied for each matrix, subjects had to correctly remember not only the direction of the individual lines but also (1) the exact cell in which each line was observed, and (2) the cell that contained no information. The number of correctly remembered empty cells for each field was computed and used in a 2 X 2 X 2 X 2 mixed design analysis of variance with grade, sex, and treatment the between-subjects variables and field the within-subjects variable. Table 8 presents the means and standard deviations for the position responses. A significant main effect occurred for Grade ( $F(1, 88) = 16.58, p < .01$ ) and Field ( $F(1, 88) = 4.48, p < .05$ ). Ninth graders correctly located the position of the empty cell more often than fifth graders (4.32 per field for fifth graders; 5.44 per field for ninth graders--of a possible 12 per field). In addition, left field responses (5.13) were higher than right field responses (4.64). A significant Treatment by Field interaction occurred ( $F(1, 88) = 4.11, p < .05$ ) with no difference between left and right fields for the Control subjects, but a significant advantage in the left field for the Experimental subjects. Figure 12 depicts this interaction. One final interesting trend appeared (although the Sex by Field by Treatment interaction was not significant--only .20 below that needed for the .05 alpha level). Although the performance of girls did not substantially differ for those without verbal training (Control) and those with training (Experimental),

TABLE 8  
Means and Standard Deviations for Number of  
Correct Position Identifications in Free Drawing:  
Full-Frame Responses\*

	Control (No Verbal Training)				Experimental (Verbal Training)			
	Left Field (Right Hemisphere)		Right Field (Left Hemisphere)		Left Field (Right Hemisphere)		Right Field (Left Hemisphere)	
	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>
<u>Fifth Grade</u>								
Boys	3.50	(1.45)	4.25	(1.21)	4.42	(1.50)	3.50	(.90)
Girls	5.58	(1.31)	3.83	(1.75)	5.33	(1.61)	4.17	(.94)
<u>Ninth Grade</u>								
Boys	5.00	(1.21)	5.91	(2.23)	5.83	(1.74)	4.75	(2.56)
Girls	5.50	(1.73)	5.50	(2.50)	5.83	(1.64)	5.17	(2.52)

\*Total possible correct per field (with full-frames) = 12.

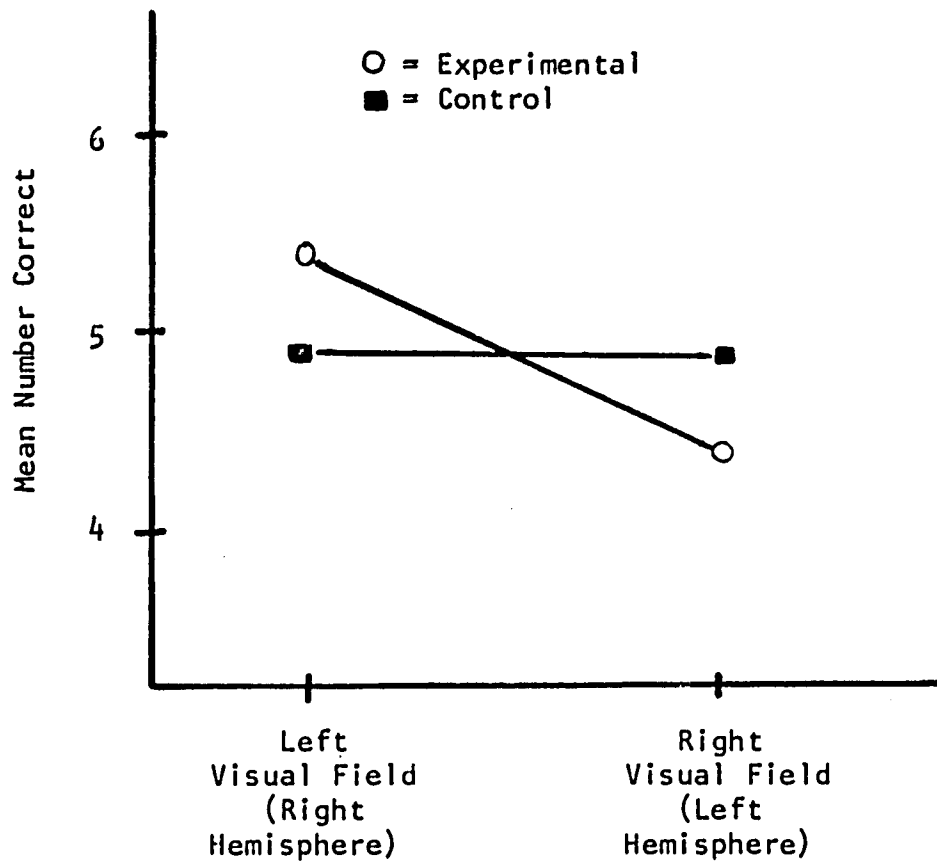


Fig. 12. Position Responses in Free Drawing: Full-Frame Responses. Mean number of correct position responses for Experimental and Control groups in left and right visual fields across grade (fifth and ninth) and sex.

the performance of boys with training was the opposite of the performance of boys without training. That is, girls had more correct recognitions of position in their left than in their right field with and without training. For boys, however, right field performance was better than left field performance without training; but with training, left field performance was better than right field performance. This lower right field performance in boys for position with training parallels that observed in the analysis of correct line drawings in Design I. The effects of verbal training for boys, therefore, appeared not only in the ability to correctly perceive and process directionality but also in the ability to correctly perceive and process position of an empty cell.

#### Half-Frame Responses from Free Drawing

The four-factor (sex, grade, treatment, field) mixed design analysis of variance with repeated measures on field was computed using half-frame responses. Table 9 presents the means and standard deviations for this analysis. The only significant findings occurred for the main effect of Grade ( $F(1, 88) = 9.01, p < .01$ ) and the main effect of Sex ( $F(1, 88) = 16.01, p < .01$ ). As in the analysis of full-frame position responses, ninth graders performed higher per field (2.66) than fifth graders (2.16) (total possible per field = 6); and girls (2.74) performed better than boys (2.07).

TABLE 9  
Means and Standard Deviations for Number of  
Correct Position Identifications in Free Drawing:  
Half-Frame Responses\*

	Control (No Verbal Training)				Experimental (Verbal Training)			
	Left Field (Right Hemisphere)		Right Field (Left Hemisphere)		Left Field (Right Hemisphere)		Right Field (Left Hemisphere)	
	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>
<u>Fifth Grade</u>								
Boys	1.58	(1.08)	2.00	(.95)	1.83	(1.11)	1.75	(.75)
Girls	2.83	(1.11)	2.03	(1.24)	3.00	(1.04)	2.17	(.93)
<u>Ninth Grade</u>								
Boys	1.75	(.86)	2.67	(1.30)	2.58	(1.37)	2.42	(1.56)
Girls	2.75	(1.42)	3.50	(1.50)	2.92	(1.79)	2.67	(1.50)

\*Total possible correct per field (with half-frames only) = 6.

## CHAPTER V

DiscussionEffects of Verbal Training

The results of Design I clearly demonstrated that the verbal labeling procedure produced a significant effect on the perception of line directionality for both fifth and ninth grade boys and girls, although the degree to which this was evident varied for the three different conditions. Overall, the free drawing condition using either the full-frame or half-frame responses resulted in both significant main effects for treatment as well as treatment interactions, while the recognition condition did not yield any differences between Control and Experimental subjects. In addition, half-frame scores were more sensitive to the training procedure than full-frame scores.

The specific direction of the treatment effect varied for sex and visual field. Overall, girls performed at higher levels than boys with training. Boys with training performed better than boys without training in the right hemisphere, but boys with training performed lower in the left hemisphere than boys without training. Girls, however, performed better in both hemispheres with than without training, with better performance occurring in the left hemisphere. This latter finding supports the view that girls prefer left hemisphere verbal strategies instead of right hemisphere spatial strategies for solving this particular "spatial" task--the perception of line directionality. The other possibility--greater right hemisphere performance--which

did not materialize was based on the assumption that right hemisphere spatial processing would be initially low for the girls in the Control group because girls prefer to employ verbal strategies in the analysis of all cognitive tasks. Since the spatial task for the Control subjects did not offer any alternative other than direct "natural" spatial analysis of the lines, the right hemisphere for girls essentially had the most to gain from the verbal labeling. The predicted right hemisphere improvement was also based on the Braille learning study by Rudel et al. (1974) which had indicated that left hand (right hemisphere) performance of girls was initially the lowest unless training first took place with the right hand (left hemisphere). Although the Braille task and the perception of line directionality are obviously not comparable in a variety of ways (including the use of a different sense modality), a verbal component was present for both--the need to associate letters to the dot configurations in the Braille task and the availability of letter abbreviations for the processing of lines in the current task. Another possibility for the relatively lower right hemisphere than left hemisphere improvement in girls is that without training, girls, as compared to the boys, had somewhat higher initial levels of performance. In Rudel et al.'s (1974) study, girls began somewhat lower than boys and thus essentially had more to gain. Overall, the findings of better left hemisphere performance in girls does agree with Rudel et al.'s data indicating better overall right hand (left hemisphere) performance in girls as compared with boys. In addition, the better overall performance (both left and right hemispheres) for girls

as compared to boys with verbal training also agrees with Witelson's (1977c) data in which more correct responses were obtained for girls on a dichaptic letters test (identifying letters by touch), in which a spatial task had a verbal component.

The significant gains of the left hemisphere for girls clearly suggests that girls can (and apparently prefer to) use left hemisphere, verbal mechanisms for information processing, at least in one type of spatial task--that of line directionality. The results also suggest that if language does have some bilateralization in girls, it is not readily evident in the performance of the right hemisphere of girls in this task.

A somewhat different type of explanation for the superior left hemisphere performance in girls involves Kinsbourne's (1970, 1973, 1975) suggestion that laterality of functions can be influenced by "priming" one or the other hemisphere. Allard and Bryden (1979) succinctly summarize this position:

...when a subject is expecting to see verbal material or is otherwise engaged in verbal thought, even though it is not task-relevant, the left hemisphere is activated. This activation inhibits the right hemisphere, makes the left hemisphere more sensitive to incoming stimuli, and produces head and eye turning to the right. Conversely, if one is engaged in nonverbal thought or expecting nonverbal material, it is the right hemisphere that is activated (Allard & Bryden, 1979, p. 5).

What Kinsbourne's (e.g., 1970) view would suggest for the present findings is that the left hemisphere advantage for girls resulted from the verbal training procedure either changing the nature of the task

from a spatial one to a verbal one, or from "priming" the left hemisphere to be more alert than the right hemisphere to incoming information.

Although Kinsbourne's (1970) theory has generally met with questionable support (e.g., Allard & Bryden, 1979), the fact remains that the current verbal procedure not only did not shift attention to the left hemisphere in boys, but rather the procedure caused a reduction in left hemisphere processing in boys. In fact, this lower left hemisphere performance for boys appears to lend feasibility to the notion of greater specialization within hemispheres in males, and thus greater incompatibility between spatial and verbal processes-- at least in the left hemisphere. For boys, providing a verbal solution as an alternative or auxiliary approach to the spatial task appears to have resulted in some factor such as "overload" or "noise," and this appeared more evident in the left hemisphere. Not only do boys apparently prefer not to use verbal analysis, but it seems that verbal mediation may be a hinderance for spatial tasks at the level of single hemisphere functioning. The question does remain, however, why the right hemisphere did not experience the interference that the left hemisphere did. It can only be surmised that the right hemisphere was "naturally" more efficient in processing spatial information and the addition of a verbal strategy was not needed. The left hemisphere, however, because it is "naturally" less adept for spatial analysis could not coordinate the two strategies in any helpful way, and in fact fumbled in an attempt to process both.

The notion of interference and the possible existence of incompatibility of cognitive strategies will be more fully discussed below in the review of the findings for the conditions designed to elicit interference--the successive and simultaneous comparisons of spatial and verbal information.

#### Verbal Training as a Practice Effect

The better right hemisphere processing that occurred in "trained" males and females does not necessarily lead to the conclusion that a verbal strategy was used by the right hemisphere. It was expected that the training exercises would have some practice or familiarization effect for both boys and girls and that this would be evident in both hemispheres. (It was the relative differential effects for sex and field that were expected to result from training.) As a result of the training exercises, the lines became more distinct and discriminable which should have narrowed the errors in guessing. If nothing else, the Experimental subjects had the knowledge that there were only four basic types of lines (left, right, straight, across), while Control subjects remained naive to this fact. In addition, the "straight" and "across" lines were probably less likely to be confused as slanted lines following the training procedure. What was outstanding, however, was that a practice effect did not appear in the left hemisphere performance of boys and that, in fact, it was superseded by some other factor such as the incompatibility of spatial and verbal material.

### General Training Studies

The current study offers another example that training, overall (using full-field responses), can be beneficial to performance. Although the literature review in the Introduction pointed out that there have been no attempts to determine the differential effects of training for boys and girls at the hemispheric level, the literature does offer several attempts to raise the performance levels of girls, as compared to boys, on spatial tasks by teaching a spatial solution to a spatial problem, or by giving practice on the spatial components of a given spatial task. Most of these studies are rooted in social learning theory which has long maintained that differential learning experiences for boys and girls provide an advantage to boys for spatial processing, but a disadvantage to girls.

It has been suggested (e.g., Cherry & Lewis, 1976; Kagan, 1964) that boys are reinforced for activity and that girls are rewarded for passivity. Because of this, boys engage in more manipulation and exploration of the environment which subsequently improves spatial processing and leads to their superior performance on spatial tests. Therefore, what doesn't occur naturally can be artificially induced in girls and the same effects occurring in vitreo should also be present with programmed experiences, at least on a temporary basis. This is the rationale underlying the training studies that have attempted to raise performance levels on a variety of cognitive tasks including spatial tasks. Conner et al. (1977, 1978) provided a brief training program for first, third, and fifth graders in which the subjects were

given practice on the component skills of the Embedded Figures Test-- a test that frequently shows superior performance for males. The results showed a positive effect of training for the girls, and their post-practice scores were equivalent to the pre-practice scores of the boys. Similar results were also reported by Goldstein and Chance (1965) with adults on the same task. Vandenberg (1975) also reported preliminary findings of an attempt to train sixth grade boys and girls to solve mental rotation problems. By providing the subjects with experience in block building, boys, overall, still scored higher than girls but girls benefited more from training than boys. One study (Thomas et al., 1973) in which training did not lead to improvement for college women involved Piaget's water level problem and the principle of horizontality.

These general spatial training studies suggest a further area of research in the investigation of lateralization and specialization differences in males and females. The current study employed a verbal intervention strategy for a spatial task to determine if verbal mediation offered a preferred or more efficient processing route for girls, and if this could raise the performance level for girls. Another approach would be to provide a spatial training procedure appropriate for a spatial task and then determine if there are differential effects for males and females and if these effects are also observed at the hemispheric levels. Two other possibilities would also include providing verbal training for a verbal task and spatial training for a verbal task. This latter raises the question of whether spatial

strategies can be successfully applied to verbal tasks. If the findings would lead to less success in girls than in boys, there would be further evidence for the preferred use of verbal analysis in girls.

#### The Existence of an Interference Effect

Although the training procedure itself was not expected to yield an interference effect, clearly there were hints of such a possibility in the comparison of Control and Experimental treatments. The lower left hemisphere processing with training provided unexpected evidence that verbal and spatial strategies are relatively incompatible or antagonistic in single hemisphere processing in boys. The three conditions that were specifically designed to demonstrate an interference effect were the two conditions for successive comparisons between letters and lines and the simultaneous letter and line comparisons. These three tasks did not, in fact, all yield positive results in support of interference. In terms of processing demands, it would seem that the least demanding of these three conditions were the two involving successive comparisons, and it was these two that did not show the interference effect. Overall, performance between boys and girls on these two tasks did not differ. However, although less demanding than simultaneous comparisons, the successive comparisons were clearly more demanding than the free drawing condition which merely gave the subject the option of using verbal labels if so desired. Yet, this latter procedure did result in disruption for the boys. One possible explanation for this discrepancy between the free drawing and successive

comparison tasks could be the amount of information provided in the two conditions. In the free drawing condition, it was first necessary to "evoke" the correct letter code for each line and then apply it as a learning or processing aid--a two-step procedure. Although the use of verbal labels was optional in the free drawing condition, subjects may have felt "compelled" to try and use the verbal labels. This is not unfeasible since all subjects were highly motivated and appeared eager to conform to the training procedure. In the successive conditions, all information was available (in the letter matrices and the line matrices presented successively) and the subject was only required to make the comparisons--a one-step procedure. In addition, in the successive comparison conditions, the center information (the first part of the match) was available to both hemispheres and the 500 msec presentation rate was probably sufficient to have allowed the hemispheres to make the necessary adjustments and compensations for information presented in two different forms. Thus, not only was there sharing between the hemispheres but there was time for each sex to translate the information into a useable form--a form that may have been different for boys and girls. To this extent, an interference model would not suggest that processing two codes is not possible, but rather that the time needed for each hemisphere to code information and to pass it back and forth between the hemispheres does differ. This is further supported by the simultaneous condition which did yield a significant interference effect. In this condition, the available viewing time for each hemisphere (100 msec) was apparently

too brief to process with maximum efficiency both letters and lines simultaneously or to translate each into a code that would be quickly "read" by both hemispheres. As a result, clear sex differences in processing efficiency emerged.

The difference observed between the successive and simultaneous tasks raises the question of whether differences exist between males and females in intra-hemispheric functions as well as inter-hemispheric functions. In a study reported in the Introduction, McGlone (1977) examined verbal performance in men and women with unilateral brain lesions. While there were no major differences in terms of the locus or extent of left cerebral damage in males and females, different patterns of verbal deficits appeared between the sexes. The different patterns of behavior included: 1) more homogeneous scores on expressive and receptive tasks for males than for females; and 2) a different profile of WAIS Verbal IQ subtest scores for males and females who were not aphasic but who still had left hemisphere damage. In other words, these results suggest that sex differences may exist not only in relation to inter-hemispheric representation of functions but to intra-hemispheric representation as well. This idea also raises the possibility of the existence of different transmission times between the hemispheres in males and females for different tasks.

That the left hemisphere in boys experienced some disruption is further supported by the results of the ability to remember "position" in the free drawing condition. Although girls showed no effect of the training procedure, this was not true for boys who dem-

onstrated a reversal with training in the hemispheres used to process position. Performance for the boys in the Control group was lower in the right hemisphere but higher in the left hemisphere. With training, performance was higher in the right hemisphere and lower in the left. It was the left hemisphere in "trained" boys that also did poorly on the free drawing task. Thus, the left hemisphere showed a change in the ability to process both lines and position. These findings together support Allard and Bryden's (1979) suggestion that the demands of a concurrent task on another task may have been detrimental in their male subjects but not in their female subjects.

One "intuitively" appealing alternative to the notion that boys would have demonstrated an interference effect is the possibility that information not compatible with a particular hemisphere would have been merely ignored or blocked out. That is, it could have been predicted that performance in the left hemisphere should not have been affected at all (except for gains attributed to practice effects) in boys since each hemisphere could have blocked out or not attended to the information not appropriate to its functioning. In fact, this may have been what happened in the right hemisphere of boys since there was no change resulting from the verbal training procedure. This also suggests that right hemisphere functioning in boys may be more lateralized for spatial functions.

Although not in support of an interference paradigm for boys, one other interesting finding is the difference in the ability to perform the two successive comparison tasks. The data analysis

indicated that letter-to-line matches were easier to make than line-to-letter matches. This occurred equally for both boys and girls. The only immediately available explanation would be that the letter matrices required more time to process than the line matrices. Thus, in the letter-to-line condition, the center letter matrix was shown for 500 msec which provided ample time to process the letters. However, in the line-to-letter condition, the line matrix was the one presented centrally and for 500 msec while the letter matrix was presented laterally and for only 50 msec. This very brief exposure may have allowed less information to be processed, regardless of sex, and therefore overall lower performance resulted.

#### Developmental Trends

As pointed out in the literature review in the Introduction, few studies exist that examine right hemisphere functioning in children, and those that exist for left hemisphere functioning are almost exclusively devoted to dichotic listening procedures. Therefore, there is little information to use in predicting developmental trends in hemispheric functioning.

Overall, it is not surprising that the current tasks always produced significantly better responding in ninth graders than in fifth graders. As far as sex differences and hemisphere differences with age, the analyses yielded only one differential effect attributable to grade. This occurred in the simultaneous comparison condition and indicated that there were no significant differences in left and

right hemisphere performance for fifth grade boys and girls, but significant differences did occur for ninth graders with girls performing better in their left hemisphere and boys performing worse in their left hemisphere. One grade by condition interaction was observed which indicated that boys and girls in the fifth grade performed equally well on the two successive conditions while both boys and girls in the ninth grade did substantially better on the letter-to-line comparisons than on the line-to-letter comparisons.

The lack of any other sex by grade interaction in the remaining conditions suggests that boys and girls essentially performed equivalently at both grade levels. The lack of significant grade by field interaction also suggests no major shift in hemisphere performance with age. An inspection of the means for the various conditions do suggest, however, that absolute differences between left and right hemispheres were frequently more pronounced in ninth graders than in fifth graders. This suggests that an age group younger than fifth graders may show even less evidence of laterality differences. Another finding that is somewhat suggested by the data is that half-frame responses for the successive and simultaneous conditions showed lower field differences at both grade levels. Thus, although maximum capacity (full-frame responses) improves with age, the finer distinctions (half-frame responses) may not change as much, suggesting limitations at some point in development beyond which "sensitivity" changes are less appreciable. The use of younger and older age groups would also clarify this possibility.

Implications for Education and Future Research

Any attempt to translate the above findings into educational practices should be met with great caution. A recently published book (1979) entitled, "The Brain: The Last Frontier" by Richard Restak advocates teaching girls to learn through verbal left hemisphere strategies and boys to learn through spatial right hemisphere strategies to take into account their respective "natural" differences in lateralization of functions. It is at this point that one must not lose sight of the fact that very little at all is known about the brain and its processes, and to encourage different teaching approaches for boys and girls may not just be premature but a reckless adventure as well. Although it is common for individuals to categorize themselves as more "verbal" or more "spatial," it is still folklore that this sort of dichotomy exists to such an extent as to influence problem solving and information processing on a routine basis. What can be advocated, however, is the use of a variety of teaching and learning strategies that display a problem or concept in all its many facets and from different points of view.

Although this word of warning about different teaching strategies for boys and girls applies to "normal" individuals, the same indeed may not be warranted for neurologically impaired individuals. In fact, because one or another type of cognitive strategy may not be available to brain injured or learning disabled individuals, it may well be that these individuals do require tailor-made remedial learning

experiences or intervention techniques to affect performance. The model of interference effects for the current study was derived from the inferences drawn in the learning disabilities research and is meant to apply only to "atypical" situations such as that found for neurologically impaired individuals or for that created in the present study in which the task focused on single hemisphere processing. The present results suggest that the model is viable and warrants further investigations. Somewhat similar studies examining cross-modal functions in brain damaged individuals have been conducted and the findings from these have generally pointed to failures in the coordination of two sensory systems such as audition and perception. It may not, therefore, seem unreasonable to consider the present finding of an inability to coordinate two different cognitive strategies an impetus for further research along these same lines.

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