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HEMISPHERIC SPECIALIZATION AND VISUAL-SPATIAL FIRST LANGUAGE: THE LATERALITY PATTERNS OF HEARING PERSONS WHOSE FIRST LANGUAGE WAS AMERICAN SIGN LANGUAGE

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ABSTRACT

HEMISPHERIC SPECIALIZATION AND VISUAL SPATIAL FIRST LANGUAGE: THE LATERALITY PATTERNS OF HEARING PERSONS WHOSE FIRST LANGUAGE WAS AMERICAN SIGN LANGUAGE

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Researchers have used Deaf Ss to evaluate the merits of the theory that left hemisphere advantage (LHA) for language is due to the greater capacity of left to process auditory stimulation as complex as speech. Laterality patterns reported in Deaf Ss are different from hearing right handers, but this may be due to how, when and if visual, or auditory language has been acquired. This study tests the contribution of visual first language experience to laterality by comparing hearing persons who learned American Sign Language (ASL) from their Deaf parents, with persons who learned sign later in life; on their ability to correctly identify tachistoscopically presented unilateral English words, static and moving signs, and visual spatial oriented lines. Non-signing controls were compared on words and lines for which they showed the expected LHA and RHA respectively, as did late learn signers. Performance of hearing native signers followed previously reported patterns of Deaf native signers with: reduced laterality (only a trend toward LHA) for words; LH trend for lines; asymmetry for moving signs and the only significant hemisphere advantage demonstrated by right to static signs. The late learn signers showed a strong RHA for both sign sets demonstrating that age of acquisition contributes to differing lateral processing patterns for this visual spatial language. Both signing groups showed greater overall accuracy than non-signers. Findings suggest the hemispheres have potential for comparable processing of material traditionally subserved by the other. Visual first language experience is one of the factors which can influence this potentiation. Other theoretical considerations are discussed including trends supportive of Kimura's hypothesis regarding processing of complex motor movement and gender differences in hemispheric functioning.

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For Michael

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I thought I had put off writing this until last in the hope of bringing whatever eloquence I could save to bear on that which mattered most -- an expression of my appreciation. The truth is however, that I realized at some level how inadequate any expression would be in light of my feelings -- left hemisphere often fails right in this way!

When hearing of my decision to return full time to graduate work, my parents came speedily to my side to assess my competence, quite certain that I had taken leave of my senses. How can I find the words to say how much it has mattered to me that they really listened to how important that step was to me and became, along with my sister, Jeanne (who always knew) my strongest and most reliable supporters.

And however do I translate an accounting of the many "free meal for our starving student"s into the warmth of being "with family" that I have felt in the sustained love, laughter and concern that my Lansing family, Myrtle Gregg, Bob LaFay and Robbie have given to me? Or, the unfailing ability of my dearest friend, Russ Dodson, to put even my most bizarre "odd man out" feelings into a normalized "you're going through what every grad student has gone through..." He has been an invaluable tether to the land of the objective.

It is my hope that this study and whatever work I can continue to contribute, will in some way repay my debt to those who have opened to me the vibrant, rich, often poignant, but never pathetic world of the Deaf: J. B. Davis, "Mr. Deafness", the diplomat who so graciously ushered me in; Carlos, the troubled boy without a language whose world changed from raging rebel to "Joe Campus" once given Sign, for showing me my task; My friend and mentor, Alan Parnes, who patiently refines my Sign and my sensitivity; The interpreters who gave so generously of their time and thoughts -- to a person they are the most truly unselfish group I have ever encountered; and specifically to one of their number, Mae Booth, from whose experiences "I know I think differently..." the idea for this study was born.

And how indeed could I have accomplished the unique method of this study without the technical skill of Kristin Olin, who out of generous friendship spent the hot summer of '82 singleframing Super 8 mm film, while Francine Brown stood in the hot lights in the Interpreters' black turtle neck sweater, posing carefully measured signs.

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And finally to my most treasured mentor, Dr. Barry Greenwald I offer my thanks.

OVERVIEW

"Laterality", "asymmetries in hemispheric function", or "cerebral lateralization of function" are ways of describing the most global assignation of specific functions to areas of the brain; either to the right or the left hemispheres. That such asymmetries exist has been known since the differing effects of damage to the hemispheres were first recorded during the nineteenth century. This paper reviews some of the theories regarding lateralization, as well as findings from clinical and experimental work which sharpen the focus of our still fuzzy understanding of what specialties the hemispheres do develop; their relative abilities to switch, or subserve each other's functions to meet the needs of the organism and the conditions under which such switches might occur.

Theories regarding the development of lateralization of function focus primarily on either anatomical differences which are seen to facilitate laterality, or on early experiences considered necessary for such specialization to occur. Of the former, the importance of stimulation of the auditory sphere of the left hemisphere is dominant; of the latter, a critical period for lateralization of language figures most prominently for purposes of this discussion.

Persons born deaf appear to be the natural experimental ground for testing of the anatomical theories, as in deafness, auditory stimulation of the central nervous system does not occur. Most clinical and experimental work with laterality of function in the Deaf is conducted with this in mind.

Though this literature is far from conclusive, it appears that deaf persons do lateralize for language functioning, suggesting that auditory processing is not necessary to accomplish this end. Closer analysis of this literature however, reveals that deaf persons are significantly LESS lateralized in function than are hearing persons. An understanding of psychosocial; educational and demographic patterns of this population applied to these findings suggests that language acquisition experience during a critical period may be a contributing variable to lateral specialization.

A comparison of performance on tasks designed to assess hemispheric processing, of the hearing children of deaf parens (who share this unique bilingual acquisition experience with their deaf counterparts); to hearing subjects who have acquired ASL before adulthood, but after age 12; and hearing persons who never learned sign language was conducted. Performance differences resulted in patterns demonstrated previously by Deaf persons with early sign language experience, in both degree and direction, permitting the inference that those differences were the result of the uniqueness of the visual spatial first language experience and later bilingual acquisition phenomena, rather than any a priori anatomical difference.

TABLE OF CONTENTS

List of Tables

LIST OF FIGURES

HEMISPHERIC SPECIALIZATION AS A FUNCTION OF UNIQUE BI-LANGUAGE ACQUISITION: THE LATERALITY PATTERNS OF THE HEARING OFFSPRING OF DEAF PARENTS WHOSE FIRST NATURALLY ACQUIRED LANGUAGE WAS AMERICAN SIGN LANGUAGE

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Data from studies of neuroanatomy (Geschwind & Levitsky, 1968; Witelson & Pallie, 1973), naturally occurring unilateral brain damage (Geschwind, 1970; Milner, 1971), split brain patients (Gazzaniga, 1970; Gazzaniga & Sperry, 1967), chemical anaesthesia of the brain (Wada & Rasmussen, 1960), and from performance of non-brain injured persons on psychological tests (Kimura, 1973; Studdent-Kennedy & Shankweiler, 1970; White, 1972) suggest that the two cerebral hemispheres of man are differentially specialized for behavioral functions in normal hearing persons. Though there is little agreement on exactly how the hemispheres differ, this evidence very strongly suggests that in right handed persons with normal hearing, left hemisphere is specialized for language and right hemisphere for visuo-spatial functions. (Poizner & Battison, 1980)

Several theories have dominated the efforts to explain laterality. One hypothesis for instance, suggests that the left lateralization of language may be a consequence of handedness, as most persons are right handed. This view explains that due to the greater skill and activity of the dominant hand, its' contralateral (controlling) hemisphere receives more and better sensory input, thereby maximizing its development of language functions (Gazzaniga, 1970). Requiring, as it does, an assumption of a strict association of handedness and language, this view does not account for the fact that approximately 2/3 of left-handers are lateralized in the same way as are right-handers (McKeever, Hoemann, Florian and Van Deventer, 1976).

Another theory holds that vocal control asymmetry is somehow neurologically connected with left hemisphere specialization of language function. Nottebohm's findings of left neural control for song in songbirds provides at least some support for this view (Nottebohm, 1971; Nottebohm, 1972). Differential effects of cutting the left hypoglossal nerve result, depending on the age of the bird, in an inability to sing in adult male birds, to achievement of a complete pattern of song in a young male who has not yet come into full song.

Marie, as early as 1922 set the groundwork for yet another though related, understanding; that of equipotentiality of the hemispheres to subserve language. By positing a developmental argument that there is a symmetry of inborn centers for speech, motor and vision functions and that humans are not born with, but develop a speech center in the left temporo-parietal region, Marie argued that asymmetry increases at a developmental rate.

Yet a fourth hypothesis, also anatomically based, counters this equipotentiality theory and is the result of postmortem work done by Geschwind and Levitsky (1968), and Witelson and Pallie (1973). They studied the planum temporale, (which includes Wernicke's area, known to be necessary to normal language processing) of the left and right hemispheres of 100 adult human brains. They found a significantly greater incidence of larger left hemisphere planum compared to that of right hemisphere. They concluded that this anatomical difference could provide a biological basis for specialization of left hemisphere for language, left therefore having a greater capacity to process auditory stimulation, which may be required for optimal analysis and manipulation of the highly complex input of human language. Recent studies indicate that the anatomical asymmetries are present in the same ratios in infants and neonates, as well (Wada, Clarke & Hamm, 1975).

Lenneberg (1971), in support of the equipotentiality theory however, observed that the assumed association between the fibre architecture and language capacity has not been established. The substrate composition therefore, may not be linked to behavioral function. Hemispheric equivalence for function then can exist even with asymmetry of structure; left and right being equally good substrates for language. Lenneberg further posits that this equipotentiality exists up to the age of two.

Left Hemisphere Specialization and the Ability of Right Hemisphere to Subserve These Specialties:

Evidence in support of equipotentiality of the hemispheres to subserve language has been largely drawn from studies of the effects on language of early lateralized brain damage. If the hemispheres are equal in their potential to subserve language, then left damage should not result in the continued impairment of language; right being capable of taking over this function. In the classic study by Cotard (1868) persons who were right hemiplegic since infancy showed no aphasia as adults though the whole of their left hemisphere had atrophied. However, as Dennis & Whitaker point out in their 1977 review of these issues, "Equipotentiality postulates equivalence of language skills, not just a lack of aphasic signs in the two infant hemispheres." They prefer to examine the question therefore, in light of whether the two hemispheres are equally at risk for disordered language as a result of cortical damage.

Because Lenneberg places the critical age for equipotentiality at less than two years, the findings of a study conducted by Annett (1973) of right and left Infant Hemiplegia, with onset of symptoms before 13 months, are significant. These results indicated that the two hemispheres at this stage of infancy are not equally prone to a disruption of language by lateralized damage, with 32% showing decremental performance after left damage compared to only 10% after right damage.

Elaboration of the quality of language impairment resulting from lateralized damage was provided in a study by Dennis & Kohn (1975), which evaluated the syntactic performance of 9 hemidecorticates with onset of infantile hemiplegia before one year of age, who showed no clinical signs of aphasia. Those with a remaining right hemisphere were slower to respond to passive sentences, deficient in discriminating the meaning of passive sentences and less accurate in responding to negative than affirmative sentences, than those subjects with an intact left hemisphere. These findings suggest that what language capacity develops in right hemisphere, takes longer and may differ in kind from the linguistic ability which emerges by age 9 in left hemisphere. However. the extent to which secondary sequelae to the massive early damage incurred by these subjects. confounds these conclusions and therefore prohibits generalizations to normal brain functioning. must be considered.

Findings supportive of a critical age for equipotentiality of the hemispheres in an intact human brain therefore. would be important and are available in the extraordinary unfolding of the life and cognitive development of the feral child, Genie, as studied and reported by Curtis (1977). Though she possesses both hemispheres without known or apparent damage, Genie's early childhood was unique and relevant to this discussion. She had been isolated, immobilized and imprisoned in a spare room in the family home. She was never spoken to, (only "barked" at like a dog by her father when fed) and was punished for making noises with her voice. Presumablv. as a result of this linguistic deprivation, when she came to the attention of the authorities at age 13 1/2, Genie only used her voice to whimper. She had not acquired language. Though she was functionally retarded it was judged that she was not etiologically mentally deficient. Her alertness and engagement with persons around her were seen as evidence to rule out Autism. Scores on the Leiter of 4.9 placed her functioning level (with a wide range of scatter) at least as advanced as that of a normal child when s/he would begin to acquire language by imitation and spontaneous production of words. Since no evidence of biological deficiency was found, the linguistic deficiency was assumed to be due to her unique experience of social and linguistic isolation.

Her spontaneous acquisition of language by exposure alone, (once removed from the deprivational environment). coupled with her established right handedness. make the study of her progress an excellent place to examine whether, as Lenneberg (1971) has posited, a critical period for language acquisition exists. If so, Genie's abilitv to acquire language should have terminated with the completion of cerebral dominance. Though Lenneberg placed this time of completion. for language acquisition purposes, at adolescence, other theorists have argued this closure occurs as early as age 5 (Krashen, 1978). Though other possible variables such as undetected birth trauma, birth defect, early neurological damage are possible influences in this single case, Genie's progress, in primary acquisition of language at her age, offers an excellent opportunity to examine if, and in what way, lateralization and language acquisition are related, without the possible influences of secondary sequelae to early known hemispheric damage which blemish the hemidecorticate studies.

Genie's continued acquisition of language has been evaluated for hemispheric processing via dichotic listening tasks which have reliably shown, over time, a continued left ear (right hemisphere) advantage for words. This was further supported by EEG data during sleep. Genie's RIGHT hemisphere was dominant for processing speech during various levels of language acquisition. Lateralization appeared complete before, and remained stable during, the retarded acquisition of language.

While the course of Genie'sacquisition of language by right hemisphere largely paralleled that of normal first language acquisition, there were differences. Her progress was much slower. The quality of language acquired by Genie, also evaluated extensively by way of tasks of increasing syntactical complexity, were similar to the observed right hemisphere language phenomenon found in the Dennis & Kohn (1975) group. While she has been able to master recursion and ordering rules, she has not performed at better than chance levels to tasks involving passive sentences, auxiliary structure and movement rules. In short, those more complex syntactic functions are not within her command. These observations are of language subserved by right hemisphere. in that the EEG measures showed that the right hemisphere of Genie's brain was activated during these linguistic tasks. This suggests therefore, that in the default of left specialization during a time critical for this outcome, right hemisphere will subserve this function, but will do so less competently. While a critical period for left lateralization of language does appear to be supported in this case, a critical period for language acquisition is suggested only for more complex functions and not for the acquisition of simple ordering and recursion.

Effects on Lateralization of Bilinqual Acquisition Experience

15

Another language acquisition related variable which has been reported to be associated with right hemisphere's participation in language functioning is Bilingualism. While total claritv does not exist in this area of neurological/behavioral functioning, several factors have emerged as related to cerebral organization for language. First is the order of acquisition. As is the case with other areas of neurological functioning, clinical observations of aphasic-like svmptoms of left hemisphere damaqed persons have formed the foundation of the Bilinqual theories. Ribot's (1881) hvpothesis that those languages learned early in the ontogenetic develooment will be more resistant to impairment following brain damage carries with it the expectation that the first learned language will also be recovered more quicklv. Yet another hypothesis has been developed, that right hemisphere is specialized for second language acquisition in contrast to left hemisphere specialization in first language acquisition. In an effort to test this hvpothesis, Galloway (1980) expected that there should be a higher incidence of right sided lesion in bilinqual than monolinqual aphasics. She found that indeed 13% right handed (RH) polyglot cases vs. 2% RH monolingual cases, and 58% left handed (LH) polyglot cases vs. 32% LH monolinguals had riqht sided lesions.

Experimental studies of the order of acquisition of second language introduce the additional variable of age of acquisition. They are summarized by Vaid & Genesee (1980) as "generally supportive of the hypothesis that hemispheric processing of language in early bilinguals resembles the pattern characteristically noted in monolinguals, but that late second language (L2) acquisition engages the two hemispheres differently." Sussman, et al (1982) report a study which exemplifies the pattern of hemispheric specialization characteristic of the bilingual population of this body of literature. Using a verbal-manual competing response technique, they found that for fluent bilinguals:

1. Bilinguals DO lateralize to the left for language;
2. Bilinguals are LESS left lateralized for language than are monolinguals;
3. "Right hemisphere's participation in L2, especially for second languages acquired in adulthood, appears highly likely."
4. "As a group the bilinguals clearly revealed a high degree of variability in hemispheric language representation compared to the consistent patterns of left hemisphere dominance for the single language of monolinguals."

As these were fluent Bilinguals there is no suggestion or evidence of a qualitative deficit in the second language subserved by right hemisphere in the Bilingual situation.

Summary

So indeed, right hemisphere, under certain circumstances, has shown an ability to subserve language. We can expect this to occur when:

1. At an early age in the neurological development of the child, right becomes the only intact hemisphere, or
2. A condition of socio-linguistic deprivation exists during the "critical period" for language acquisition prior to adolescence, or
3. A second language, is acquired later in the developmental process: an increase in the likelihood of right hemisphere participation accrues.

The quality of language which right hemisphere has been able to produce under the first two of these conditions is simple and does not include the more complex syntactic functions of which left hemisphere is capable. There is no evidence of this qualitative limitation when the language subserved (L2) followed the natural acquisition of another language; when the individual had acquired a formal language naturally.

Right Hemisphere Specialization and Left Hemisphere's ability to Subserve These Functions:

What then of right hemisphere's primary specialized functions and the potential of left to subserve these? Our discussion up until now, not unlike the chronology of the hemispheric literature, has focused primarily on left hemisphere and the function of language. Perhaps because of its newness in evolutionary terms, there has been an historical fascination of scientists with language and an assumption of its link with intelligence (Kinsbourne & Hiscock, 1977). The anatomical structures which underlie verbal utterance are not present in non-human primates (Liebermann, 1968; Liebermann, Klatt & Wilson, 1969). "Thus, man's proud perch atop the highest rung on the phyletic scale-ladder he constructed was solely due to his speaking, intelligent 'dominant hemisphere'." (Smith, 1974) No such unique neural architecture characterizes human spatial orientation, as this function is shared with many species on the phylogenetic scale. It is also a function which "could be regarded as more archaic than language, bilateral before language evolved, and partially crowded out of the left hemisphere by verbal function when it lateralized both in phylogeny and ontogeny." (Kinsbourne, 1974). This coupled with the less obvious nature of deficiencies in visuo-spatial skills, may serve to explain why right hemisphere and its specialized functions, were the subject of less and later theorizing.

John Hughlings Jackson was one of the first to consider that an extreme one-sided view of cerebral function with right hemisphere positioned as the "minor hemisphere", was inefficient, suggesting that the posterior lobes of the right hemisphere were the seat of visual ideation or thought; right considered therefore, the "leading side" for this function (Jackson, 1958). He reasoned that "If then it should be proven by wider experience that the faculty of expression resides in one hemisphere, there is no absurdity in raising the question as to whether perception - as corresponding opposite - may be seated in the other." This notion was not accepted by the scientific community for nearly a decade. In fact, because by observational methods employed at that time, damage to the right hemisphere produced no apparent language deficits, the prevailing view was that right hemisphere was "stupid space" (Levy, 1981).

As was the case with the early evidence of left hemisphere language function, the most striking evidence for specialized right hemisphere function came from clinical observation of persons who had suffered right hemisphere damage. Profound disturbances in awareness and orientation were seen. Some were so spatially disoriented that they could not find their way around their own homes. (Springer & Deutsch, 1981)

Two major classes of cognitive deficits have been observed in right hemisphere damaged patients. The first is the difficulty in perception, manipulation and memory of spatial relationships of objects (to each other and to the individual). Secondly, a difficulty in perception and memory of visual, auditory and tactile stimulation which are unintegrated, complex and difficult to describe verbally. Other functions with which right hemisphere damaged persons have difficulty are the recognition, perception and memory of: faces, drawings in which a part of the contour is missing, music and nonverbal sounds. (Nebes, 1977)

Studies of neurologically normal persons undergoing psychological testing are supportive of these observations. They reveal right hemisphere advantages for performance of these same functions. Studies of split brain subjects reveal right hemispheric specializations as non-linguistic functions primarily involving spatial processes (Springer & Deutsch, 1981).

While there is speculation regarding why right hemisphere seems specialized for these functions, the more relevant question to this discussion is whether left hemisphere has an equal ability to subserve them.

Kinsbourne's (1974) position, stated earlier, suggests that the traditional right hemisphere skill of spatial orientation was bilateral before language evolved. Perhaps by evolutionary vestige then, left hemisphere could have the equal potential to subserve the functions of right. If not equal, then to what degree and under what circumstances?

Kohn & Dennis (1974) examined the visuo-spatial performances of the same left and right infantile hemiplegic hemidecorticates previously compared on language skills. While there was no significant difference reflected between right and left hemidecorticates in I.Q. scores and tasks involving personal orientation, there were severe impairments of the right hemidecorticate group (whose only functioning hemisphere was left) on those tasks measuring directional sense, orientation and visually guided route finding. In these hemidecorticates, developmental deficits of visuospatial abilities were found, thus leading the authors to observe, "The same capacities evolve to a level normative of considerably higher chronological ages when mediated by an isolated right brainhalf." They also noted that even this limited ability of left hemisphere to assume right hemispheric function does not exist when damage occurs in adulthood. The authors conclude that, "either brain half can provide a substrate for at least some of the functions based on analyses of spatial components. How long such hemispheric equivalence of the immature nervous system persists, is not clear."

Another perspective on right hemisphere specialization in the visuo-spatial skills is its capacity to subserve these while also subserving language. This is manifested in the case of Genie (Curtiss, 1977). While performing at her linguistic developmental level on other normally left hemisphere analytic tasks, this right-handed woman, the product of acute socio-linguistic deprivation, demonstrated an unusual right hemisphere advantage for word processing. Her performance on traditionally right hemisphere visuo-spatial tasks was not only superior, but on some functions, "the highest scores in the literature for children or adults." (Curtiss, 1977) There appears to be therefore, in Genie, a lateralization to the right for both language and non-language functions, and a remarkable superiority of the traditional visuospatial skills in this condition of the absence of language acquisition during a critical period for such acquisition.

The superior right hemisphere performance, though not discussed by the authors, is noteworthy in its co-existence with this left hemisphere handicap. The authors did speculate that consistent with the view that right hemisphere is the first to develop due to the greater involvement of perception with environment, that the amount of visual stimulation received was adequate in this case, for right hemisphere development. That which makes her unique is the marked impoverishment of her linguistic and auditory experience during early developmental years. It was concluded that while Genie was likely born with normal left dominance potential for language, inadequate language stimulation yielded a functional atrophy of the usual language centers of the brain. (Curtiss, 1977)

And so we see the emergence of a trifurcation in the explanatory theories. Is it the importance of auditory processing in a better equipped left hemisphere which affects laterality? Is it, as suggested by Genie, and studies of the effects of second languages, the circumstances of language acquisition? Or is it an interaction between the two? What are the necessary ingredient to potentiate left hemisphere language?

If the necessary and sufficient basis of left hemisphere specialization resides in stimulation of the greater auditory processing capacity of left hemisphere, it follows then that an exploration of the hemispheric dominance for language and the perceptual functions of persons whose auditory association areas were never stimulated, would be a valuable contribution to our understanding of the usefulness of this theoretical argument. The Deaf are such a population. They are not necessarily without language, however, using a visualmanual language of sign. In some Deaf persons both spoken and visual languages are used. These languages are totally separate, each having a syntax and grammar of its own. Such persons are therefore, Bilingual. There is additional value in the study of this population in that the sign language used by the Deaf displays both complex language structures and complex spatial relations, offering a valuable opportunity for refining our concepts of cerebral asymmetry.

The Effects of deafness on Laterality of Function

While a body of literature examining the effect of deafness on laterality of function exists, most of it unfortunately lacks certain basic considerations which are necessary to assure the validity of the interpretations made. This is due primarily to the absence of a socio-cultural, clinical knowledge of the Deaf population, on the part of many of the researchers; seasoned though they were in their primary areas of expertise. Such knowledge is necessary to understand and manage the possible contribution of these psychosocial variables of deafness. In speaking to the importance of this experiential knowledge of the Deaf population in scientific endeavor, and the multiple misinterpretations that can result without it, Hans Furth (1966) says, "A scientific fact is worthless unless it fits into a framework of comprehensive interpretation." Understanding of these variables is so very central to the questions posed and the inferences drawn in research with the Deaf population, that it requires a thorough understanding before proceeding with a review of this particular literature and findings. Appendices A & B have been provided as a thorough discussion of these issues. The reader is requested to read these and use them as reference in sorting through issues which may be confusing and difficult to follow without this information.

Summarizing what these Appendices present, we see that influencing variables associated with deafness are: age of onset, severity of hearing loss, use of mechanical aids to hearing, age of first use of hearing aid, deafness of parents, deafness of older siblings, early parent-child mode of communication, mode of communication preferred by the Deaf subject, mode used during research procedure, communication competence of instructor during procedure, competence of the subject in using that mode and finally, consideration of the degree of dependence of a signing mode on English. The Deaf population can contribute much to our understanding of laterality and hemispheric specialization if these variables are understood and considered.

The literature on lateral specialization for language in Deaf persons falls primarily into two groups: clinical case studies of aphasic-like symptoms following neurological damage and experimental studies of groups of neurologically normal Deaf subjects.

Reports of Aphasic-like Symptoms in Deaf Persons Following Lateral Cerebral Damage:

Impairments of language or aphasic-like symptoms, after left hemisphere damage, have led to the inference that the language specialization areas have been damaged and are therefore, in the left hemisphere of the brain. Evidence of this type in the congenitally Deaf population, is markedly scant, only 10 cases (Grasset, 1896; Critchley,1938; Burr,1905; Leischner,1943; Tureen, Smolik and Tritt, 1951; Douglass & Richardson, 1959; Sarno, Swisher & Sarno, 1969; Battison, 1979; Kimura, Battison & Lubert, 1976; Underwood & Paulson, 1981) having been reported.

The authors of most of these reports stated their intent to evaluate the merits of a statement by Hughlings Jackson (1878). They quote:

> "Further, the untrained Deaf-mute has his natural system of signs, which to him is of speech value so far as it goes...No doubt by disease of some part of his brain the Deaf-mute might lose his natural system of signs, which are of some speech value to him, but he could not lose speech, having never had it." (Jackson, 1878)

That quote is taken out of the context of his discussion of pathologically speechless persons and served to exclude the Deaf from this group, following directly the caveat:

> "We shall not, for example, deal with those untrained Deaf-mutes who never had speech, but the cases of those

persons only who have had it, and lost it by disease... the condition of an untrained Deaf-mute is in very little comparable with that of our arbitrarily taken case of loss of speech. The Deaf-mute's brain is not diseased, but, because he is Deaf it is un-educated so as to serve in speech. Our speechless patient is not Deaf...Moreover, our speechless man retains a service of words which is not speech; untrained Deaf-mutes have no words at all."

By this Jackson is neither saying that a Deaf person would not lose whatever speech he did manage to acquire, nor as these authors assume, that his natural sign should be expected to be impaired by damage to the same areas of the brain which, in hearing persons, would result in loss of speech. He was allowing that damage to some area of the Deaf person's brain would result in a loss of natural sign, but did not speculate on its location. He implied a neurological difference between spoken and manual language. Given the time of this conjecture, Jackson's thinking is particularly far-reaching and, given also his acknowledgement of a natural system of signs (implying a separate language), rather informed.

How does this small body of literature of reported aphasic-like impairments in Deaf persons who have suffered damage to their left cerebral hemisphere, add to our discussion of the hypothesized primary importance of the auditory sphere in the left lateralization of language? If this hypothesis were true, then auditory stimulation (with the complexity of language) would be required for the greater potential of left hemisphere to develop into left lateralization for language. According to Lenneberg (1971) this should take place during the earliest developmental years. Congenital deafness then would be expected to prohibit this linguistic stimulation of the auditory cortex. The likely outcomes in lateral specialization for language in Deaf right handers which would be consistent with the hypothesis then, are either:

1. No dominance for language, which would be observed in language impairment that is less in severity and duration than that observed in hearing left hemisphere damaged aphasics, or
2. Right dominance for language, in which no language impairment would be expected to result from left hemisphere damage.

Evidence of language deficit equal in severity and duration to that observed in hearing persons with the same damage would be seen as evidence of left lateralization for language and therefore, counter to the hypothesis that auditory stimulation is necessary to accomplish this.

Though all but one of the reported cases reflect left hemisphere damage in what in many cases we are left to assume were right handers, they are not particularly revealing to our understanding of impact on language. Nearly half of the cases (Burr, 1905; Critchley, 1938; Tureen, et al, 1951; Battison, 1979) were not clearly pre-lingually Deaf and therefore not relevant to our discussion. Of those who were pre-lingually Deafened, problems of missing historical data complicate an understanding of when and how languages were acquired. All cases reported impairments of English based communication modes, but very little, if any damage to independent sign systems. Because there seem to be differing degrees of impairment across these two modes of communication, let us evaluate them separately.

First, the impairment in functioning in all English BASED modes suggests that the absence of auditory stimulation does not does not result in right hemisphere dominance or specialization for this function. Were that the case, we would expect to see NO English language impairment. Our ability to generalize beyond this observation would require an analysis of the quality of linguistic impairment on a basis comparable in extent and duration to that seen in hearing aphasics following like neurological damage. This we cannot do for several reasons. First, there is a significant amount of variance in execution of manually communicated language; much more than the variance in pitch, volume & tone of voice in spoken language. Poizner & Battison (1980), phrase the consequent problems encountered in evaluating the linguistic behavior of Deaf aphasics: "how can we define an error in signing, and best arrive at a description of the impairment?" Secondly, Hoemann (1978) reports studies in which an error rate of 42% for written spelling jumps to 78% in the same subjects when using fingerspelling, saying, "This dissimilar performance suggests that fingerspelling is acquired primarily as a means of communicating rather than as a way of spelling English words." Without therefore, a sample of pre-morbid functioning, it becomes impossible to accurately measure impairment. Third, speech of Deaf persons is not comparable to that of hearing persons even when it has been achieved. Written communication and reading is also premorbidly significantly less proficient. Finally, manually expressed English is not directly comparable to spoken English. Overall, these disorders of signed systems which are heavily based on spoken language are not particularly informative due to the fact that the patient's signing is being mediated by spoken language, which is a different language. Similarly, failures in these modes may be due to apraxia for complex motor movements rather than actual impairments of either of the language systems.

These studies therefore are only suggestive of the following patterns:

1. As McKeever (1979) points out in reviewing the re-reported cases of aphasic symptoms in left hemisphere damaged Deaf persons, "none of these cases was profoundly aphasic even in expression following relatively short recovery periods."

2. Aphasic errors in manual English are of the same type as aphasic errors seen in hearing right-handers so damaged, though less in degree.
3. English based signing modes showed greater impairment than ASL.

With regard to the impact of left hemisphere damage on independent sign language, these reports described either no impairment, or varying degrees of moderate to mild impairment. The absence of more severe sign deficit could be the result of right hemisphere specialization for sign. There are other possible explanations however, which in the absence of better data do not permit our comfortably drawing these conclusions. For instance, the report of this apparent integrity of sign language after left hemisphere damage could be the result of inadequate, or absent measurement of an existing impairment in this manual mode. If the experimenter's knowledge of the breadth of manual language is not tuned, dysfunctional patterns may be overlooked entirely.

Where sign impairment is described, we could view it as evidence of left laterality for sign language. However, the impairments are much less in severity and duration than seem to be experienced in English based modes in the same patients, suggesting greater involvement in sign, of either the intact right hemisphere, or previously unmapped and, in these cases, undamaged areas of left hemisphere. We are unable to speculate beyond this point due to the difficulties in measuring sign behaviors. About independent sign, we can observe with interest however, that:

1. Left hemisphere damaged Deaf patients all showed considerably less impairment in comprehension than in expression; which may at least partially be accounted for by non-linguistic factors of non-linguistic apraxia and/ or use of non-preferred and least practiced hand.
2. All independent sign impairments noted were much less in severity and duration than impairments of English based modes in the same individuals.

Summary

The clinical measurement, observation and reporting problems produce the major weakness in these reports. Poizner & Battison (1979) observed, "without adequate linguistic knowledge of the language their Deaf patients used, these case histories become suspect and unreliable."

Another complication in efforts to interpret the language deficits observed rests in the contributions of differential second language processing to aphasic symptoms. Douglass & Richardson (1959) report these are the first to be impaired in bilingual aphasic subjects and the last to be restored. While this bilingual aphasia literature is complex, contradictory and beyond the discussion of this paper, the absence of historical data on these Deaf "aphasics" on when, and how language acquisition developed in these persons, places the possible contribution of second language factors entirely out of the range of measurement and control.

While clinical evaluation of this problem is frought with problems of inadequate measurement, confusion of English based manual language with that which is independent of spoken language, and the confounding of hemispheric specialization for English with that of independent sign, our analyses of these cases reveals several patterns worth noting:

- There are clear differences between the impact of left hemisphere damage on English dependent and independent sign systems.
- English dependent modes are affected longer and more severely than independent sign systems, by left damage
- Deficits in English based modes appear in type to be similar to aphasic symptoms in hearing aphasics.
- Sign impairments when observed are more often expressive than comprehensive and may be due to motor rather than linguistic difficulties. They are also noticeably quick to return.

These observations of existing reports of left hemisphere damage in Deaf persons suggest that complete right dominance for language does not result from auditory deprivation and that left lateralization is greater for sign that is dependent on a spoken language than that which is independent of it. Complex auditory stimulation does not appear to be a necessary ingredient for left lateralization for spoken language.

Finally, clinical reports as a method of inquiry, however heuristic they may be, suffer in their usefulness in generalizeability to normal cerebral function. There is the obvious case selection bias of a brain damaged population; these are not neurologically normal subjects. There is also difficulty in assuring the accuracy of site and extent of the lesion itself, as well as in isolating the effects of the injury on blood supply. The brain tends to adjust its work as best it can when damaged. We cannot make assumptions therefore, that functioning in other areas of the brain, post insult to an area, is the same as it was before trauma.

Certain of these problems can be eliminated in experimental exploration. Subjects can be matched for multiple variables rather than sharing only the commonality of brain damage. Reception and perception can be added to the focus of study, all in a neurologically normal population.

Experimental investigation of asymmetries in normal subjects has been carried out in various ways. The objective of investigators is to find ways to lateralize inputs--to present stimuli to only one hemisphere. One of the oldest of these methods takes advantage of the natural split in visual pathways. In humans this split divides our visual world into 2 fields, each of which projects into the hemisphere on the opposite side. If the visual pathway on one side is stimulated (via stimuli in one visual field) for a very short time before conjugate lateral eye movement can change the field by scanning (under 200 msec), it allows investigators to compare the abilities of the separately stimulated hemispheres. While other methods have been derived, this tachistoscopic presentation seems to be the most frequently used. Classic patterns of cerebral specialization in neurologically normal hearing persons show a right visual field/left hemisphere advantage (LHA) for language stimuli and a left visual field/ right hemisphere advantage (RHA) for faces, geometric shapes, dot localization and other non-linguistic stimuli. (Poizner & Lane, 1982)

Experimental Assessment of Cerebral Specialization in Neurologically Normal Deaf Adults:

The experimental literature on the hemispheric functioning of otherwise neurologically normal Deaf persons is sparse. The application of these methods to this population affords an excellent opportunity to investigate laterality patterns for which hypotheses of auditory importance would suggest an absence. While most of this evidence is in one or another way building upon our understanding of the relative merits of the major theories of causality in hemispheric dominance for language and differential lateral functioning, the actual theories tested in this small body of literature are primarily limited to the effect of anatomical asymmetry vs. an equipotentiality of the hemispheres to subserve language in spite of these anatomical differences. A critical period for language acquisition is not directly addressed or evaluated by these investigators; neither is the possible effect of bilinguality, nor the theory of vocal control.

Methodologies used with the Deaf have primarily assessed visual perception with a few measuring tactile and one, amazingly enough, auditory perception via a dichotic listening task (Ling, 1971). Tasks have involved identification and/or matching of uni- or bi-lateral tachistoscopically presented stimuli including words, static signs, moving signs, abstract and concrete pictures, non-linguistic designs and dots in matrices. Comparison

Groups have been comprised of various combinations of Hearing and Deaf subjects, with wide variation in the matching, description and/or control of subject variables.

Because the whole of these studies have been undertaken for the purpose of examining hypotheses regarding the importance of complex auditory stimulation, most have compared groups of Deaf with Hearing subjects. They have interpreted any differences found between groups accordingly, as a function of the absence of auditory stimulation. Only two refer even tangentially to the bi-lingual nature of the experimental situation, or the experimental population. None either attempt to control, or incorporate/evaluate the possible contributions of bilingual factors to their findings.

Poizner, Battison & Lane (1979) have attempted to summarize the findings of the major of these studies (McKeever et al, 1976; Manning et al, 1977; Neville & Bellugi, 1978; Phippard, 1977; and Poizner & Lane, 1979) by way of right field/left field ratios taken from dependent measures of either accuracy, or speed of responding used by previous experimenters. Using those data, Figure 1 presents the outcome of these major studies. Ratios greater than 1.0 reflect left hemisphere advantages (LHA's); less than 1.0, right hemisphere advantages (RHA's), with asterisks indicating statistically significant field differences. Figure 1 further divides the experimental results by task and stimulus type. Laterality ratios are shown for visual presentation of static ASL sign, ASL moving signs, printed English, static manual alphabet handshapes, and non-linguistic visual patterns. The hatched bars identify ratios of Deaf subjects and open bars those of hearing controls.

Insert Figure 1

As to the general patterns which emerge we see the following trends:

1. Deaf and hearing subjects tend to show a LHA for printed English, with much less pronounced asymmetries in the Deaf, often not reaching significance.
2. Deaf and hearing subjects tend to show RHA's to signs presented statically;
3. Manual alphabet handshapes elicit weak RHA, while non-linguistic patterns tend to elicit greater right hemisphere involvement.

In general then, it appears that, consistent with the clinical literature, left lateralization for language is possible without complex auditory stimulation, but that the resulting patterns of hemispheric specialization are different from those in which it is present. Exceptions to these patterns are seen in

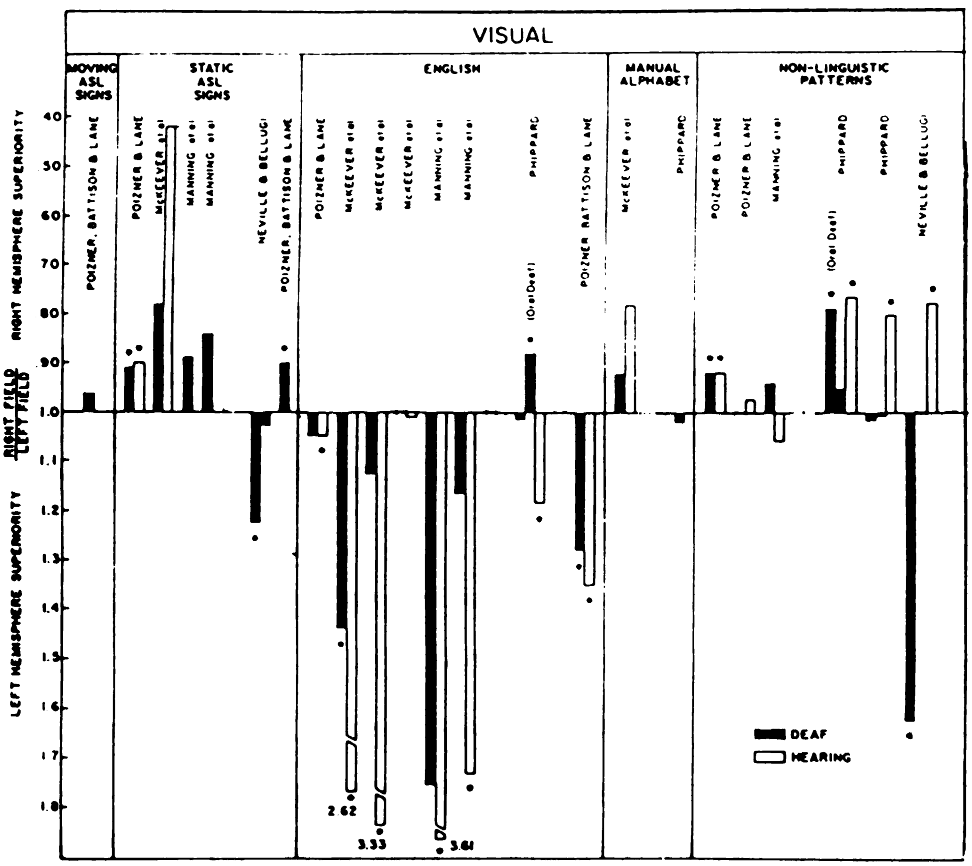


Figure 1. Right field/left field ratios of deaf (hatched bars) and of hearing subjects' performance to both linguistic and nonlinguistic stimuli from six studies.

the work of Phippard (1977) and Neville & Bellugi (1978). A review of two of the more illustrative studies of this general body of research, as well as one which advances the methodology significantly and finally, of the two with exceptional findings are appropriate to our discussion.

The study conducted by McKeever, Hoemann, Florian and Van Deventer (1976) illustrates most of the issues involved. The authors began their exploration setting their premise as:

> "left hemispheric language lateralization depends on the inherent superiority of left hemisphere auditory association cortex, it carries with it the implication that people who have never had auditory language experience would not develop left hemisphere language dominance. On the other hand if the superiority of the left hemisphere in language functions derives from some other anatomical or functional characteristics of the brain, then left hemisphere specialization should be unaffected by deafness."
>
> (McKeever et al, 1976)

Predicated on this assumption a visual processing task was utilized for bilaterally presented English words, signed letters, static signs and ASL. Controlling for age, sex and other known handicaps they compared college age Deaf subjects who had learned ASL "before the age of 5", with hearing subjects who were "proficient in ASL". No information was provided on first language, comparability of ASL skills, or the age and method of learning ASL in the hearing Ss, however. No information on age, method of acquisition or competence in English were given for Deaf Ss. Deaf subjects responded in ASL for all stimuli and hearing subjects in English.

Results showed hearing subjects to have a substantial LHA to uni- and bi-lateral words and a RHA on the ASL task. Deaf Ss showed lateral preferences in the same direction as hearing subjects on all tasks. Only unilateral words however, reached significance for the Deaf, showing LHA. This LHA was significantly less than that shown by the Hearing Ss, however. Additionally, hearing Ss showed less right hemisphere capacity for words and less left hemisphere capacity for ASL than did the Deaf. The authors interpreted these findings as "consistent with the prediction...that the deprivation of auditory experiences results in markedly reduced asymmetries of cerebral information processing capacities." and "an increased capacity...for 'minor hemisphere' processing...seems indicated for the Deaf."

Poizner & Battison (1980) see this conclusion as unwarranted based on several methodological criticisms. First, McKeever et al pooled the scores of ASL signs with that of manual alphabet recognition because the former was so very low. This effectively caused evaluation not for ASL, but for handshapes which are a code for English letters, thereby contaminating ASL with English. Secondly, because only linguistic stimuli were used, no test of general visuo-spatial processing in the Deaf was made to support the authors' conclusions. Finally, the Deaf and Hearing subjects used different response modes, producing results which are not truly comparable.

This last point is probably the most obvious indicator of the absence of concern with bilingual factors. The authors set out to test comparatively the processing of two types of linguistic stimuli which are in fact also representative of two separate languages. Though the response mode of ASL for the Deaf was likely intended as an accommodation to their speech handicap, by allowing the response modes to vary in this way, a confounding occurs. The dependent variable was mediated by one of the languages being tested (ASL) in the experimental group (Deaf), and the other (English) in the control group (Hearing). It is possible for instance that the LHA of the Deaf group to uni lateral words is less than it might be had it been responded to without translation into ASL, a language the authors conclude is in itself processed with greater right hemisphere involvement.

The absence of differences in the bi-lateral (all ASL) task could be explained by many task and strategy variables. Neville & Bellugi (1978) state that their Deaf subjects have reported using a strategy of selectively focusing attention (though not gaze) on one field preferentially for a time, switching back and forth across fields during bilateral presentation. They suggest that this would be a strategy more likely to be used by Deaf persons who customarily receive information by focusing on the signer's eyes, perceiving the signs via peripheral vision. The study by Manning, Goble, Markman & LaBreche (1977) using bilateral presentation only, resulted in no lateral asymmetries at all in the Deaf. These findings strengthen the explanatory utility of this strategy variable.

It would seem therefore, that while this study, as a model of these experimental studies, indicates that Deaf persons do show evidence of lateralization, results are nonetheless inconclusive. Results could also have been influenced by:

1. Strategy variables unique to the Deaf in bilateral presentation,
2. Effects of translation in the use of differing response modes,
3. Differential cerebral organization for a second language,
4. The absence of stimulation of the auditory sphere
5. The unique visuo-spatial nature of ASL, and
6. Confounding of ASL with English in pooling signed stimuli results.

Another study by Poizner & Lane (1979) evaluates more thoroughly the hemispheric processing of ASL by incorporating as static sign stimuli, signs which in life use do not require movement. This prevents confounding of dominance for ASL with dominance for any reconstruction process which could possibly result from the presentation of one tachistoscopic moment of a totally moving sign context. An additional contribution of this study was its assessment of whether Deaf subjects, seeing a sign and responding by using that sign were processing it as linguistic stimuli, or simply identifying its shape. Two subject groups were used: 10 familially Deaf persons who, having Deaf parents, learned ASL as a first language (Deaf group) and 10 hearing persons who were totally unfamiliar with ASL in the other (Hearing group). Each group was measured in their response time to target stimulus identification of 4 types: Arabic numbers, ASL numbers, Non-ASL handshapes and Geometric shapes known to produce a RHA in hearing persons.

Results included a clear RHA for Deaf subjects for signed numbers and a significant LHA for the hearing group in processing Arabic numbers. The interpretation that the Deaf were processing the stimuli as linguistic material was supported by several items. First, the Deaf reacted much faster (200 msec) to the sign than did the hearing who were unfamiliar with its linguistic utility. Second, the Deaf Ss did not respond reliably faster to one sign target than the other, as did the hearing. Poizner & Lane see this as consistent with the view "that Deaf subjects labeled the signs and processed the labels, whereas the hearing subjects relied exclusively on shape cues." Third, the Deaf Ss reacted faster to signs than non-ASL hands, the hearing doing the opposite. Finally, unlike the Deaf, a hearing Ss who showed a large sign asymmetry was likely to show the same asymmetry to non ASL hands, Deaf Ss also showed a RHA for non-ASL handshapes comparable to the Hearing Ss.

The authors conclude that a RHA for signs in the Deaf implies that the spatial processing requirement dominates the language processing requirements in determining cerebral asymmetry. However, this material is also potentially overlearned. The use of response time for recognition as a measure therefore, may not constitute evidence of linguistic use or incorporation. Finally, only the visuo-spatial task requirements are inferred as causal. Left glaringly unaddressed therefore, is the absence of RHA in the hearing or Deaf groups in processing the geometric shapes: shown in previous studies (Hellige, 1975; Hellige & Cox, 1976) to yield a RHA in hearing subjects.

Advancing the methodology in a highly creative way, Poizner Battison, and Lane (1979) introduced the significant variable of motion to the testing of ASL processing by way of a stimulus presentation via 8 mm movie. Three frames were exposed singly to a beginning, middle and end point in the execution of asymmetric signs, totalling 167 msec of animated tachistoscopic exposure per trial. Static signs were also presented as were English words. In the Deaf group were 15 congenitally Deaf adults who learned ASL as a first language and used it as their primary mode of communication. No information on if, when and how English was learned, or competency achieved, is given. Hearing subjects were 8 hearing persons unfamiliar with ASL.

While Deaf Ss received all three stimuli sets, hearing received only English words. Deaf Ss responded to English stimuli by fingerspelling the words, staying in the English based mode. For signs they responded in ASL, also staying within stimuli mode.

Hearing Ss showed the expected LHA for English words. The pattern of asymmetry previously seen in the Deaf of an LHA for English words and a reliable RHA to static signs, was obtained, though comparison with Hearing Ss on English words showed less asymmetry by the Deaf. Moving signs were processed with virtually equal accuracy across both fields. The highest degree of variability within a group occurred in the Deaf for processing English words.

The authors concluded that the LHA for English words in the Deaf "implies that auditory experience is not a necessary condition for left hemisphere dominance for words." They allow however, that the segmented output of fingerspelling may have contributed to this LHA. The shift toward LHA, with no real advantage emerging as reliable in processing moving signs is interpreted as supportive of the view that left hemisphere functions primarily in the analysis of skilled motor sequences and of temporal sequences in normally hearing persons.

They grapple with the question, "If our Deaf subjects LHA with English words is the result of left hemisphere specialization for lexical processing, however, why did the same Ss also show a RHA to signs portrayed statically?" They reject the hypothesis that two "language centers" exist in each hemisphere of the deaf, one for English and one for ASL, as "unparsimonious" and "unwarranted" because "spatial properties of language can 'mask' left hemisphere linguistic activities."

Another possible contributor to this outcome not considered by the authors is the bilingual status of the experimental population. To evaluate this contribution would require information on when and how English (L2) was acquired for these deaf persons and the degree of competence they had achieved. Such information might relate to the high degree of variability (both marked LHA and RHA in individual Ss) shown by the Deaf in producing the group LHA for words.

While not directly addressing the question of Bilinguality Poizner & Battison (1981) reflect the complications involved in interpreting this body of literature due to the "lack of control of the language background of Deaf subjects: clearly ASL signers are needed for research of this sort." I would also add that complete language histories for languages tested, including English, are also necessary.

The magnitude of reported influences of bilinguality on hemispheric functioning make this line of investigation necessary in the Deaf bilingual population, to better evaluate the relative contributions of these factors beyond the presence or absence of auditory stimulation.

Kolers (1963) for example has suggested that in bilinguals different languages may have separate memory stores. Hoemann (1978) tested this hypothesis on short term memory in the Deaf using methods which had been successful on spoken language Bilinguals. He acknowledged that when one language was spoken and the other manual, special considerations exist. For instance, since both languages use different sensory systems they can occur simultaneously. One can speak and sign at the same time. Using static signs, Hoemann concluded that in short term memory Deaf persons do code manual and English stimuli categorically, compatible with Koler`s hypothesis.

Similarly, a study of long-term memory (Siple, Fischer & Bellugi, 1977) for ASL signs and printed English words led authors to conclude "ASL and English are treated as two separate languages in the same way that two oral languages are by fluent Bilinguals."

While none of the studies in this relatively small experimental body of literature, directly tests the effect of bilinguality, one study by Phippard (1977) contains enough information for some of these assumptions to be made. Examining the question, "Would cerebral lateralization of function develop in the absence of language acquisition?" and concerned about whether delayed exposure to language was an impediment to the development of a normal pattern of cerebral differentiation, a comparison of Deaf and Hearing subjects was made. Two Deaf groups were used: one had received exclusively oral training (training in speaking and lipreading English with no use of manual sign), the other received training in Total Communication (the simultaneous use of both manual and oral languages). Because the Oralist Method of educating deaf children prohibits the use of any gestures or sign communication, we may assume that these children would not have been the Deaf children of Deaf parents we have discussed in Appendix A; whose only parent-child language would have been manual. The Oralist group therefore would have acquired NO formal language during the 'critical period' for language acquisition. The Total Communication group (which combines use of ASL and English) would then be Bilingual, with ASL = L1 and English = L2.

Using a matching task of tachistoscopically presented letters and spatially oriented black lines across groups, she found that while the Controls showed the expected LHA for letters, the TC (or Bilingual) group showed only a non-significant Left hemisphere trend and the Oral group (No language <5 years) showed a right hemisphere advantage for letters. Spatially oriented lines were processed with the expected RHA in Controls. Oral subjects also showed a RHA, whereas the TC group showed no lateral preference. Fingerspelling stimuli were shown to TC only and no lateral preference was shown, while unfamiliar faces, shown to TC and Control only reflected the expected RHA in Controls and a non-significant Left Hemisphere trend in the TC group.

The patterns of visual asymmetries differed from the hearing Controls in both experimental groups. The Oral Group (language deprived) demonstrated greater reliance on right hemisphere for both language and visuo-spatial material. The TC (or bilinguals) demonstrated no significantly greater reliance on either hemisphere, though a trend toward left hemisphere strength in letters and face perception was observed.

The other study reporting findings uncharacteristic of the previously described laterality patterns of Deaf persons is that of Neville & Bellugi (1978). They first report an earlier study by Neville (1975) in which the lateral functioning of Deaf persons was examined to explore the relationship between acquisition of speech and cerebral specialization. In this study 15 normally intelligent, non-speaking Deaf children (9 to 13 years of age) were compared with hearing children of the same age range. Subjects were required to identify line drawings of common objects while evoked potentials (EP`s) were recorded via electroencephalograph (EEG) from left and right temporal sites. The EP`s from the right hemisphere were significantly larger than the EP`s from the left in the Hearing Ss. Initial findings showed the laterality pattern characteristic of Deaf Ss in previous studies, with no asymmetry of amplitude or latency of EP components. Behavioral performance was quite similar to the hearing Ss, however.

This prompted further analysis of the data which was made by evaluating the EP's of 8 of these Deaf children, the parents of whom were determined to be deaf. Their first language, learned naturally, was ASL. These Ss DID have asymmetrical EP`s -- OPPOSITE in direction from the hearing Ss, indicating a LHA for the visuo-spatial task.

The remaining 7 Deaf children showed no evidence of lateralization. These children could not speak and did not know sign language. Though they were able to communicate with other people by gesture and pantomime, they had had no experience with formal language such as English or ASL.

Summarizing this earlier report Neville & Bellugi (1978) say, "the acquisition of aural-oral speech and language is not the relevant variable in the development of cerebral specialization...Perhaps the acquisition of some formal language is the critical variable in the development of hemispheric specialization for both language and non-language skills."

These findings raised however, several questions, most specifically, the apparent left hemisphere specialization for non-language tasks for which hearing subjects show right hemisphere specialization. The authors raise two possible explanations:

1. Deaf persons learn language as do hearing persons, with left hemisphere playing a major role. However, due to the strong visuo-spatial structure of ASL, non-language visuo-spatial tasks are also preferentially performed by left hemisphere, OR
2. Owing to its strong visuo-spatial structure, sign language is acquired with right-hemisphere specialization, leaving left hemisphere to specialize for non-language tasks.

Neville & Bellugi (1978) further comment on the need to know more about how linguistic material would be processed by these subgroups of Deaf which differ primarily in early language experience.

These authors conducted a second study, in which there were 14 congenitally Deaf adults (15 to 35 years of age) who were different subjects from the previously reported study, whose major form of communication was ASL. No information is provided on the hearing status of their parents; age and method of acquisition of ASL; competency, age and method of acquisition of English. A language and a non-language task were used. All Deaf subjects participated in the ASL task, but only 8 were given non-language tasks on which eight Hearing controls matched for age and handedness were also run.

Non language stimuli were dots variably located in a matrix (Levy & Reid, 1976), presented bilaterally and unilaterally to the Deaf and only unilaterally to the hearing (as they found bi-lateral presentation too difficult). Fixation digit was Arabic which was reported before the dot was localized. Instructions were given in written English. The language stimuli of symmetric static line-drawn signs were presented Bi-laterally and unilaterally to the deaf, with signed numbers used as fixation stimuli, which were reported by signed response. The Deaf showed a significant LHA for uni-lateral signs and no lateral difference in bi-lateral presentation. Deaf Ss also showed a significant LHA for unilateral dot presentation, but no difference in bilateral presentation. Hearing Ss showed a significant RHA for the unilateral dot localization task as expected.

The authors suggest four major conclusions to these results:

1. Significant lateral asymmetries in performance indicate that lateral specialization is not dependent on auditory stimulation or the acquisition of speech.*

2. LHA for sign language indicates it is acquired with left hemisphere specialization like spoken language, even though "it is acquired in the visual-haptic modalities."

3. LHA for dot localization in the Deaf suggests that "since spatial localization is an important aspect of the grammar of sign language, it may be adaptive to grammar of sign language, it may be adaptive to bring bring together these two functions within the same hemisphere."

4. These data suggest that "both biological and experiential factors, such as language acquisition and the MODE of language acquisition, interact in determining the functional organization of the brain."

(Neville & Bellugi, 1978)

Summary

Over the course of our discussion we have culled several theories which are considered important to cerebral lateralization of function, as it is manifest in humans. These are:

1. The importance of the auditory sphere of the left hemisphere,
2. The contribution of vocal control asymmetry,
3. Equipotentiality of the hemispheres with a "critical age" for acquisition of language, and a possible variation of this:
4. Order and age of acquisition of first and subsequent languages may contribute to hemispheric functioning.

Applying these to this body of research with the Deaf we find that while a tremendous amount of work is still needed for unambiguous patterns to emerge, we can begin to identify those areas which promise the most fruitful avenues of inquiry.

First, there is controversy among these experimenters over how best to interpret the patterns of reduced asymmetry found in these studies. Parsimony would suggest however, that the very presence of left hemisphere specialization for language processing in persons who have never experienced complex auditory stimulation would argue against this being a necessary factor in the emergence of left lateralization. While the potential contribution of vocal control has not been amplified by this topic area, the absence of vocalization as a primary mode of expression in this population would suggest that this variable is not a necessary condition for left lateralization for language, either.

The reduction in magnitude of asymmetries as well as the high variability within groups of Deaf Ss, calls for deeper analysis. Once we look past the deafness as the explanatory variable, the importance of other hypothesized explanations is heightened; specifically, the concept of equipotentiality as viewed through a bilingual framework.

The work of Phippard (1977) identifies the comparative outcome of Oral training in language development (likely no formal language during the years of normal language acquisition) as resulting in an RHA for language and non-language material alike. This calls to mind the unusual right hemispheric specialization for language and non-language functioning of Genie, in whom early language deprivation was also experienced. There exists analogically a further relationship between the Oral Deaf, Genie and the Left Hemidecorticates reported by Dennis and Kohn (1975), in an inability to reach competence with higher order language functions. (Moores, 1977).

This suggests that in cases where no formalized language has been acquired during early years of natural language acquisition, left hemisphere defaults to right in specializing for language. The traditional right hemisphere function of visuo/spatial processing appear to remain in the capacity and specialty of right under these circumstances. Acquisition of either an auditory language, or as suggested by Neville and Belugi (1978), a formal language, then appears to be a developmental experience necessary to the potentiation of a biological predisposition to left hemisphere specialization for language.

The Total Communication Group (a formal language, though not an auditory, acquired first) of Phippard (1977) however, shows a left hemisphere trend for English letters AND facial recognition. A greater number of this group would be expected to be the 10% of Deaf children whose parents are deaf, who also showed an LHA for visuo/spatial tasks in the Neville (1975) study. These subjects had learned both ASL and English (acquired visually or tactilely -- not auditorily) before adolescence. These findings lead us to our fourth theory of lateral hemispheric processing, the influence of Bilinguality, which has been shown to result in quite similar laterality patterns for the languages involved. While ASL does indeed differ from English in dramatic ways, Lenneberg suggests that differences in languages should not interfere with natural bilingual acquisition:

> "When language learning is at its biological optimum, namely in childhood, the degree of relatedness between the first and second language is quite irrelevant to the ease of learning that second language. Apparently, differences in surface structure are ignored and the similarity of the generative principles is maximally explored at this age."
>
> Lenneberg, (1967),

suggesting some validity in the reasoning offered by Neville and Bellugi (1978) that sign would be acquired in much the same way as spoken language; with major left hemisphere involvement.

Useful in the development of this body of research would be a clear isolation of the variable of deafness, while focusing on the influence of the unique Bi-language acquisition experiences of these persons on hemispheric processing of English words, Static signs moving signs and visual design stimuli. Of further interest would be the effect on each of these functions of later life acquisition of ASL, as this is the course of ASL acquisition for most Deaf persons, including those Orally trained Deaf who, past the years of influence of education, find its facility appealing. Of later acquisition of language Lenneberg says,

> "Most individuals of normal intelligence are able to learn a foreign language after the beginning of their second decade, although the incidence of 'language learning blocks' rapidly increase after puberty. Also automatic acquisiiton from mere exposure to a given language seems to disappear after this age, and foreign languages have to be taught and learned through a conscious and labored effort."
>
> Lenneberg (1967)

Bilingual literature suggests greater right hemisphere involvement with such later acquisition of second language. This could possibly account for the co-existence in previous research of a strong RHA to ASL in some Deaf Ss, and an LHA in others: the former possibly having acquired the language later; the latter, earlier.

Present

Study

The current study isolates the unique early Bilingual experiences of this Total Communication population from the contributions of deafness by investigating the lateral functioning of the Hearing children of Deaf parents whose first naturally acquired language was ASL. The benefits of working with this speaking, hearing population spill beyond these design considerations into such methodological areas as:

- the elimination of any hidden independent variable associated with deafness such as attendant undiagnosed neurological differences.
- If unique laterality patterns are established, a hearing population permits the use of auditory methods as well as standardized written measures in any further correlational studies.
- language competency evaluation is possible and useable with a speaking population.
- instructional mode, and receptive and expressive language tested may be consistent. For example, spoken responses to word stimuli will control for the possible segmenting influence of fingerspelling.
- comparable response modes which permit more controlled and reliable comparison with hearing controls.

If no differences in laterality patterns are found, inferences can be made that these unique Bilingual experiences are not contributory to hemispheric specialization of function; suggesting that reported differences observed in the Deaf Groups are unrelated to these language acquisition factors and more closely related to the absence of auditory stimulation.

In this study therefore the three exact types of stimuli used by Poizner et al (1979) were used; words, ASL static signs, ASL moving signs and a fourth; geometric shapes, was added to assess visuo-spatial skills unrelated to language. Though these stimuli were presented in one session, with order of presentation counterbalanced, for descriptive clarity we will treat them as four separate experimental conditions.

Consistent with the methodology developed by Poizner, Battison and Lane (1979), movement was simulated in animation through sequential presentation of still photographs, achieved in single frame exposure of 8 mm. movie film, taken at strategic points during a sign. Stimulus duration was held under latency of eye movement in tachistoscopic method (initially stimulating only one hemisphere) by exposure of only three frames of 8 mm film.

METHOD

Overall

Subjects

Group 1 was comprised of 10 hearing adults who are children of Deaf parents and whose first language, acquired naturally, was American Sign Language. Five of these were first born. There were 7 women and 3 men. Ages ranged from 20 to 58 with a mean of 43.7 years. All were right handed as were their parents, with 2 Ss reporting a left handed grand-parent. Mean years of highest grade completed were 15.9, ranging from 12 to 19 years. None had corrected vision less than 20/20. Eight reported having difficulty learning to do math. None reported a history of neurological problems of Epilepsy or blackouts.

Group 2 was comprised of 10 Hearing persons whose first language was English and who acquired ASL as a second language, after the age of 12. Seven were women and three were men. Ages ranged from 18 to 59, with a mean of 35.8 years. All were right handed, only one reported one left handed parent, with none reporting a left handed grand parent Four were first born children. Eight reported having learned another language than sign, one as early as 10 years; all others during secondary education. Education ranged from

12 years to 20, with a mean of 16.5 years. None reported corrected vision less than 20/20. None reported having had problems learning, nor neurological history. Subsequent to participation, one subject told of a history of Epilepsy with non-traumatic onset approximately 9 years of age. The effect of this subject's score will be discussed later.

Group 3 was comprised of 10 Hearing controls whose only language is English and who have no familiarity with ASL. Six women and four men ranged in age from 19 to 47, with mean of 35.7. All were right handed, one reported one left handed parent, none reported left handed grandparents. Only one was first born. Years of education averaged 15.3, ranging from 12 to 20. Four had never learned a second language, two of those who did learn a second language did so naturally in the home, one at age 8. None had corrected vision less than 20/20. None reported learning difficulties or neurological problems.

All subjects were recruited by open letter to relevant organizations in the State of Michigan, requesting their participation (see Appendix C).

Information was acquired on handedness, age, sex, highest academic level achieved, Grade Point Average, profession, birth order, competency in English and ASL, age and method of acquisition of second language, corrected vision and history of neurological events or conditions in an effort to control for these factors. At the same time Informed Consent was be obtained in writing. (see Appendix D).

Stimuli and Apparatus.

The methodology used by Poizner et al (1979) was used used to the extent possible technologically. A few changes were made in an effort to improve fixation. Therefore, all stimuli were presented on Super 8 mm movie film. Four stimulus sets were used, all exposed by a single frame filming technique and described separately per Experimental condition.

The fixation was controlled by the pseudorandom distribution over one fourth (10) of the trials of each stimulus set, of a fixation image (the "(?)" figures of the Helvetica Press-type Set), which required identification by the subject when seen. This was a totally nonlinguistic task to offset any possible effects of competing or complementary tasks to the experimental tasks.

Subjects were seated and positioned relative to the projected 8 mm image to assure a visual angle of three degrees of the stimuli center to the left or right of fixation. Distance between fixation point and stimulus; and the distance between Subject and projected image, were varied. For instance, if the subject was seated 76" from the projected surface, then the projected image was adjusted to a fixation/stimulus distance of 4".

Procedure.

A warning stimulus was presented by the fixation point rapidly pulsating (by repeatedly exposing and covering the lens for two consecutive frames each, while filming the fixation point) for 1 second (a total of 18 frames) before the onset of the stimulus. At stimulus onset either the fixation point remained for the duration of the stimulus exposure, or the special fixation image "(?)", appeared for the duration of the stimulus exposure. Subjects were instructed to maintain fixation, signal the presence of the special fixation image when present by raising either index finger, and then to report the stimulus. Approximately ten seconds (180 frames of black film) elapsed between trials, with the subject given the time they required to respond to the film. All signed responses were transcribed in the notation of Stokoe et al (1976), Dictionary of American Sign Language when there was no rapidly apparent English gloss for the sign. An ASL bilingual, recorded the signed responses.

Experimental order was counterbalanced across subjects. Subjects received the following instructions:

> "You will see a white circle in the center of the screen, like this. It will begin to pulsate, like this. When it does, I want you to focus your attention on it. This design may, or may not, then

appear. You must signal when you see this special design by raising either index finger. Do not signal unless you see this design.

At the same time, with or without the special design, a picture will appear either to the left or to the right of the circle. You must then report the (word, sign, or point) which appeared on the side. You must make this report by (voice, sign, or point).

At all times your focus must be concentrated on the circle. There will be no advantage to directing your attention to one side or the other.

We will do a few practice trials. I will tell you when the actual test begins."

Five practice trials were used in which the special fixation was used twice with stimuli. A minimum of two correct responses on these trials was achieved before proceeding with actual trials; practice trials repeated if necessary. For the actual test trials responses were recorded on the Subject Answer Sheet (See Appendices).

Laterality Coefficients (LC) as described by Marshall Caplan & Holmes (1975), considered to be free of overall accuracy levels, were computed for all subject scores for each stimulus set. Group mean LC's were used as the dependent measure of hemispheric functioning, with a significance level of .05 selected for all planned comparisons.

Experiment I

Subjects.

Groups 1, 2, and 3.

Stimuli.

Stimulus Set I consisted of the same 20 high frequency three letter English words used by Poizner, et al (1979), (all words appeared at least 50 times per million in the Thorndike-Lorge count). These were vertically printed (chart pak Velvet Touch lettering, Helvetica Bold 72 PT/M10772C) to eliminate the effects of any scanning from left to right that might take place after exposure. Each word was presented for a total exposure of 112 msec, on two frames of film. The words were centered (3 degrees) to the left or right of fixation point and span (.5 degrees) in width and (1.5 degrees) in height. Words used were: JOY, LEG, SKY, ROW, WAY, ALL, ACT, CRY, LOW, PUT, BOW, TEN, OUT, TEA, SUM, PAN, MAP, NOD, RAY, WHO.

Procedure.

Subjects were instructed verbally in English. They were instructed to respond in English. These words were recorded on the Subject Answer Sheet under Experiment "Words". Five practice trials preceded the 40 test trials. Responses were scored correct only if the complete exact word was reported by Ss. Two of three letters correctly identified were scored as incorrect.

Expected Results.

It is expected that hearing control monolinguals (Group 3) and late learn signing subjects (Group 2), will show the reported LHA for words, characteristic of right handers.

Motivated Hypothesis I:

If, as suggested by earlier studies, early Bilingual experience involving one visuo-spatial language, does affect hemispheric specialization for the processing of the verbal one of those languages (in this case English), than right visual field (Left Hemisphere) advantage as measured by the mean LC will reflect less left hemisphere advantage for native signers than that of late learn signers, or non-signing controls. This outcome (Hm: $M1 < M2 = M3$; LHA) will permit us to reject the null hypothesis.

Null Hypothesis I:

If early Bilingual experience with a visual spatial first language has NO effect on hemispheric specialization for the processing of one of those languages, then it is expected that all groups will show the same LHA for processing words, as reflected in no differences between the mean laterality coefficients for Groups 1, 2 and 3. This result (Ho: $M1 = M2 = M3$)

would require acceptance of the null hypothesis.

Experiment II

Subjects.

Groups 1 (native signers) and 2 (late learn signers)

Stimuli.

Stimuli for Set II consisted of the same static signs used by Poizner, et al (1979). These were selected as bilaterally symmetric about the midline of the body, so that the arms and hands were equidistant from the fixation point when presented in either visual hemifield. In filming, a fluent Deaf ASL signer was positioned so that the midline of the body appeared (4.4 degrees) from the fixation point when viewed by a subject. Signs spanned approximately (3.8 degrees) in width with the closest edge of the sign (2.5 degrees) from the fixation point. All signs selected had been common ASL signs, "chosen to minimize the transparency of meaning." Facial expressions were neutral and invariant from sign to sign. The signs in the stimulus set did not move in presentation. Three successive frames were shot in the static image for a total of 167 msec. These signs were all pretested by Poizner et al (1979) to be readily identifiable without their standard movement. Static signs consisted of the following with specific form determined by Poizner et al (1979) as referenced in Stokoe et al (1965) where optional variations exist in the language (such spe-

cifications appear in parentheses):
ASK, AFRAID, WANT, TEACH, HEADACHE, MORE, EQUAL, PLAY, HAVE, LOVE, CONTINUE ("A" hands), RAIN, LICENSE ("L" hands), SELL, MEET, LOOK-AT-ME pl. (i.e., "many people look at me: "4" hands), VACATION ("5" hands on upper chest), CELEBRATE, CAT, MISCHIEVOUS.

Procedure.

Subjects were instructed in ASL by a fluent Bilingual. They were instructed to respond in sign. These signs were recorded in notation of Stokoe, et al (1976) when there was no rapidly apparent English gloss for the sign.

Responses were scored correct only if Ss produced the complete sign, including appropriate motion. Miming of hand position alone (usually accompanied by facial/body indicators of "I don't know") were scored incorrect.

Expected Results.

Motivated Hypothesis II:

If the early vs. late acquisition of a visual spatial language has an effect on hemispheric specialization for the processing of that language; with Right hemisphere playing a greater role in late acquisition, then it is predicted that the left hemisphere participation of native signers, as measured by the LC of Group I should show greater LHA than that of late learn signers and the RHA should be greater in Group 2 than Group 1. Such an outcome (Hm: M1>M2 as measured by a Left LC, and Hm: M1 < M2 as measured by a right LC) would permit rejection of the null hypothesis.

Null Hypothesis II:

If early vs. late acquisition of a language has no effect on hemispheric specialization for processing of that language, then the visual field advantage, as measured by the mean laterality coefficient, of Group I (who learned American Sign Language early) should not differ from that of Group II (who learned American Sign Language late as a second language). In this event (Ho: M1 =M2) the null hypothesis would be accepted.

Experiment III

Subjects.

Groups 1 and 2

Stimuli.

Stimulus Set III was comprised of 2Ø signs which were filmed in three individually exposed frames (167 msec) at the beginning, mid and end positions of the sign's execution. These three frames were chosen to maximize intelligibility and smoothness of apparent motion. An attempt was made to capture different rates of motion within signs by selecting positions for the second frame to be spatially closer to either the beginning, or end position. For each frame of film the sign was made bi-laterally symmetric about the midline of the body.

Moving signs used were those described by Poizner et al (1979): ADDRESS, NOW (lax "Y" hands), EVERY-SUNDAY, CAN, ANGRY ("5" hands at mid face), LOSE ("Ø" hand opening to "5"), ABANDON, DARK, FREEZE, QUIET, MACHINE, HERE, FIRE, WITH, CLEAK, FINISH, SHOES, RESTRAIN-FEELING, SAVE, INTRODUCE ("B" hands).

Procedure.

Subjects were instructed in ASL by a fluent Bilingual to respond in identifying stimuli by sign. All responses were recorded on Subject Answer Sheet under Experiment "Moving

Signs". Stokoe, et al (1976) notation was used where English gloss was not readily apparent.

Expected Results.

Motivated Hypothesis III:

If age of acquisition of a visual spatial second language does have an effect on hemispheric specialization for processing that language, as predicted, then native signers would be expected to show a greater LHA than late learn signers as measured by the mean LC. Further, late learn signers would be expected to show a RHA in a mean laterality coefficent reflective of right hemisphere functioning. Such result (Hm: M1> M2, LHA and M2 > M1, RHA) would permit rejection of the null hypothesis.

Motivated Hypothesis IIIa:

Further, if ASL with motion added utilizes the processing strategies of both hemispheres in native signers, then RHA=LHA in Group 1.

Null Hypothesis III:

If age of acquisition of language has no effect on hemispheric specialization for processing that language, then the average laterality coefficient for native signers should not differ from that of late learn signers.

Null Hypothesis IIIa:

Further, if motion in ASL has no effect on hemispheric processing, then these mean LC's would be reflective of the previously reported RHA for processing static signs for both groups. Such resulsts (Ho: M1 = M2; RHA) would require acceptance of the null hypothesis.

Experiment IV

Subjects.

Group 1, 2, 3.

Stimuli.

Eight renderings of related black lines measuring 7x2.5 mmm and separated by 18 degrees of angle, were used, each exposed for 2 frames (112 msec) and pseudorandomly presented two or three times in each visual field.

Recognition of spatial orientation of short lines has been demonstrated to be a minor hemisphere function (Atkinson & Egeth, 1973).

Procedure

Subjects were instructed in English. A card with all eight stimulus designs was placed in front of the subject who was instructed to identify the stimulus presented in visual half fields by pointing to the matching design on their response card. All responses were recorded on Subject Answer sheet under "Oriented Lines" with appropriate coding (see Appendix H)

When the trial items were performed with better than 50% accuracy, the task difficulty was increased by manipulation of room light and/or lens filters which decreased the figure-ground contrast and sharpness, until 50% accuracy was achieved.

Expected Results.

It is expected that late learn signers and non-signing controls will manifest the RHA previously reported for right handers for processing visual spatial stimuli.

Motivated Hypothesis IV:

If, as suggested by previous studies, the early experience of acquiring a visuo-haptic language results in the greater use of left hemisphere for processing visuo-spatial stimuli then native signers (having this unique early language acquisition experience) will manifest a mean LC indicating lower right hemisphere involvement for visual spatial stimuli than will late learn signers or controls. Another possible outcome supportive of this hypothesis would be a LC indicative of greater LEFT hemisphere involvement for native signers; with late learners and controls reflecting the expected RHA. This result (Hm: $M1 < M2 = M3$, RHA; and/or Hm: $M1 > M2 = M3$, LHA) would both permit rejection of the null hypothesis.

Null Hypothesis IV:

If hemispheric specialization for visuo-spatial tasks is unaffected by early or late acquisition of ASL, then it is expected that all Groups will show the previously reported RHA for visual spatial stimuli as measured by right LC. This result (Ho: M1 = M2 = M3; RHA) would require acceptance of the null hypothesis.

RESULTS

Figure 2 presents the mean percentage correct identification of stimuli by each group on each of the four experimental tasks. Overall accuracy levels ranged from 44% correct by Control subjects (non-signers) responding to words, to 67.5% correct by Group 1 (he native signers) responding to the visuo-spatial stimuli of Experiment IV. The non-sign using Controls (Group 3) were consistently less accurate than both of the sign competent groups, though this difference did not reach significance (Tables 1 and 3, Main Effect for Group: $F(2) = 2.03$, $p = .1446$; $F(1) = .01$, $p = .9438$).

Insert Figure 2

The experimental design compared all three groups on only two of the experimental conditions (stimulus types), words and oriented lines, and only the two signing groups on all four experimental tasks. Initial data analyses were conducted separately, therefore. A summary of all variance analyses is shown in Table 1; with three groups on two experiments, and Table 3, with the two signing groups on all four tasks.

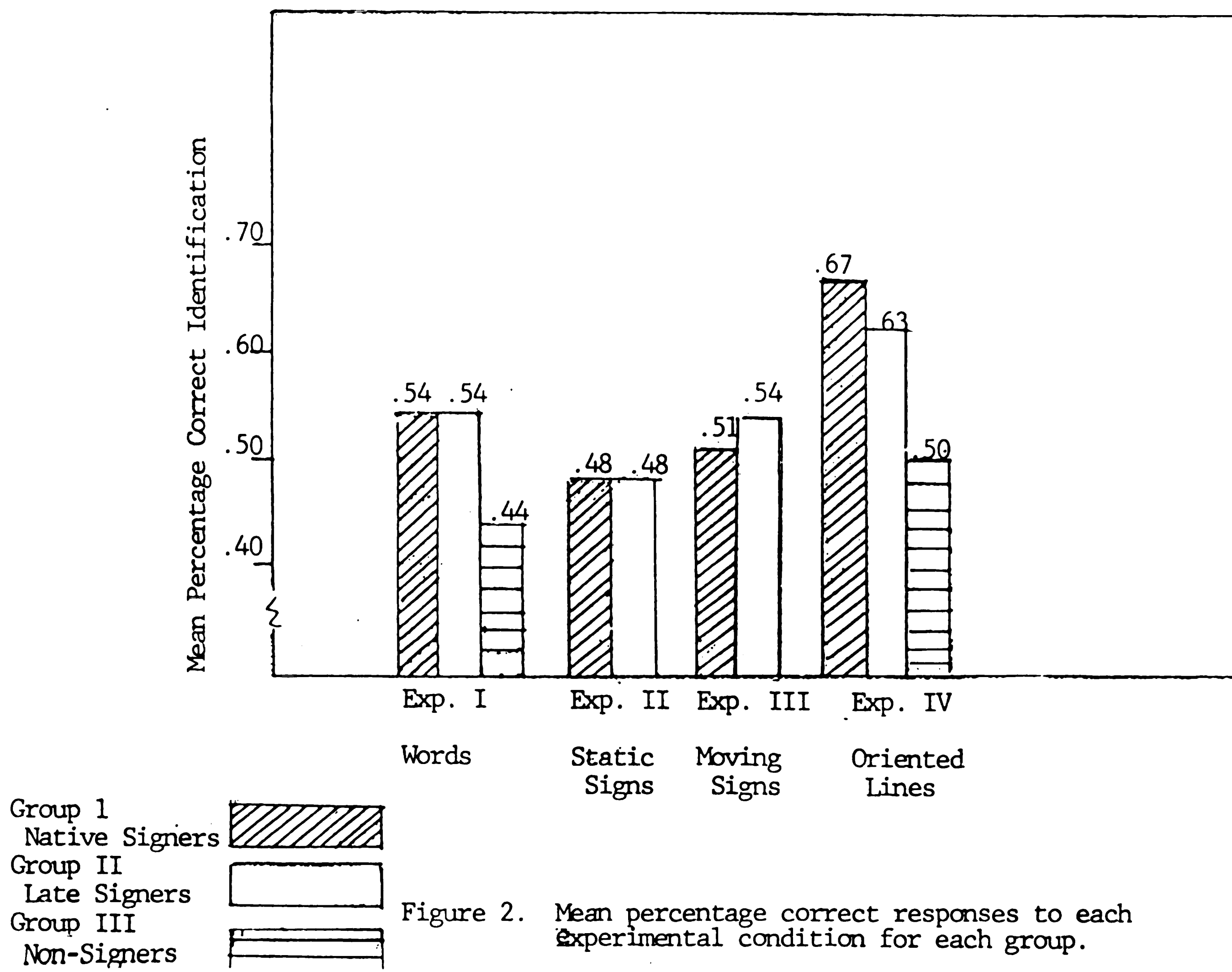


Figure 2. Mean percentage correct responses to each experimental condition for each group.

Experiments I and IV

A multivariate analysis of variance was performed first on the hemisphere** correct scores of Groups 1, 2 and 3 on Experiments I and IV. Gender was found to have no effect on overall accuracy, nor to interact significantly with the performance of the separate hemispheres on these tasks. There was a significant interaction between Experiment and Gender ($F(1) = 7.00$, $p = .0132$), indicating that overall accuracy of men was affected differently by stimulus type, than was overall accuracy for women. fect for Groups, in the overall analysis, indicating that the subjects' overall accuracy levels were comparable in response to words and oriented lines. Thus, differences between the groups in patterns of hemisphere correct scores cannot be attributed to differences in overall processing ability.

Insert Table I

** For purposes of consistency and in an effort to avoid the usual right/left, field/hemisphere confusion inherent in verbal descriptions of this research area, all references to lateral performance will incorporate the inference of contralateral function which is an assumption of the methodology. RVF will be referred to as Left Hemisphere and LVF, as Right Hemisphere.

TABLE 1

Summary of Multivariate Anova Applied to the Experimental Data of Groups 1, 2 and 3 on Experiments I and IV With 10 Subjects per Group.

	df	F	p
Multivariate Main Effect (Gender)	1	.24	.6307
Multivariate Main Effect (Group)	2	2.08	.1446
Multivariate Main Effect (Experiment)	1	7.41	.0112*
Multivariate Interaction Exp X Hemi	1	14.82	.0007**
Multivariate Interaction Exp X Hemi X Grp	2	5.13	.0130*
Univariate G X H Interactions and Simple Effects:			
Experiment I (G X H)			
Univariate Main Effect (Group)	2	1.50	.2407
Univariate Main Effect (Hemi)	1	11.03	.0026**
Univariate Interaction (G X H)	2	1.47	.2470
Experiment IV (G X H)			
Univariate Main Effect (Group)	2	1.72	.1988
Univariate Main Effect (Hemi)	1	9.16	.0054*
Univariate Interaction (G X H)	2	6.07	.0067**

While the three groups did not differ in overall accuracy across tasks, the two Experiments did (Main Effect for Experiment; $F(1) = 7.41$, $p = .0112$) with greater accuracy of response reflected in higher mean percent correct responses to the oriented lines of Experiment IV.

There was a significant interaction effect of Experiment with Hemisphere scores ($F(1) = 14.82$, $p < .001$), indicating that the hemispheres performed differently with each experiment. And most importantly, the test of whether there was an interaction between Experiment, Hemisphere and Group was significant ($F(3) = 3.63$, $p < .05$), indicating that stimulus type played a role in the varying performances of the hemispheres of each of the groups.

Experiment I

Because this Experiment X Hemisphere X Group interaction was demonstrated, further subanalyses were conducted on the hemisphere correct scores of the three groups on Experiment I (words) alone. There was not a significant Main Effect for Group, indicating no reliable difference in overall accuracy scores from one group to the next. There was a highly significant Main Effect for Hemisphere however ($F(1) = 37.50$, $p < .001$) suggesting that one hemisphere performed consistently better for all subjects in processing words.

Insert Table 2

Because a Left Hemisphere Advantage (LHA) was expected in Groups 2 and 3, T Tests for Correlated Means were performed to compare left and right hemisphere performance within all groups on Experiment I. Table 2 provides a summary of these scores. On Experiment I difference scores for all goups were in the direction of left hemisphere superiority in performance (as reflected by positive difference scores), with only Group 3 (Control) reaching the expected significance ($T(9) = 3.12$, $p = .012$). Figure 3 visually arrays the relative proportion of hemisphere correct responses for each of the three groups on both Experiments I (words) and IV (lines) reflecting the consistent though somewhat varying left hemisphere superiority for the word stimuli. Though in the direction of left hemisphere superiority, the difference score for Group I was very small and, as was expected, it did not reach significance (diff = .400, $T(9) = .67$, $p = .522$), indicating that while a slight left hemisphere advantage was reflected, this was a small difference.

Planned Laterality Coefficients were computed for all subjects and using the mean LC as the dependent measure, T Test comparisons were made of the performance of the three groups in processing words. As was expected, Groups 2 and 3 did not differ significantly in hemisphere correct scores to Experiment I, and could therefore be averaged for further analyses. Comparing these to Group 1 (native signers) produced insignificant differences ($T(28) = -1.11$, NS). Planned comparison of Group 1 and Group 3 only, resulted in a difference between groups that did not reach significance ($T(18)$ -1.46, $p = .162$). While this was not sufficient to reject the null hypothesis: that the unique bilanguage experience of a visuo-spatial first language, naturally acquired, has no effect on the hemispheric processing of English, there was nonetheless a discernible difference between the groups. The author's curiosity therefore, combined with the opinion of Hardyck, "..the process of reporting data in terms of statistically significant differences does more to obfuscate and obscure knowledge than any other process. Statistically signi-

>

TABLE 2

Summary of T Scores for Differences Between Correlated Means of Hemisphere Correct Responses of Groups 1,2 and 3 on Experiments I, II, III, IV

		Mean	SD	Diff	SD	Corr	2Tp	T	df	2Tp
Exp. I										
Grp 1	LHC	11.0	3.05							
	RHC	10.6	3.53	.40	1.89	.844	.002	.67	9	.522
2	LHC	11.7	3.89							
	RHC	9.9	3.21	1.80	2.93	.673	.033	1.94	9	.085*
3	LHC	9.8	2.48							
	RHC	7.7	3.30	2.10	2.13	.764	.010	3.12	9	.012*
Exp. II										
Grp 1	LHC	8.5	2.59							
	RHC	9.6	2.91	-1.10	.99	.941	.000	-3.50	9	.007*
Grp 2	LHC	7.8	2.74							
	RHC	10.6	2.27	-2.80	1.75	.771	.009	-5.06	9	.001*
Exp III										
Grp 1	LHC	10	2.86							
	RHC	10.4	2.87	- .40	1.43	.876	.001	- .88	9	.399
Grp 2	LHC	9.8	2.93							
	RHC	11.8	2.82	-2.0	2.53	.612	.060	-2.49	9	.034*
Exp IV										
Grp 1	LHC	13.9	2.85							
	RHC	13	3.46	.90	2.28	.755	.012	1.25	9	.244
2	LHC	11.2	4.23							
	RHC	13.8	5.67	-2.60	3.40	.802	.005	-2.41	9	.039*
3	LHC	8.7	4.73							
	RHC	11.3	5.33	-2.60	1.83	.940	.000	-4.47	9	.002*

ficant differences, especially in relation to within subject experiments are probably the ideal way to obscure meanings of results, a condition that is only exacerbated by journal practices of publishing only p values.", prompted a qualitative evaluation of the data.

Post-hoc comparisons were conducted therefore, which would provide additional information on just how the individual hemispheres of the groups compared in their separate performances. While the left hemispheres of both native signers (Group 1) and non signers (Group 3) were comparable in their processing ability of words ($T(18) = .96$, $p = .348$), the right hemispheres differed in a way which approached significance ($T(18) = 1.90$, $p = .074$), with the mean percent of correct responses non-signers of .3850 and of native signers of .5300. This difference did not exist between the two signing groups however, with both right ($T(18) = .46$, $p = .649$) and left hemispheres ($T(18) = -.45$, $p = .660$) of each group performing with comparable accuracy. This suggests that the way in which signers tend toward reduced laterality for processing words is in a greater capacity of the right hemisphere accuracy rather than a lessened capacity of either hemisphere, when compared to non-signers. This additional capacity of right hemisphere tends to be the strongest for the native signers.

Experiment IV

While the subanalyses of all groups' responses to Experiment IV (oriented lines) shows no overall difference in accuracy (Main Effect for Group), a highly significant difference in accuracy of the separate hemispheres was found ($F(1) = 9.16$, $p = .0054$). Further, an interaction of Group X Hemisphere was significant ($F(2) = 6.07$, $p = .0067$), indicating that oriented lines were responded to differently by the hemispheres of each group.

T scores for correlated means (Table 2) show these differences to be significant within Groups II (late acquisition of sign), ($T_{corr}(9) = -2.41$, $p = .039$) and 3 (non-signers) ($T_{corr}(9) = -4.47$, $p = .002$), with their actual difference in mean scores being equal and in the same direction of greater accuracy (-2.60) by, as predicted, the right hemisphere. While the difference score of Group 1 (native signers) was not significant ($T_{corr}(9) = 1.25$, $p = .244$), it was in the OPPOSITE direction(+.90), suggesting native signers have a somewhat more accurate left hemisphere in this visuo-spatial task.

Comparisons using Laterality Coefficients for each subject as the dependent measure, show Groups 2 and 3 not differing significantly ($T(18) = .21$, $p = .837$), with highly significant differences emerging between Group 1 and Group 3 ($T(18) = -2.91$, $p = .009$), as predicted. This is sufficient to accept the motivated hypothesis of Experiment IV; that first language experience with a visuo-spatial gestural language has an effect on hemispheric processing of visuo-spatial stimuli.

Post hoc analysis of individual hemispheres reveals that the two signing groups (1 and 2) are comparable in both their left hemisphere ($T(18) = 1.67$, $p = .114$) and right hemisphere accuracy ($T(18) = -.38$, $p = .708$). Native signers (Group 1) and non-signers (Group 3) however, differ significantly ($T(18) = 2.97$, $p = .009$) in the efficiency of left hemisphere for processing visuospatial material, with the left hemisphere of native signers reaching the highest effiociency of all groups on all stimuli (mean =.6950).

Experiments II and III

The second phase of variance analyses was conducted on Group 1 and 2 (native signers and late acquisition signers) on all four Experimental tasks, with the essential focus on the two sign language tasks, (static and moving) of Experiments II and III. This entire analysis followed the same progression as did those just reported on words and lines, and results are shown in Table 3.

Gender was again found to have no effect on overall accuracy ($F(1) = .24$, $p = .6307$); men performed no better, nor worse, than women. There was a significant interaction of Experiment X Gender ($F(3) = 8.57$, $p = .01$) indicating that men and women differed in their overall accuracy when responding to separate stimulus types. overall accuracy (Main Effect for Groups, $F(2) = 2.08$, $p = .1446$). Experiments however did differ in overall difficulty (Main Effect for Experiment, $F(1) = 7.41$, $p = .0112$) with lowest mean scores for these two sign using groups on Experiment II, static signs; and the highest mean scores on Experiment IV, Oriented Lines (see Figure 4). There was a highly significant intereaction effect for Experiment X Hemisphere ($F(1) =14.82$, $p = .0007$) indicating that the two hemispheres performed differently across the four varying stimulus conditions. Most important a significant interaction effect between Experiment, Hemisphere and Group ($F(2) =5.13$, $p = .013$) indicates that this hemisphere difference in performance to stimulus type is unique to individual groups. Figure 3 visually arrays the mean percent correct responses of the separate hemispheres for all groups on all four stimuli conditions.

Insert Table 3

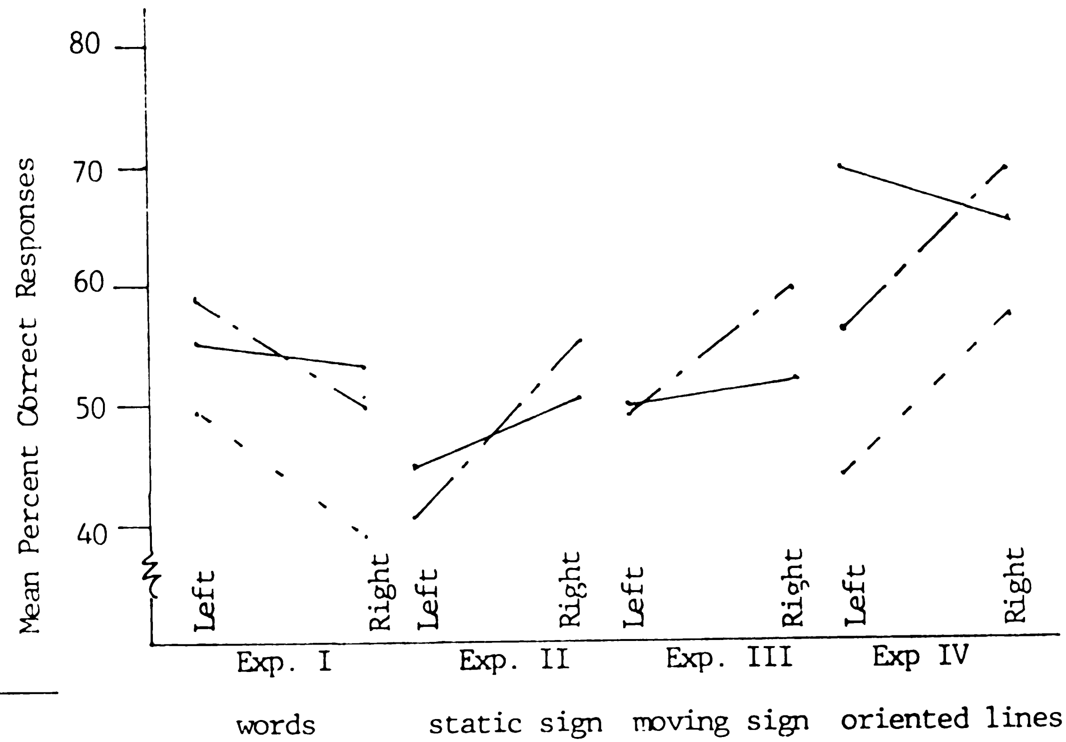
Insert Figure 3

›

TABLE 3

Summary of Multivariate Analyses Applied to the Experimental Data of Groups 1 and 2 on Experiments I, II, III, and IV and Subanalyses of Experiments I and III

	df	F	p
Multivariate Main Effect (Gender)	1	.48	.4973
Multivariate Main Effect (Group)	1	.01	.9438
Multivariate Main Effect (Experiment)	3	3.99	.0122*
Multivariate Interaction Exp X Hemi	3	6.23	.0010**
Multivariate Interaction Exp X Hemi X Grp	3	3.63	.0185*
Univariate G X H Interactions and Simple Effects:			
Experiment II (G X H)			
Univariate Main Effect (Grp)	1	.02	.8965
Univariate Main Effect (Hemi)	1	37.50	.0000
Univariate Interaction (G X H)	1	7.13	.0156
Experiment III (G X H)			
Univariate Main Effect (Grp)	1	.25	.6233
Univariate Main Effect (Hemi)	1	6.79	.0179
Univariate Interaction (G X H)	1	3.02	.0995



Group 1

Hearing Native Signers

Group 2

Hearing Late Signers

Group 3

Hearing Controls

Figure 3. Mean percent correct responses of all groups on all four experimental tasks by hemisphere.

Experiment II

To further understand how the stimulus types affect group hemisphere scores differently, subanalyses for Experiment II (static signs) only, revealed a significant Hemisphere X Group interaction ($F(1) = 7.13$, $p = .0156$), indicating this stimulus type produces different hemispheric action depending on whether the subject was a native signer or a late learner. T scores for correlated means (Table 2) used to compare right and left hemisphere scores within groups reveal a highly significant right hemisphere correct superiority for both Groups 1 ($Tcorr(9) = -3.50$, $p = .007$) and 2 ($Tcorr(9) = -5.06$, $p = .001$) with the difference scores being greater for Group 2, the late learners of sign (-2.80), than for Group 1 (-1.10), the native signers, for processing static signs. The mean LC's for each subject were used to measure this difference between Groups 1 and 2 and showed that these groups did differ significantly (T pooled $(18) = -2.04$, $p = .05$) in the degree of right hemisphere advantage they showed in correct responses, indicating that this right hemisphere superiority for static signs was greater for the late learners. This permits acceptance of the motivated hypothesis of Experiment II, that age of acquisition of sign language does have an effect on hemispheric processing of signs in their static form. It is of value to note that this stimulus type produced the only significant T scores for correlated means for the Experimental Group 1 (first language signers) indicating that this stimulus type was the only one which produced significant laterality of function in native signers.

Finally, comparisons of the individual hemispheric accuracy of these two signing groups for processing static signs resulted in neither a signficant difference in right hemispheric efficiency ($T(18) = -.86$, $p = .403$), nor in left ($T(18) = .59$, $p = .565$) suggesting that differences in laterality scores were attributable to shifts in the same direction in the performance of hemispheres of these signing groups.

Experiment III

Subanalyses for Experiment 3 (moving signs) shows that groups again performed with comparable accuracy on this task. A significant effect for hemisphere across Groups 1 and 2 was found ($F(1) = 9.16$, $p = .0054$). There was no hemisphere by group interaction. Thus, though the hemispheres performed significantly differently from each other, they did so in a comparable manner in both groups' responses to Experiment III. T scores for correlated means indicate that while Group 1 performs with an RHA that is not significant ($T_{corr}(9) = -.88$, $p = .399$), Group 2 shows an RHA which is greater, reaching significance ($T_{corr}(9) = -2.49$, $p = .034$). The mean of subjects' LC's were used to compare the differences between groups. Though the predicted RHA was produced by both, and as predicted, this RHA of Group 2 was greater than that of Group 1. These differences did not reach significance. As this comparison was selected as criteria for hypothesis testing, this is not sufficient to reject the null hypothesis that age of acquisition of sign language has no effect on the hemispheric processing of that language when the natural motion is used in stimulus presentation. It must be noted however, that the predicted directions of the motivated hypothesis is supported in the significant RHA in Group 2 with Group 1 not approaching this significance.

Overall Considerations

Due to several factors (i.e., the need to vary the stimulus difficulty to achieve an acceptable range of accuracy on lines; the small size of the fixation design, etc.) the subjects were highly variable in their ability to see the fixation design. It was often impossible for the experimenter to distinguish its presence under presentation conditions where accuracy was being controlled. Though the fixation task demand was a standard part of the performance requirement of all Ss, this measure of fixation control was not used in statistical analysis. It is not expected that results will be affected by this omission however, in that studies reported by McKeever (1976) indicate an absence of effect of fixation control on hemispheric performance.

Finally, Anova were performed to evaluate the hemisphere correct responses within each group, across experimental conditions. Table 4 contains the summary of these analyses. For Group 1 (native signers) experiment (stimulus type) had a significant effect on overall accuracy, (Main Effect for Experiment), but this did not effect relative performance of hemispheres (Interaction of Experiment X Hemisphere). Therefore, though overall accuracy did differ by experiments, this did not affect relative performance of the hemispheres.

Insert Table 4

For Group 2 (late sign learners) however, stimulus type (Main Effect for Experiment) did not have an effect on overall accuracy. Hemispheres differed with a high degree of significance across all tasks (Main Effect for Hemisphere) and the interaction between Experiment X Hemisphere in this group reached a high level of significance. This indicates that the differences in hemisphere functioning across stimuli are attributable to differences in stimulus type, not stimulus difficulty.

Overall accuracy of Group 3 did not differ significantly across Experiments (Main Effect for Experiment), nor did the hemispheres differ in overall accuracy (Main Effect for Hemispheres). There was however a significant interaction between Experiment X Hemisphere ($F(1) = 31.02$, $p = .01$). Again the hemispheres differed significantly from each other in their performance as a function of stimulus type, not stimulus difficulty.

In summary then, differences in hemispheric functioning were attributable to the types of stimuli they were processing. Although tasks were different in their level of difficulty this did not contribute significantly to the differences either within or across groups.

TABLE 4

Summary of Multivariate Anova Applied Separately to the Performance Scores of Groups 1, 2, and 3 Across All Experimental Conditions.

	df	F	p
Group 1 X Experiments I, II, III IV			
Multivariate Main Effect (Exp)	3	3.62	.025*
Multivariate Main Effect (Hemi)	1	.08	.78
Multivariate Interaction E X H	3	2.48	.08
Group 2 X Experiments I, II, III IV			
Multivariate Main Effect (Exp)	3	1.22	.32
Multivariate Main Effect (Hemi)	1	14.50	.0041**
Multivariate Interaction E X H	3	5.92	.0031**
Group 3 X Experiments I and IV			
Multivariate Main Effect (Exp)	1	1.16	.3102
Multivariate Main Effect (Hemi)	1	.29	.6154
Multivariate Interaction E X H	1	31.02	.0103*

DISCUSSION

The laterality patterns of the hearing native signers are consistent with the prediction that a visual spatial first language experience, without auditory deprivation is sufficient to produce significantly different patterns of asymmetry for certain cerebral information processing capacities. Figure 3 arrays the hemisphere performances of the three Groups on each of the four Experiments.

Experiment I

Non-signing hearing control subjects showed a significant LHA to English words, as expected. Late-learner, sign-users showed a slightly less than significant LHA for English words, and the hearing, English-speaking, native signers showed only a barely discernible left hemisphere trend. Their performance on this task is similar to the laterality response pattern to English stimuli, found repeatedly in Deaf subjects: consisting of a reduction in the difference between the hemifield scores, with only a tendency toward left hemisphere superiority which usually does not reach significance (Poizner & Lane, 1978; McKeever, et al. 1976; Phippard, 1977; Suter, 1982; Manning, et al, 1977; Neville, et al., 1983). While it is not possible to directly compare this group with the Deaf subjects of previous studies, it is interesting to note that hearing native signers appear to be less left lateralized for English words than the Deaf Ss reported in the study from which this methodology was adopted (Poizner, et al., 1979). The Deaf subjects in that study produced one of the few reported significant LHA for words (T for correlated means) for Deaf Ss.

One possible explanation for the difference between the previously reported Deaf group and the native hearing signers of this study could rest in the operation of an unidentified variable associated with the actual deafness of those subjects. However, every explanation of that nature would suggest the reverse pattern, i.e., auditory deprivation should yield less LHA for English. A more parsimonious explanation seems to rest in a methodological variable, which was suggested by the authors of that study to explain the unusually pronounced left laterality produced by the Deaf Ss in their study. Their subjects responded to stimuli by identifying them via fingerspelling. This is a more segmented process than either hearing controls or the hearing native signers of this study would experience in saying the word, and could possibly differentially engage the left hemisphere. Because the native signers of this study were hearing the same mode of response across groups tested, in the language being tested was used, assuring control of these possible influences.

In not reaching significance, the reduced laterality of hearing native signers is more characteristic of the Deaf subjects in previous studies. This reduction in laterality with response mode controlled then, can be inferred to be a function of the unique first language visual spatial experience.

The post hoc comparisons of the separate hemisphere scores of groups 1 and 3 suggest that the apparent reduced laterality of signers was the result of an increase in the capacity of right hemisphere to process English words, without a reduction in capacity of left hemisphere. While both hemisphere scores of native signers are numerically higher than non-signers, Group comparisons of these hemisphere performances reveal significant superiority of the right hemisphere only, with Group 1 performing better than Group 3. It must be noted therefore, that while first language experience with a visual spatial language appears to result in reduced laterality of functioning, it does so in this study by an increase of performance capacity of the right hemisphere, rather than by a loss or reduction in competence of the left hemisphere, which when compared with left lateralized, hearing non-sign using controls, is also superior in its performance. Though previous studies (McKeever et al, 1976; and Poizner et al, 1980) have reported greater overall accuracy of Deaf subjects, this data on separate hemisphere comparisons is not provided in previous studies reporting reduced laterality in Deaf Ss.

The question arises of why Group 2, the late-learn, sign users, produced a left hemisphere advantage below the expected significance. There were no experimental or demographic variables which would have predicted this result. Because some of the subjects in this and the non-signing control group reported experience with a language other than English or ASL, (three in the non-sign control group with age of acquisition below 12 years) a post hoc analysis of variance was performed to evaluate any possible influence this language experience may have had on their performance. No effect was found, eliminating this explanation.

Subsequent to data gathering one of the Ss of Group II shared a history of Epilepsy with: onset at approximately 8 years of age; seizure activity about one per month; undiagnosed and uncontrolled until early 20's and controlled for the next 20 years. This subject reported post ictal word finding difficulty and occasional inability to speak lasting minutes to hours after a seizure, suggesting left hemisphere involvement. In examining the Laterality Coefficients of Group 2, this subject produced one of the only two positive LC's, indicating an RHA for processing English words. Analysis of variance was conducted post hoc, removing this subject's score from the statistical comparisons. Table 5 arrays the earlier comparisons which were affected by this later analysis. While the effect for experiment was reduced slightly, the interaction between Experiment and Hemisphere was more discriminable as was the interaction of Experiment X Hemisphere X Group. All of these had been significant at the outset, however so while removal of this subject's score tended to produce greater evidence of support for the motivated hypothesis of this study, it did not do so in a way which altered the overall conclusions. However, T Test for correlated means 2 for Group 2 on Experiment I without Subject 2Ø now results in a significant difference (T corr (8) = 2.4Ø, p = .Ø43*). Though no further comment is necessary, a second possible explanation for this now only somewhat reduced LHA for Group 2 is that there might be something inherently different about persons who would choose to learn a visual spatial language, such as a greater capacity to utilize visual spatial processing via a greater generalized participation of right hemisphere in cognitive functioning. The data produced by this study however, does not permit evaluation of the merits of this explanation, however.

Insert Table 5

The insiqnificant, but nonetheless apparent superiority in accuracy for the signing groups deserves comment and may offer hope to the benefits of later life education, in the possibility that plasticity of certain cognitive functioning sustains past a critical period for language acquisition, permitting development of hemispheric skills into adulthood. The greater overall accuracy of the late-learn signing group compared to those subjects who do not use sign would support this interpretation in their obviously greater processing capacity. Further however, the right hemisphere correct performance of the late sign learners for words, though less than their own left hemisphere correct scores, was nonetheless higher (by percent of correct; not compared statistically) than the stronger (significantly) left hemisphere performance of normal hearing controls.

It is not clear whether this superior performance in processing capacity among persons who have learned to use sign, is due to actual central neurological functioning differences, or to the peripheral perceptual processing. On the side of a perceptual explanation, Hebb (1949) hypothesized that increased speed of reading with practice could produce a learned extension of the retinal field of perception of letter patterns; i.e., selective retinal training with increased acuity. Neville (1978), in pondering the continued absence of hemifield advantage by Deaf Ss in bilateral word conditions, reported the strategy her deaf subjects admitted using of selectively focusing attention (though not the gaze) on one or another field preferentially; shifting back and forth, thereby producing equal scores. She speculates that "deaf users of sign language are particularly adept at selectively picking up peripherally located visual information because of the nature of sign language." While the present study does not use the bilateral procedure which Neville's speculations address, an increased peripheral acuity could have been developed among signers and could be at work in their performance in this study; a possible example of selective retinal training Hebb hypothesized can occur with practice. Another possibility is that use of a visual spatial language could produce an activation of both the language left hemisphere and the spatial right hemisphere whenever visual stimulation occurs.

Neville et al. (1982) identify the question of whether reduced laterality of Deaf Ss compared to hearing LHA for English may be due to the hearing Ss processing English acoustically and phonetically; functions for which left hemisphere is primarily specialized. While they suggest a paradigm for testing this question by comparing non-speaking Deaf with speaking hearing-impaired Ss, the results of this study would suggest that this this factor does not explain the lateral performance differences in that the native signers are hearing and are a suitable test of that hypothesis.

This same phenomenon of greater accuracy for word recogntion by deaf signing subjects has been observed in previous studies (Manning et al, 1977; Poizner, et al 1979) in which correct responses were measured. A central neurological explanation gains support by one unpublished study reported by McKeever (1976) which suggests that familiarity with sign at least, can affect hemispheric performance. In this study, hearing subjects unfamiliar with sign were tested by ASL tachistoscopic stimuli and produced no lateral asymmetry. Subsequent to a 10 week course in ASL however, they showed a significant RHA just as did McKeever's earlier subjects who had extensive experience with ASL. Such an outcome suggests a unilateral effect, arguing against a simple increase in peripheral vision as a unitary explanation for performance differences. Though the actual data is not presented by Mckeever, it would sseem a reasonable assumption that a significant gain in RHA over a ten week period of education in sign language acquisition was not produced by a decrease in left hemisphere competence, but rather an increase in right hemisphere processing ability for this material. These findings come together most parsimoniously then in the understanding that these increases in right hemisphere competence in English word conditions and overall superior performances by persons who have used a sign language are likely the results of using sign language, produced by increase in either perceptual acuity, or lateral hemispheric processing, or both. Future research using dichotic listening tasks would help to evaluate the merits of this visual acuity argument. Differences found in the hearing native signers, between performance on a visual task vs an auditory one would illuminate the question in a way which the Deaf population does not offer methodologically.

Another way to assess the merits of Hebb's hypothesis regarding the capacity to increase foveal vision with practice would be to compare persons who have macular degeneration which has left them with peripheral vision only. Any plasticity which exists would be expected to manifest itself adaptively in persons with such a visual handicap.

TABLE 5
Comparison of Original Analysis of Variance Scores
With those after Removal of Subject 20 from Group 2

	Original			Without S 20	
	df	F	p	F	p
Groups 1,2 & 3 X Experiments I & IV X Hemisphere					
Multivariate Main Effect (Group)	1	2.08	.1446	1.91	
Multivariate Main Effect (Experiment)	1	7.41	.0112	6.94	.0140
Multivariate Interaction (Exp X Hemi)	1	14.82	.0007	19.11	.0002
Multivariate Interaction (Exp X Hemi X Grp)	2	5.13	.0130	6.55	.0050
Experiment I (G X H)					
Univariate Main Effect (Group)	2	1.50	.2407	1.29	.2933
" " (Hemi)	1	11.03	.0026	13.82	.0010
" Interaction (G X H)	2	1.47	.2470	1.96	.1613
Experiment lV (G X H)					
Univariate Main Effect (Group)	2	1.72	.1988	1.61	.2188
" " (Hemi)	1	9.16	.0054	11.03	.0027
" Interaction (G X H)	2	6.07	.0067	6.99	.0037

Experiment IV

Performances of all groups on visual spatial tasks involving processing of oriented lines expands on these issues of differential processing as well as conforming to predictions. First, the overall accuracy for all groups was higher on this task. This could be due to the fact that the experimenter could exercise greater control over assuring 50% accuracy on test trials, due to greater options in manipulating perceptual difficulty while also permitting accuracy of identification (thereby assuring comparable performance across subjects). Many of these options were not present in other tasks (such as diminishing sharpness of focus, or brightness, etc.)

Another possible contributor to the overall accuracy difference on this task could theoretically be the different probability factors attendant to a forced choice recognition task vs. that of a whole report which was the condition of the other three experiments. In this experiment the probability of a correct guess by chance was 12%, while in each of the others the probability of a chance correct was essentially zero. The combined percent correct for all groups on this task was 59% compared to 54% for all three groups on the word condition. This 5% difference is not sufficient to infer that the difference in probability had an appreciable effect on actual outcome. The fact that the Groups did not differ in their overall performances however, makes comparison statistically and methodologically sound.

Hearing non-signing controls showed a highly significant RHA for processing these visual spatial stimuli consistent with previous reports of normal right handers. The late learn sign users, again more accurate (though not significantly) overall than the control group, also produced the expected RHA for this visuo-spatial task. And as predicted, the native signers did not show a significant RHA in hemifield performance, but rather showed a trend in the opposite direction. The differences between the laterality coefficients of native signers of this study and non-signing controls did not reach significance.

This is consistent with the reports of performance of Total Communication Deaf Ss studied by Neville (1977), Phippard (1977), Neville & Bellugi (1978), Neville (1980) and Neville, Kutas and Schmidt (1982). Oral Deaf subjects in studies where this variable could be controlled, showed a RHA for visual spatial and language skills (Phippard, 1977; Neville 1977). Deaf subjects with no language also showed this similar right hemisphere processing for both types of material (Neville, 1980). It would seem that the native signers of this study show a pattern for processing visuo spatial material like that of the Total Communication deaf. This is consistent with our hypothesis that first language experience with a visual spatial language is a sufficient environmental variable to produce a different pattern of hemispheric functioning for that language.

The actual differences between the separate hemispheres of the groups rested in the performance of the left hemisphere, as can be seen in Figure 6. In fact, the left hemisphere performance by native signers in processing oriented lines, though not significantly different from their own right hemisphere competence, was the highest percent correct of either hemisphere, of all three groups across all four experimental conditions. Once again then, the reduced laterality is NOT produced by a decline in performance of either hemisphere, but rather by an increase in performance capacity. Based on these data, when left hemisphere is able to process visuo-spatial material it gives its best performance.

Several explanations have been considered to account for the LHA of Total Communication Deaf signers. Neville et al (1982) addressing central neurological implications, suggests that given the visual spatial nature of ASL, "these areas which normally subserve audition and speech, may have become organized to process visual information in congenitally Deaf Ss". This raisess the issue of the merits of an assumption of not only greater left hemisphere language capability to which the visuo-spatially capable right hemisphere defaults developmentally, but also an absence of inherent potential of left hemisphere for visual spatial skills to which these capacities must be brought. A question which emerges from such an understanding is whether this shift in development would result in right being less competent for its "natural" visuo-spatial, holistic processing strength, or whether such a shift would simply maximize the visual spatial processing of both hemispheres. The data of this study, in which right hemisphere performance of the native signers is greater than (though not significantly) the non-sign controls, would suggest the latter (greater potentiation of both, with no loss in either).

Levy (1982) dismisses the central neurological explanation of differences found in Neville's Total Communication Deaf Ss, opting for an attentional activation explanation of increased arousal and attention among Deaf persons due to "living in a silent world with no access to a formal communication system could reasonably be expected to make a child unresponsive to external stimulation; whereas for a signing Deaf child, any visual signal could serve to alert the linguistic left hemisphere in preparation for processing". While the overall better performance of the native signers of this study would be consistent with an increase in attention, the acute dependency on visual stimuli for information and communication which Levy attributes correctly to living in a silent world would not be a motivational factor for this hearing group whose opportunities for social interaction, or information for that matter, were not limited to visual sensory functioning. The interpersonal dependency on this sensory mode for the interpersonal needs of parental interactions would, however. The power of this motivation should not be discounted.

Another possible understanding is related to the questions and issues raised in Neville's position, regarding primary specialization of the hemispheres and what happens to these specializations if the specialties of the other hemisphere are developed. This is inherent in the position borrowed from Gazzaniga (1977) and taken by Bradshaw & Nettleton (1981) regarding the problems attendant to reducing hemispheric functioning via a verbal/nonverbal dichotomy,

> "Overall, the right hemisphere is irrelevant for non-language functions. Indeed, if the left hemisphere is specialized for language, either primarily or in consequence of some further, more fundamental division of labor, then right hemisphere "nonverbal" or "visuo-spatial" superiority may not be one of specialization per se, but may occur by default, reflecting the price paid by the left in nonverbal terms for assuming the control of language. Thus, the right hemisphere may not be uniquely specialized in man, rather continuing to do what it does elsewhere in the phylum."
>
> Bradshaw & Nettleton (1981)

With such a view it could be seen that a visuo-spatial first language experience, facilitates left hemisphere's potential for both language and non-language functioning. The present study does not test this question. However, actual hemispheric functioning is producing the champion performance of the left hemisphere of native signers on this task, it seems challenging to logic and prediction that this skill could be totally alien to inherent capacity, and could be learned so well in the lifetime of an organism, as to surpass performance of that which it is naturally qualified and best equipped to do; namely language.

Experiment II

The hemispheres of the two sign using groups performed differently in processing signs in their static form. While both groups found this the most difficult (though not significantly) of the experimental tasks, both showed the RHA reported for the deaf and hearing signers in previous studies (McKeever, et al, 1976; Manning et al, 1977; Neville & Bellugi,1977; Poizner & Lane, 1978) including the study from which this filmed methodology was drawn (Poizner, et al., 1979). The native signers produced a right hemisphere ratio (.882) of nearly the same magnitude as the Deaf Ss in that study (.90). Figure 1 illustrates these ratios computed, as did Poizner and Lane (1978) to provide a means of comparing the various dependent measures of previous laterality studies on the Deaf. Figure 4 reflects these performance ratios as computed for this study. The late learn signers produced a significantly larger right hemisphere ratio (.69),

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Insert Figure 4

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than the native signers. The strong RHA for late learners is not only consistent with the patterns of hearing signers who were used as Controls in previous studies, but as ASL is a second language for this group their RHA would also be consistent with the laterality patterns for second language processing of bilinguals who acquired that language after adolescence (Vaid & Genessee,1980), and the underlying theoretical conceptualization of non-dominant hemisphere specialization in processing of second language acquired late, is also supported by this finding. The McKeever report (1976) of an RHA emergence after 10 weeks of training in sign use adds credence to this latter interpretation. However, additional validation could be gained on the visual spatial/second language explanations, by direct comparison of Total Communication Deaf, Oral Deaf and late learning hearing Ss on this task. If all produced comparable RHA's, then the visual spatial nature of the stimuli would seem the better explanation. If the Total Communication Deaf showed reduced RHA, then age of acquisition would be inferred the more likely contributor.

The reduced laterality produced by the native signers was once again accomplished by an increase in performance of the left hemisphere, rather than a diminished performance, as both groups' overall accuracy was exactly the same (.48%).

Though other conditions elicited hemisphere trends in BOTH directions for native signers, depending on stimulus type, this was the only experimental condition on which they demonstrated a significant laterality effect, and in its reduced laterality (compared to late learners) it was similar to patterns demonstrated previously by Deaf Ss whose first language experience was also ASL. Differences between the two groups of this study can be inferred to be a function of age of acquisition, as predicted. Auditory deprivation then is not necessary to produce this effect though future research with direct comparison with Total Communication deaf would help to parcel out the relative contribution of each of these variables.

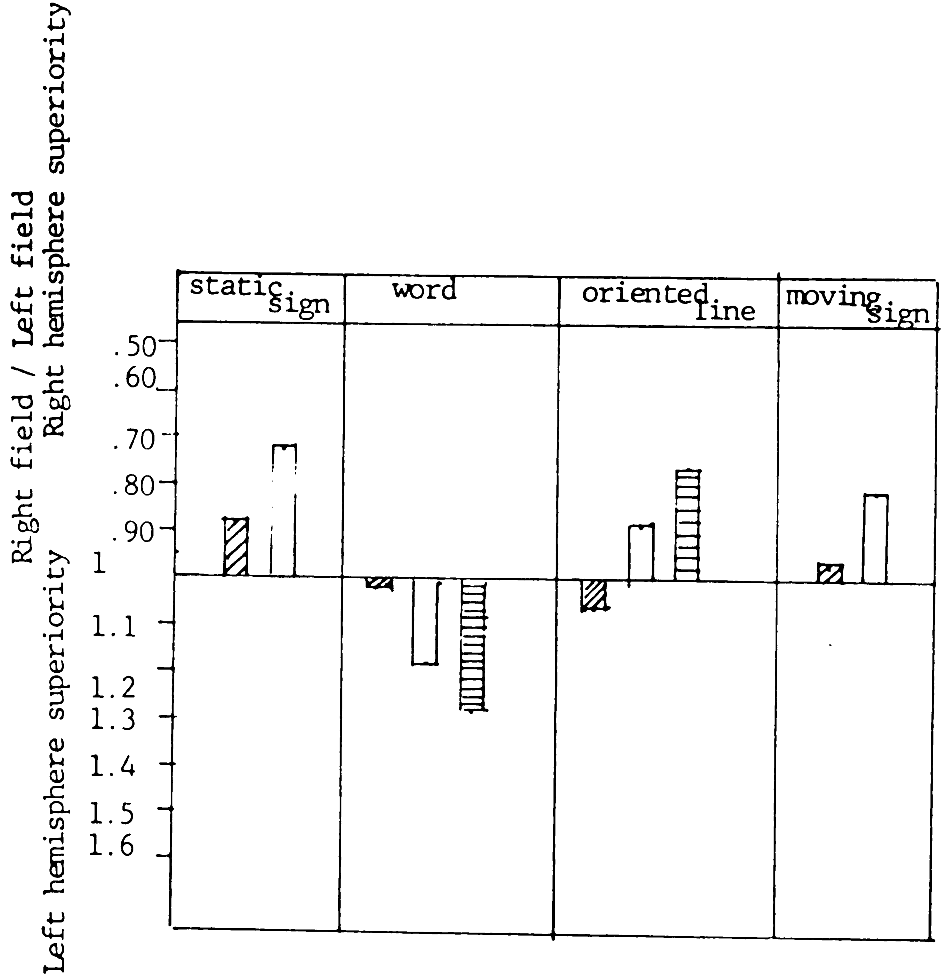
Sergent (1982) has suggested that stimulus difficulty can increase right hemisphere performance. Because this experimental condition was most difficult for both groups, this variable could have contributed to the RHA for native signers for whom asymmetry prevailed in other tasks. Replicating the static sign film, and varying task difficulty by manipulating exposure time (2 frames vs. 3 frames per trial) and/or brightness, etc. could add information about the contribution of task difficulty to hemispheric functioning, though without such a demonstration the existing difference between groups may be considered related to language acquisition variables.

Poizner & Battison (1980) suggest that the possible confounding of a reconstruction process; either a right hemisphere gestalt strength of completing missing motion, or a left hemisphere analytic strength, is ruled out by the use of this particular set of static signs in that they do not rely heavily on motion in normal usage. The resultant RHA then is considered by these authors to be a function of the overriding demand characteristics of the spatial properties invoking right hemisphere involvement. The visual spatial task presented in the Poizner and Lane (1978) study did not produce any lateral asymmetries in either hearing or deaf Ss, and Poizner, Battison and Lane (1979) did not present visuo spatial stimuli to their subjects. In light of this fact and the display of left hemisphere competence demonstrated by the native signers of this study for the visual spatial lines of experiment IV, their explanation of overriding demand characteristics of spatial properties producing the RHA for static signs is wanting.

The findings of this study would be better understood by a conceptualization which incorporates the difference between lexical and syntactic aspects of linguistic processing. Liberman's (1974) hypothesis that in hearing persons, left hemisphere is specialized to deal primarily with the grammatical codings of speech perception is relevant in that movement, which is present in signs presented statically, is the vehicle of syntax and grammar in ASL. We will return to this issue again later in our discussion.

Visual array of the course of performance for the separate hemispheres on these two sign tasks supports this interpretation (see Figure 5) in that while right hemisphere performance was essentially unaffected by the static nature of sign stimuli compared to moving, left hemisphere performance declined for both groups when required to process sign without motion, with greatest decrement seen in late learners. The competency level of either hemispghere of native signers was marked at its lowest in this left hemisphere performance.

Insert Figure 5



Group I.
native signers

Group 2
late learn signers

Group 3
non-sign controls

Figure 4. Right field/left field ratios of hearing native signers (slanted line marks), late learn signers (unfilled bars) and non-sign controls (horizontal lined bars) performance on all four stimulus tasks of linguistic and visuo-spatial material.

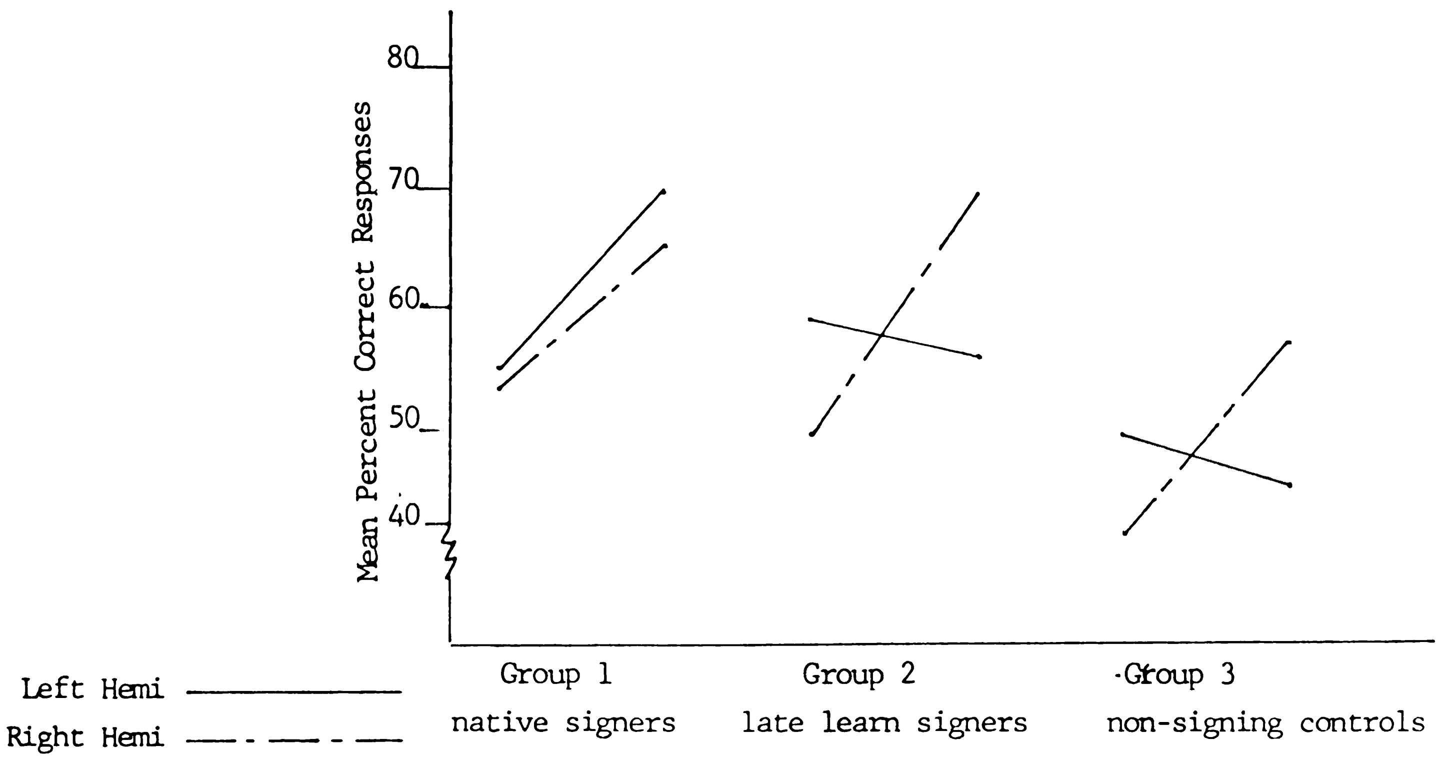


Figure 5. Mean percent correct responses of the hemispheres of each of the three groups across word and line conditions.

Experiment III

Signing groups performed directionally and relatively as predicted in processing moving signs, but not significantly so. Using the comparable performance ratio shown in Figure 4, the hemispheric performance ratio of the native signers (.96) is almost identical with that of the Deaf Ss (.97) of Poizner et al (1979) (see Figure 1), the only other group reportedly tested on moving signs, in an insignificant RH superiority trend. In this study we see (Figure 6) that this is accomplished by a slight increase in LH capability over its performance to static signs where no motion (ASL syntax) is incorporated, with almost identical performance by RH for signs with or without motion.

Insert Figure 6

The late learn signers perform with an RHA which though significant is less of a difference in hemisphere competence than they demonstrated in processing static signs; with improvement in their left hemisphere performance as well with the addition of motion. Because overall accuracy was equal for both moving and static signs, stimulus difficulty would not appear to be the causal factor in the reduced RHA. for signs with movement. The data could better be understood as further support for an explanation of left hemisphere's specialization for syntactic and grammatic decisions: motion and direction providing those in ASL. The sign "want" for instance, though not dependent in normal usage on motion for communication of the concept, could be seen as "give" without indication of Subject-Object directionality, which even minimal motion provides in ASL.

Poizner,et al (1979) further analyzed the moving and static signs by complexity of movement in an effort to explore Kimura's (1976) hypothesis that left hemisphere is specialized for analysis and production of complex skilled motor movement, with right specializing in simple movement. Five static signs and nine moving signs were identified as "simple". The balance were considered "complex". Laterality Coefficients were then computed on the number of Ss responding correctly across each item when presented in each visual field. These were then treated as a group of pairs; a batch of Simple and a batch of Complex, and averages were computed. Small numbers did not permit further statistical analysis. Table 6 shows the results, comparing them to those of Poizner, et al. (1979).

Insert Table 6

The correct responses to simple items presented Statically produced a mean LC of -.128 by native signers and -.263 by late learn signers, indicating a strong RHA in late learners with much less reliance on right in the native signers. This is consistent with the prediction of right hemisphere specialization for analysis of simple motor sequences. The native signers show a score nearly equal to that of Poizner et al (1979) Deaf Ss. Our late learner's score, if interpreted in this schema would suggest that left lateralized speaking right handers rely more heavily on right hemisphere for this function than do uniquely lateralized Deaf and native signers.

Scores to complex signs presented statically were less right hemisphere dependent with -.055 by native signers and -.206 by late learners, reflecting less right hemisphere involvement in both groups with the greater complexity of the movement. Greatest reliance of the two groups is again shown by the late learners' stronger right hemisphere score. These data have not been examined to determine if this reduction in laterality coefficient is due to a loss of competence in either hemisphere, or a greater strength in one.

For moving signs the pattern is the same, with native signers' scores of -.177 (right) for simple moving, to -.001 (slight left trend), for complex; late learners -.343 (strong right) for simple and -.090 (much more asymmetry) for complex signs which are moving.

These data for native signers agree remarkably with that of the Deaf native siqners of Poizner's study, differences in scores reflecting greater right hemisphere involvement produced by the late learners who are (based on word and line tasks) lateralized traditionally. This supports Kimura's findings of left hemisphere's ability to function in processing complex, but not simple movements more neatly with the uniquely lateralized group. However, the late learn performance augurs more for an understanding of greater reliance on right hemisphere than left in the analysis of motor sequencing in the general population; in both simple and complex movements.

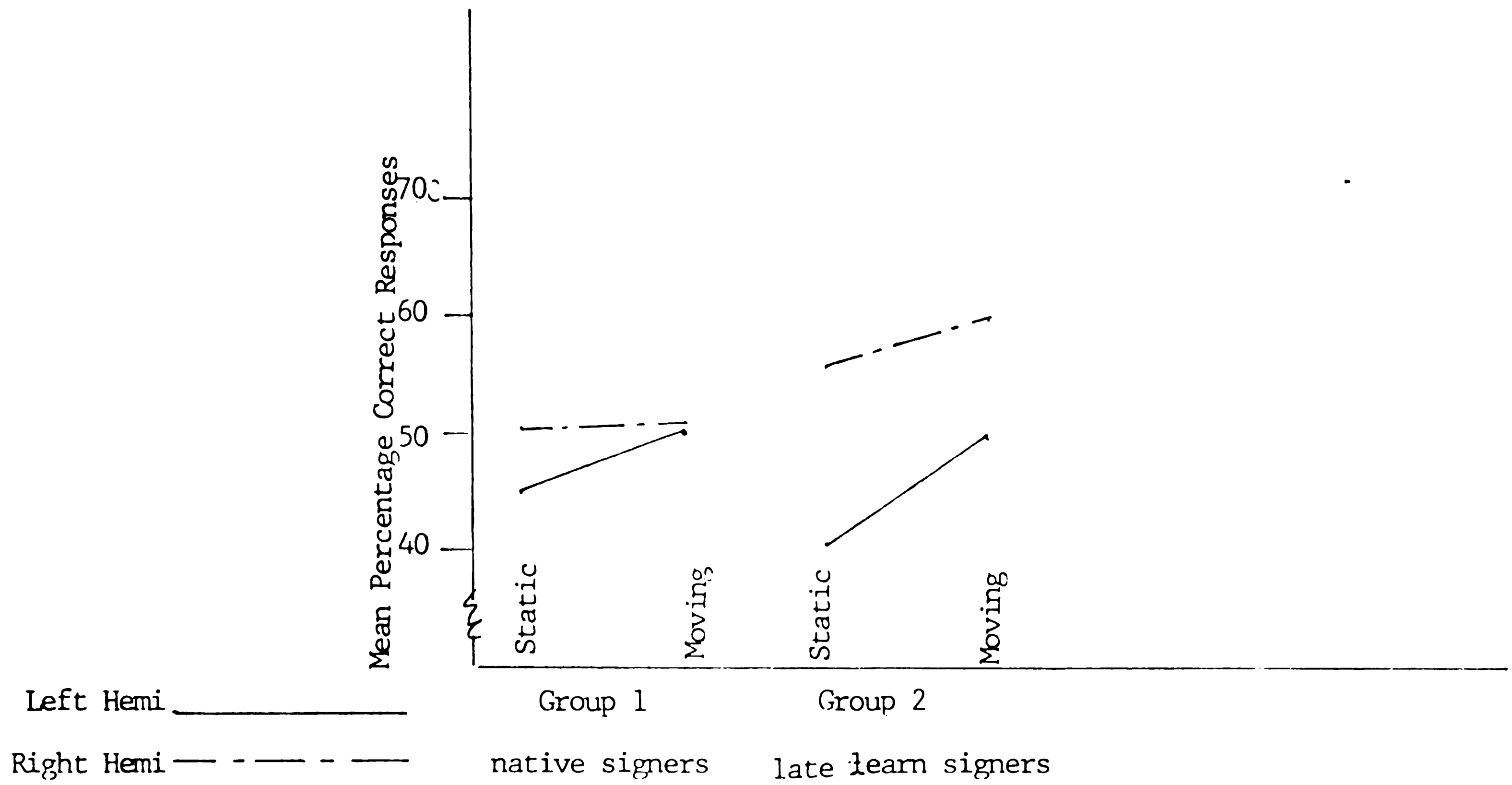


Figure 6. Mean percent correct responses of the hemispheres of each of the signing groups across static and moving sig n conditions.

TABLE 6

Mean Laterality Coefficients computed on the Correct Identification in Each Hemifield per Groups of Simple Signs and Complex Signs, Both Static and Moving, as Identified by Two Signing Groups of Present Study and Deaf Native Signers of Poizner, Battison and Lane (1979).

	Simple		Complex	
	Moving	Static	Moving	Static
Deaf native signers Poizner et al (1979)	-.19	-.02	-.13	-.04
Hearing native signers	-.177	+.001	-.128	-.263
Late learn signers	-.343	-.09	-.05	-.206

Overall

Groups differed from each other in hemispheric performance not only by direct comparison on separate experimental conditions but also in their hemispheric shifts across tasks. The non-signing controls showed a strong complete shift of hemisphere superiority across the two experimental conditions in the expected and previously reported directions for right handers (see Figures 5 & 6).

The late learn signers, while better overall than nonsigners shifted hemisphere superiority in performance significantly across all four experimental conditions, in the predicted and previously demonstrated directions. The native signers, with insignificant hemispheric trends only, demonstrated asymmetry across all but one experimental condition; static signs, with this shift in the previously demonstrated direction. The shifts in the laterality of the two control groups validates the tasks used. The shift to RHA in the native signers tends to argue against an explanation of their asymmetry reflecting greater ease in performance due to merely heightened visual acuity as a result of using a visual language, and toward the inference of actual hemispheric lateral asymmetry on tasks which demonstrated this behaviorally. This latter conclusion requires further research, as is the case with studies based on the assumptions of performance pattern on tachistoscopic presentations reflecting actual differences in neurologic functioning. Neville, Kutas and Schmidt (1982) have demonstrated in their work with Event Related Potentials that these measures (more direct in their capacity to measure activation patterns electroencephalographically) combined with tasks designed to elicit lateral functioning may be a more sensitive measure of actual neurological functioning. In these studies they have found that while behavioral measures are not always the same as findings which emerge from ERP's, when behavioral asymmetries are produced, these are directionally consistent with ERP asymmetries. When differences between the measures are seen it is when only trends toward behavioral asymmetries are observed. In such cases the underlying ERP's demonstrate laterality patterns both in morphological functioning as well as activation level which, though more pronounced, are in the same direction as the behavioral trends. That Neville's studies with Deaf Ss have demonstrated these differences, not only adds support for a neurological inference in this study, but also suggests that the utility of using the population of native hearing signers within that paradigm would provide valuable information on teasing out more fully the relative contributions to hemispheric functioning of the two different variables of auditory deprivation and visuo-spatial first language experience.

The present methodology was successful in demonstrating the traditional LHA for words and RHA for visuo-spatial stimuli in control subjects, thereby assuring that comparisons reflect actual differences between the experimental groups as a function of stimulus type. Previously suggested concerns of the usefulness of tachistoscopic presentation of words with the deaf who are "notoriously poor readers" would seem to be irrelevent to this study in which the hearing native signers had an average educational achievement level of 15.9 years in the traditional educational system. The additional improvements in methodological considerations afforded by use of a hearing population; of instructions given in the language being tested, as well as the responses given in the same language, would also seem to tighten the inferences drawn. It must be kept in mind however, that behavioral performance such as that which is produced by this experimental method is still only inferentially associated with actual neurological functioning.

That caveat in mind, if these performances are correctly inferred to be a function of a totally different organization of neurological functioning in this group of hearing native signers it is the result of their unique first language experience. An explanatory model which permits acceptance of the overall potential of both hemispheres to subserve the majority of basic functions of the organism, such as a "separate but equal" understanding assigned to the theoretical work of Friedman and Polson (Hardyck, 1983) would seem most helpful here. For instance, it would seem that these subjects demonstrated the potential of right hemisphere to process English in that their non-dominant right hemisphere performance for English was comparable to the dominant left hemisphere performance of non-signing controls for the same stimuli. They also demonstrate the potential of left hemisphere to process visuo-spatial information, in that their left hemisphere tended to do better at oriented lines than did the right hemisphere of controls (specialized for visuo-spatial processing in controls).

However, what we also see is the limit of left hemisphere in identifying signs correctly when they are presented without motion which is the vehicle of grammar and syntax of ASL. Zaidel (1983) points out that an RHA can be expected for lexical decisions, but that right hemisphere is poor at sentential analysis. What comes to mind is the limit previously reported in the hemispheric functioning of Genie (Curtiss,1977) and of the left hemidecorticates described by Dennis and Kohn (1975), in whom the work of the sole right hemisphere produced poor performance in syntactical operations. The relationship between left hemisphere and syntax and grammar begins to emerge. When left hemisphere is absent so are complex syntactic skills. When syntax is missing in static sign so is left hemisphere's accuracy of identification. If left hemisphere functions by performing its syntactical and grammatical work visuo-spatially in sign then without these cues it may be less capable of making the lexical decisions for which right hemisphere retains superior competence.

While Neville has suggested that for persons using a visuo spatial language it may be adaptive to bring visuo spatial processing into left hemisphere's stronger language skills, Kinsbourne's suggestion assumes that both hemispheres were equally capable of visuo-spatial processing. Though a point of speculation beyond the data of this study it may be fruitful in understanding these unusual laterality patterns to ponder it.

If ASL is a language it is a product of man's adaptability to the demands of his environment; a tool and not simply another part of his environment to which S/HE must adapt. As such this product must reflect an existing potential or capacity of the organism, rather than the physiology of the organism reflecting its adjustment to the needs of the product language. It has been demonstrated that even with the benefit of plasticity due to the early life removal of left hemisphere in the hemidecorticates, right hemisphere has been unable to adopt the special syntactic skills of left hemisphere. Data from this study shows that left hemisphere is not only able to adopt visual spatial skills, traditionally considered right hemisphere specialized skills, but does so with superior results. Yet without the critical component of direction and movement which provide the cues for its syntactic functioning, left cannot perform this, its necessary function in processing sign. Left hemisphere may not be as capable therefore of the integration of these separate functions.

This may be reflected in the comments of the signers, both native and late learners as they repeatedly protested the difficulty of trying to identify a sign without motion, even when it was made clear that these signs did not require motion for normal transmission of information or meaning; "I have never tried to identify a sign without movement before.", "It's unnatural", "That was the hardest of all the tasks -- I kept trying to make it move." Right hemisphere performance was not impaired by this condition however, apparently able to adjust to this task demand.

These findings then appear to accommodate very nicely the conjecture offered by Kinsbourne (1977) that visuo-spatial skills were once bilaterally represented. The first language experience of a visuo-spatial nature would be best understood as potentiating this capacity in left hemisphere, while also potentiating its ability to subserve complex syntactic language operations. Perhaps the greater sharing of resources between left and right hemisphere required in processing a visuo-spatial language, permits greater flexibility of each to develop a capacity for both types of cognitive operations; thereby producing the reduced laterality which is made up of increased capacity of each to perform the specialized functions of the other, which tend to develop more dichotomously with auditory language acquisition.

Beyond the theoretical considerations to which this study has hopefully contributed, there are implications in how previous research using both Deaf Ss and hearing-signing controls is interpreted. Not all Deaf are alike, nor are all interpreters. Though replication and further research is necessary, the findings of this study also suggest that early education of Deaf children with sign language should result not only in NO loss of potential, but more likely greater potentiation of existing capacities to process information. And finally, the benefits in turning a research spotlight on this previously unwatched, though obviously uniquely organized neurological group of hearing native signers emerge. What other construct related differences do they manifest? What are the clinical neuropsychological patterns which right and left hemisphere damage producein persons with this early language experience? Do they recover pathologically lost functions quicker, as their greater lateral task sharing would suggest? If so, would borrowing from their early experience provide one of the many prophylactic environmental conditions which could mitigate the devastating effects of unilateral cerebral damage, a health problem which has greatly challenged rehabilitation efforts?

Related findings.

Though the ANOVA, conducted to determine the effect of Gender on hemispheric functioning did not produce a significant interaction for Experiment X Hemisphere X Group, showing only an interaction between Gender and Experiment (indicating only that the various stimulus types had a different effect on the overall accuracy of the sexes), previous studies (Levy, 1983) suggest that differences between the sexes should be apparent on exactly the stimulus types of this study. For this reason, and consistent with Hardyck's (1983) earlier prescription that research on this type of phenomenon can best be explored by looking beyond statistical significance levels, a post hoc qualitative look was taken at the separate performances of men and women participants of this study. It is important to bear in mind that by so doing we are looking at extremely small numbers (three men in Groups 1 and 2 and four in Group 3; with seven and six women respectively) and this examination therefore is NOT a statistical comparison. It is an effort however, to "eye ball the data" with a new variable in mind.

Predictions based on the previous studies and summarized by Levy (1983) would be that both sexes would be lateralized to the left for language and to the right for visuo-spatial stimuli, but that women would be less lateralized than men, better overall at language and less competent overall in visuo-spatial performance. And, according to Levy:

> "The evidence, you see, is that the hemispheres of male brains are specialists -- they speak different languages, verbal and visual-spatial...The hemispheres of female brains, on the other hand, don't seem to be such specialists. And they may be able to communicate in a much less formal, less structured and more rapid way. If this is so, then it's entirely possible that females are much better than males at integrating verbal and non-verbal information -- at reading the emotional content of tones of voice and intensities of facial expression, for example; at interpreting social cues such as posture and gesture; at quickly fitting all sorts of peripheral information -- information in different modes -- into a complete picture."
>
> Levy (1983)

Here, in the sign tasks is an opportunity to observe the verbal and non-verbal integrative skills of men and women who are unique in their competence to use this visual spatial language.

Insert Figure 7

Charting the average percentage correct hemisphere scores separately for men and women within the groups of native signers (Figure 7), Group 2 late learn signers (Figure 8) and nonsigning Controls (Figure 9) we see in controls the expected left and right laterality for words and signs respectively and only a hint of greater laterality for men than women, with a slightly superior overall performance by men on oriented lines and a negligible female superiority on words.

Insert Figure 8

For the late signers there is a similar trend with overall better accuracy for both sexes. Women show a strong RHA for all but words (LHA) as do men, but women are more consistent in accuracy across tasks with men's performances being highly variable. These women appear to be more right lateralized for visuo-spatial skills than are Controls. The male late signers, though less right lateralized for visuospatial stimuli than male controls, show a much greater superiority over the women of this group on this task. Women appear less lateralized than men and are only slightly more accurate overall on words. The integration of verbal and visuo-spatial stimuli, as manifested in the sign tasks, is right hemisphere specialized in late-learn signing women; slightly more so in moving signs. Men perform comparably to women only when movement is included; showing substantial decrement in LH performance to static signs.

Insert Figure 9

And finally, patterns of men's and women's responses in the experimental group of native signers reveal women again performing much more consistently across tasks in overall accuracy, with men showing wide variations. The pronounced laterality of the men in the previous groups has quieted in these men. The women more clearly outshine the men in language and the men are far superior to the women on the visuo-spatial task. All however, are less lateralized. There is a RH trend in men for all stimuli INCLUDING words, and a LH trend in women for all stimuli INCLUDING visuo-spatial lines, but not for static signs, on which they join the men in a RH trend. They are far superior to the men in overall accuracy for both signing tasks. Their LHA for moving signs is the strongest laterality they produce.

All groups showed a tendency toward:

- Female superiority for words
- Male superiority on visual spatial stimuli, most pronounced in signing men,
- RHA for all but native sign women on visuo-spatial tasks, with all signing men producing a reduced asymmetry.
- Superior performance by females in integrating verbal & non-verbal material on sign stimuli with late learn signing men matching them only on moving signs.

- All showed an RHA for all sign tasks except native sign women who showed their strongest hemisphere advantage in the LHA for moving signs.
- Native sign males show an RHA for all stimuli; Native sign women show an LHA for all but static signs.

The intention of this and previous studies of the effect of deafness on hemispheric functioning was not to examine the relative effects of gender. An effort was made to control for this variable in the design of this study and, given the absence of an interaction effect, apparently succeeded. This qualitative, or clinical evaluation of the data across this variable, with all of the limits born of a small sample, suggests that:

1. The trends of this data are consistent with Levy's predictions of how the genders are likely to differ in hemispheric functioning.

2. Gender may be a highly influential variable to outcome in experimental work on hemispheric functioning,

3. It must therefore, be controlled in such studies.

4. Further research on the comparative effects of visual spatial first language experience such as the stimuli of this study appears to be an extremely fruitful theatre of inquiry on gender differences in lateral functioning and the environmental conditions which can influence them.

Questions which emerge center around why the native signers produced reverse lateral trend patterns as a function of gender? Levy (1982) reports that left hemisphere matures earlier in female development; right hemisphere in males, dand that skill acquisition which is consistent with the maturing hemisphere is expected to effect later cognitive superiority. Somewhere in this factor may rest the variable which is manifest in this reverse pattern.

Incidental findings worth mentioning which emerged in the course of this study are that while locating women who were the children of Deaf parents was relatively easy, finding men with this family history was quite difficult. Even inquiries made of members of the interpreter community as well as of the Deaf community produced recognition by most persons who pondered the question, that it seemed as though the males "disappeared ". Whether this is reflective of the attitude that interpreting is somehow within the realm of "women's work", or that men have subjects for this study was in trying to find men who had learned sign language in later life. Here, the difference between the sexes in motivation to acquire sign was most apparent, in the dearth of men who fit this description; even when polling the college level interpreter training programs.

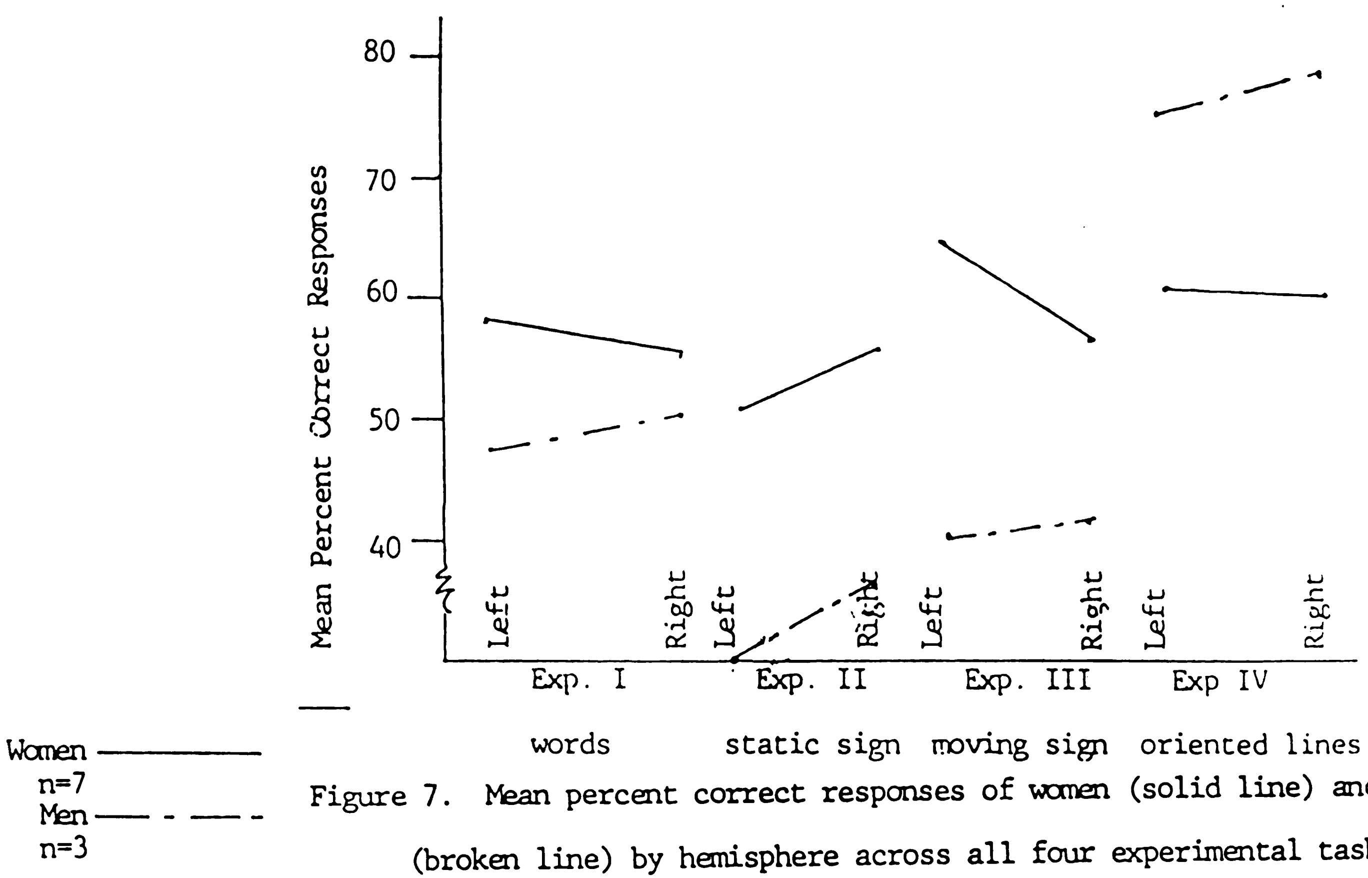


Figure 7. Mean percent correct responses of women (solid line) and men (broken line) by hemisphere across all four experimental tasks. for Group 1, native signers.

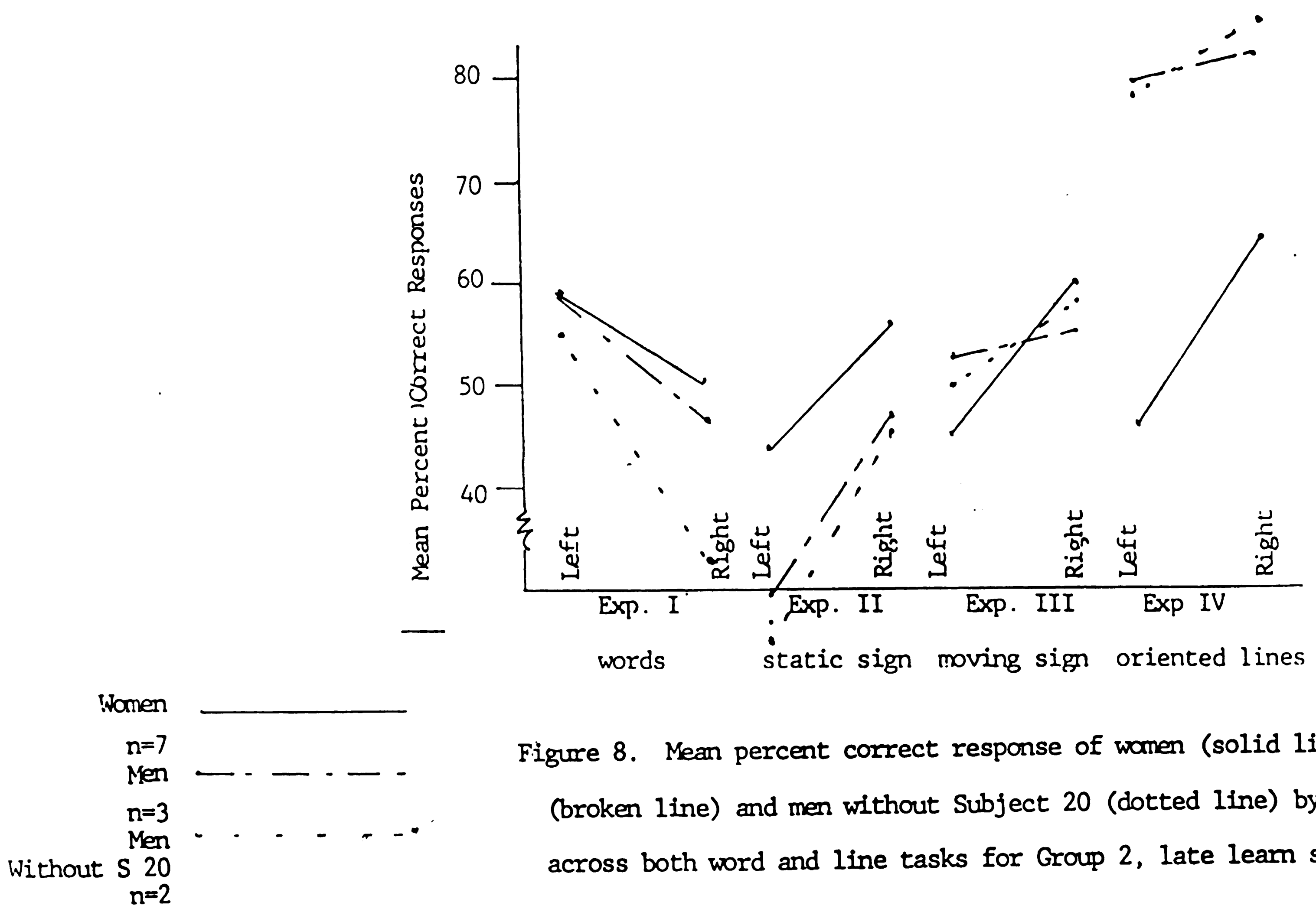


Figure 8. Mean percent correct response of women (solid line), all men (broken line) and men without Subject 20 (dotted line) by hemisphere across both word and line tasks for Group 2, late learn signers.

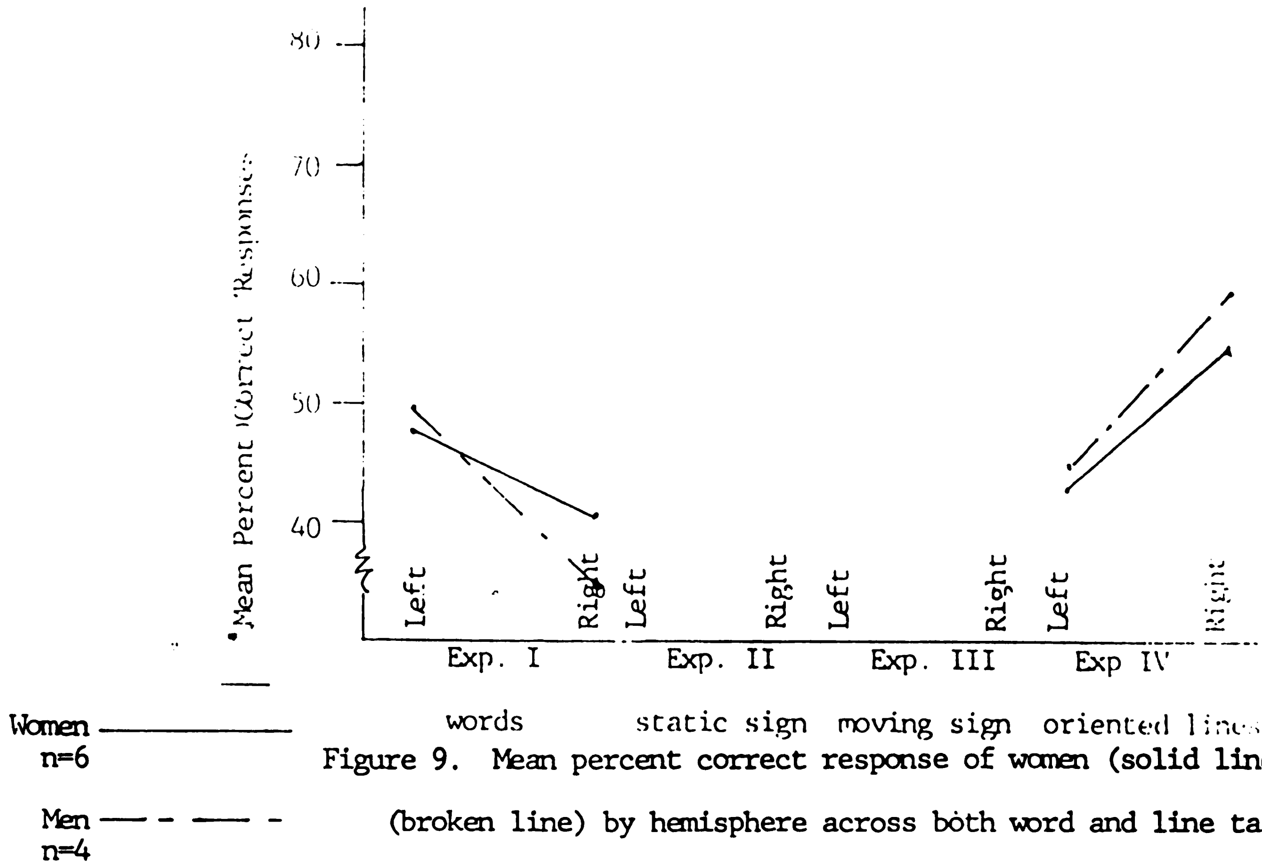


Figure 9. Mean percent correct response of women (solid line) and men (broken line) by hemisphere across both word and line tasks for Group 1, non-signing controls.

CONCLUSION

Hemispheric functioning is clearly differentially affected by visual spatial first language experience in hearing persons with a reduced laterality in processing all stimuli when compared to both late learning sign users and non-signing controls. Reduction in laterality cannot be construed to mean a loss of ability or capacity to process visual information, in that both signing groups produced levels of accuracy which were discernibly higher than those of non-signing controls, reflecting increases in the processing capacities of the hemisphere traditionally considered inferior for each set of stimuli. This laterality pattern of a left hemisphere trend for English words, a left hemisphere trend for traditionally right hemisphere visuospatial material, a minor trend for right hemisphere advantage in processing moving signs and a significant RHA shown only for processing signs in their static form is the pattern traditionally demonstrated by Total Communication, or native signing Deaf Ss in previous studies. These patterns of asymmetry in the Deaf are often interpreted as a result of the absence of auditory stimulation. This study, as predicted, demonstrates that first language experience is sufficient to produce this pattern without auditory deprivation. Future research comparing Deaf and Hearing Native Signers, preferably utilizing the possibly more sensitive laterality measure of ERP's would help to elucidate the relative contributions of variables of deafness and first language experience of a visual spatial nature.

Late learning signers demonstrated the pattern expected of them, in showing traditional LHA for English words and RHA for Oriented Lines, while demonstrating a processing pattern for sign language which is consistent with either a bilingual understanding of late acquired second language processed in the non-dominant hemisphere; or with an understanding of sign, being a visual spatial language, processed by the right hemisphere--dominant as it is for visual spatial material in this group. Their performance was comparable to the laterality patterns previously reported in hearing signers, suggesting that previous interpretations that the differences observed in their performance, compared to Deaf subjects, were due to their differences in hearing status, may be augmented by this variable of early vs. late acquisition of sign language. The right hemisphere tendency toward specialization for signs shown in native signers (unaffected by the variable of late second language acquisition) would suggest that the visuo-spatial demands of the language are at least contributory to the role right hemisphere would play even in "normally" left lateralized right handers. Further research comparing persons who were late learn signers and also competent in a third late learned language, on whether the two second languages and visual spatial stimuli were processed similarly would further clarify these possible explanations.

Various theoretical explanations such as the effect on performance of activation level, visual acuity and task difficulty can not be totally ruled out without additional research when considering separate parts of this study. However, that which seems most consistent with the entire pattern of findings is an understanding which assumes a pre-existing potential of both hemispheres to process various stimulus types of visual perceptual material when certain environmental conditions facilitate maximization of these capacities. In these data, the left hemisphere has been seen to demonstrate superior performance in processing visual spatial material and the right hemisphere has been shown to perform comparably with the left hemisphere on the specific language tasks studied. Only the performance by left hemisphere in processing signs without movement, which could be seen as a task requiring maximal integration of language and non-language material for success, or as a task in which the normal syntactic cues possibly used by left hemisphere are absent, shows an inability to perform comparably with the other hemisphere. Obviously more research is needed.

Perhaps the most significant contribution this study has made is in identifying a new experimental population which offers this unique laterality pattern as well as skill in a unique language. That sign language can be processed simultaneously with a spoken language adds to its potential to contribute much to our understanding of the interrelatedness of the two hemispheres. And this population permits methodological consistency of language mode from instructions, to stimuli, to response.

And finally, given the higher performance levels of signers whether they learned the visual language late or early, there may be good reason to re-evaluate some of the existing assumptions about how best to educate Deaf children.

APPENDICES

Appendix A

Socio-Linguistic Developmental Factors Associated Cognitive Development of Deaf Persons

In thinking of deafness we assume the absence of sound. Yet total absence of sound is rare; hearing impairment, with varying degrees of residual sound is not. The hearing mechanism is extremely complex and a continuum or range of hearing exists. Audiologists measure hearing loss in decibel ranges for each ear and at different frequencies (pitch). Assessment of Profound (97-110db), Severe (65-96db), Moderate (40-64db), Mild (25-40db), Slight (15-24db), and Normal (0-15db) ranges of hearing loss are made. Speech sounds fall approximately between 15 and 65 decibels, rendering some persons in the Moderate range and all in the Severe and Profound ranges, incapable of using auditory input for linguistic purposes (Holm, 1978). But only the most profoundly deaf have NO sound. The degree of impairment then becomes central to any generalizations and assumptions made about its effect on individual functioning and should be reported in relevant studies. Deafness for our purposes would best be defined by Furth (1973) description, "a functional hearing loss of sufficient severity to prevent aural comprehension of speech even with hearing aids."

The residual hearing function in an individual with a hearing loss can be aided by mechanical amplification. Early intervention in infancy is believed to potentiate the use of this residual hearing. "In contrast, the later use of the hearing aid encounters what amounts to an atrophy of the unused residual hearing capacity and hence fails." (Furth, 1973). Report of the use of a hearing aid and the age at which it was first used should be given for deaf subjects described in relevant research.

Age of onset is the twin important component with degree of hearing loss, in defining the population of the deaf for research purposes. For persons deafened after the acquisition of language, even as early as age 2 or 3, the problems are not the same as for those deafened pre-lingually. If a person has developed a language it is "practically impossible for him to forget it or not to use it, although speech may deteriorate." (Furth, 1973). For such persons expressive and receptive SPEECH is the main problem. The later in life the loss is incurred, the less the impact on speech. For persons pre-lingually deafened the issues are quite different.

For the pre-lingually deaf, the impact of the handicap is profound. Lunde (1956) illustrates the impact on the infant's normal associations with the hearing world by comparison to the hearing infant who by the end of 16 weeks seems to identify sounds and by 28 weeks is at Esper's stage of sound imitation, vocalizing vowels and consonants which will become words. Toward the end of the first year the stage of verbal understanding begins; by 2 1/2 years the use of spoken language is understood and by 3 a hearing child embarks on the logical arrangement of words in sentences and becomes aware of "self" via expression of ideas.

Four years of age brings the "why" questions and 5 the ability to discuss remote and difficult concepts. By the time the average hearing child begins school s/he has the ability to express self with a vocabulary of 1,000+ words.

By contrast, the deaf infant hears no speech sounds, phonemes, words, verbal cadences, vowels or consonants to imitate. Nor does s/he hear the sound of his own voice by which to shape its performance. The deaf child does not receive information via spoken language. If a deaf infant is born to hearing parents a problem may not be suspected until 12 to 18 months of age, when the child should begin to show the development of speech. Given the effects of parental denial, professional dismissal of parental anxiety and time spent in various searches for cause, the diagnosis is often not made until three years of age. (Furth 1966) Thus, vital years are spent without language. The child is not afforded communication or the medium by which his inner world can understand, organize and be linked to, the external world. If the parents rely on spoken language, the child has neither appreciation to motivate, nor opportunity to experience, verbal communication via sound. The major communication problem for these deaf people is the absence of a language frame of reference when they are learning to speak, write or read. Such a child begins school with a vocabulary of 4 to 20 words, the first learning task being the understanding that objects have names. For persons prelingually deafened, LANGUAGE, not speech, is the problem. Age of onset should be reported in any study of the cognitive functioning of deaf persons.

If the child's parents are also deaf, as exists in 10% of the cases, however, the situation is different in a quite profound way. Though they do not speak their language, such parents have a language - a mode of communication; a language of sign. Possibly by way of the same early life experiences conveyed in a visual mode, by gesturing parents, these deaf children respond early to parental gestures and sequentially imitate subparts of these. Deaf infants begin to use communication by way of signs, an 8 month old forming the hand shape of the sign for milk when hungry (author's personal observation). Studies of the acquisition of ASL (McIntire, 1977; Bellugi & Klima, 1972) indicate that chldren learning ASL pass through developmental stages similar to those reported for children learning spoken languages. However, it appears that a deaf child's progress through these stages emerges two to three months earlier than the hearing child learning spoken language. (Wilbur & Jones, 1974). Deaf children of deaf parents are not totally deprived of language and its development during the early years of language acquisiiton. Though clearly a minority of the deaf population these deaf persons are the advantaged. Parental hearing status should be reported in all relevant studies.

Studies comparing Deaf children of Deaf parents with Deaf children of hearing parents indicate that Deaf children of Deaf (DoD) score significantly higher on achievement tests even when matched for IQ's and etiology of deafness with their counterparts who have hearing parents (Meadow, 1975). Tomlinson-Keasey & Kelly (1978) interpret these differences as due to the earlier exposure and therefore clearer symbolic world to which these Deaf children are exposed. They appear to have normal psychological, cognitive, linguistic and familial develoment (Schlesinger Meadow, 1972: Moores, 1977). In fact, they are four times more likely to continue their studies into a college program (Stevenson, 1974). For these children acquisition of the English language would mark a second language subsequent to the total foundation of a first language. Hearing status of natural parents should be reported in any research of the psychological, cognitive, social functioning of Deaf persons.

Some hearing parents who qive birth to a deaf child are able to attain a diagnosis early in the infant's life and learn sign language, instituting it in the family communication milieu. This is more likely to be the case in younger deaf children than older deaf persons, dependent as these circumstances are on the recent changing trends in diagnostic technique and parental education. In such a case, the infants' experience would be much closer to that of the deaf child born to deaf signing parents described above. Communication mode of the parents, used with the child during early developmental years should be reported and considered in all relevant studies.

Another mitigating factor in the early linguistic environment of the pre-lingually Deaf child is the hearing status of older siblings. If they are Deaf AND have learned a system of sign language they may have an influence on the child's language acquisition. They will have a language to introduce to the child.

There are cases of hearing loss in which the condition causing this loss is either directly related to a neurological disorder or has also produced residual brain damage. Examples of such etiologies would be maternal rubella, Usher's Syndrome, premature birth, meningitis, etc. (Vernon, 1969). Because one would naturally expect some cognitive manifestation of an accompanying chronic brain syndrome in the performance of Deaf persons who have this double condition, the etiology of Deafness should be reported and considered in decremental performance observed in Deaf persons participating in research bearing on related areas of functioning.

These multiple factors of etiology, age of onset, degree of usable speech sound, early communication milieu, parental hearing status, education, etc. combine to effect preferred modes of communication, self perception, cognitive functioning, and dependence and command of spoken language. This data must be included as relevant history and used to shape a valid understanding of the cognitive functioning of this population.

Appendix B

Communication Modes Available to Deaf Persons

The major handicap of deafness is the barrier to communication; being cut off from the normal means of acquiring and transmitting language. Though volumes have been written on the subject, the intimate link between language and thought is not fully understood. Levine (1977) states that the forms of language include "all mutually understood codifications used by individuals in effecting communicative relations with others." Any approach to researching cognitive functions of Deaf persons must include therefore, an examination of the communication mode used by the subjects investigated. Considered here are the basic communication modes available to Deaf persons: Speech, Speechreading, Writing, Fingerspelling, the Language of Signs (ASL) and Total Communication. One major distinction can be made among them in their reliance on spoken, or phonetic language.

<u>SPEECH - is dependent on English</u>

When we as hearing persons attempt to learn to speak a foreign language we become aware of how difficult it is. Yet unlike a Deaf person, trying to learn to speak, we can hear the sound we are trying to imitate as well as our own efforts to articulate and pronounce the new language correctly. If however, we did not

have a structural linguistic frame of reference, or an understanding of why people's mouths moved and what meaning they derived from it, the task would seem impossible; perhaps meaningless. For a Deaf person without language, learning to speak English is a confusing, tedious and largely rote exercise with little apparent value.

<u>SPEECHREADING - is dependent on English.</u>

Once verbal language is learned it may be "read" from visual scan of the speaker's lips. The studies conducted by the Tracy Clinic (Lowell, 1957; 1958) demonstrate how difficult it is for the Deaf person. They found that non-Deaf college sophmores who were inexperienced in speechreading were better at it than Deaf persons who had studied it all of their academic lives. This is attributed to the fact that the hearing person has a solid language base of syntax and vocabulary to fill in gaps of what they missed visually. Forty to 60% of English is homorphemous; looking like other sounds on the lips. A person who is unequipped to fill in these gaps understands little. These studies also indicated that the best lipreaders in a one-to-one situation understand only 20% of what is said.

<u>WRITTEN LANGUAGE - is dependent on English.</u>

No universally accepted lexical system of signed language currently exists. Therefore, the only language which can be written and read by the Deaf is the spoken one. Vernon (1969) cites evidence that 30% of Deaf adolescents are functionally illiterate. The average reading level of the Deaf adult is below the fourth grade level. It is important to note that literacy is a measure of the use of spoken language. It is dependent therefore on the acquisition of a spoken language. It should not be interpreted therefore as a measure of linguistic competence, rather as an index of the ability to read, what to a congenitally Deaf person is, their second language.

FINGERSPELLING (also called Dactylology) - is dependent on English.

In this mode different finger positions in hand signs are assigned to each of the 26 letters of the alphabet. The dominant hand of the signer is used alone. (one hand configuration = one letter.) Communication is thus spelled out manually, letter by letter, requiring a knowledge of the signed alphabet, a command of the verbal language used, its spelling and ATALENTFORGUESSINGWHERETHESPACESGO. The hazards of speechreading do not exist in this mode and expressive speech articulation problems are also avoided. Because this mode is acquired for communication purposes not simply as a way to spell English, it is imprecise in its practical use. It should not be used as a measure of spelling, or other English based competency skills. Hoemann (1978) reports error rates in spelling when subjects switched from written spelling to fingerspelling. Important to neuropsychological studies is the fact that, though spelling English words, fingerspelling is read from right to left NOT in the traditional Western mode of Left to Right.

MANUAL ENGLISH - is dependent on English.

In this mode a different single, bimanual static or moving hand configuration is used to represent English words. It uses fingerspelling, often uses standard root signs which are embellished by different letters and literally substitutes these standard (one sign = one word) signs for each English word; retaining sentence structure, grammar and syntax of English. Both hands are used.

SIGLISH - is largely dependent on English.

It incorporates fingerspelling, uses one sign to equal one concept, is heavily though not purely based on English and shifts between English and American Sign Language idiom. Both hands are used.

AMERICAN SIGN LANGUAGE (ASL) - is NOT dependent on English.

It is a manual-visual language that uses standard signs to represent CONCEPTS (one sign = one concept) has a unique grammar and syntax, and only occasionally uses fingerspelling (for some proper nouns, names, etc.). Both hands are used.

There are several misconceptions regarding this autonomous language. It is often described as a universal language whose grammar is poor compared to spoken languages; vocabulary concrete and iconic, and consists of qestures accompanied by facial expressions. Markowitz (1980) shows that these descriptions are not supported by linguistic analysis.

It is not universal. Danish Sign Language, Japanese Sign Language, British Sign Language, etc., are as different from each other as are their spoken languages. To the unseasoned observer of cross-cultural Deaf communication, however, the easier transition made by these persons (for whom pantomime comes easily) out of their native sign languages and into pantomime will not be recognized, as such. That is however, how such communication is accomplished.

ASL has been criticized as being "conceptual" rather than "word-based". Markowitz points out that "the principal function of language is to convey concepts. However, in a sign language, concepts are represented by signs rather than words." Put another way by Turk (1976), himself a Deaf person, "Oral communication is only an aural form of sign language with arbitrary sounds standing for ideas."

Sign is not ungrammatical. Transliteration or word-for-word translations will produce ungrammatical or meaningless sentences due to the different word order and sentence structure of various languages. "Throw Mama from the train a kiss." is not an indication that the original language was ungrammatical rather that translitation has occurred. ASL is an independent structured language with its own grammar and syntax.

When considering the iconicity of signs there are several points to keep in mind:

1. Signs for the same concept are different in different sign languages.
2. If sign language were iconic it would be quite easy for the novice to understand sign. It is not.
3. Iconicity does not play a major role in the acquisition of sign language. A child learning the sign for "milk" has probably never (and need not have) seen either a cow, or the hand action used to milk one which constitutes the sign.

Though many signs are visual representations of the concepts they symbolize, there are many more which are as arbitrary as are words in their representation. Though ASL can express concrete, imaqoic, concepts, it is not restricted in its ability to deal with abstract ideas and includes signs for abstract thoughts such as LOVE, FAITH, BELIEF, TRUST, PRIDE, etc.

It is then, not merely universal, ungrammatical, concrete, iconic or gestural. It is a language independent from all spoken languages. According to Stokoe (1965) there are three parameters of sign which are of central importance to lexical, synthetic and grammatic components of ASL: handshape, motion and location.

GESTEMIC - is totally INdependent of English.

It is comprised of natural gestures, pantomime and local gestures (one gesture = one concept) and is often called natural sign & international sign. Both hands are used.

TOTAL COMMUNICATION - is partially dependent on verbal language.

Also known as Simultaneous Communication this mode is based on a philosophy of using any and all communication methods available simultaneously. It uses both speech, lipreading and sign options at once, affording maximal information to the receiver from each of these modes.

Any study of Deaf persons must include a description of the communication skills and competence of the experimenter and the subject; the mode used in testing and, in studies of language processing, an account of the contributions of English language.

In summary, all modes of communication available to Deaf persons except American Sign Language and Gestemic (or natural sign), are dependent for successful expression and reception of information, on knowledge and use of verbal language: English. To adequately evaluate language processing in Deaf persons, one must consider the dependence of the communication mode used on English.

Appendix C

Good Day:

This letter is a request for your help by participation in a project designed to increase our understanding of how the human brain processes information in hearing and Deaf persons.

While previous studies have suggested that deaf persons seem to process information in a unique and somewhat different way from hearing persons, there is still little known about why this is true. For that matter, a major obstacle in diagnosis and rehabilitation of deaf persons who have suffered a stroke or other injury to their head, is the inability of psychologists and neurologists to use the wealth of information which currently exists for hearing persons, with deaf persons who need their services.

As a person who uses sign language, you are unique in that you are hearing. By studying the effect of the use of sign language on the way hearing persons process information, we may better be able to understand the effects this unique language may have on the information processing strategies of deaf persons. Because Stroke hits hardest at communication, something our deaf friends and relatives hold dear, it is important that we learn as much as possible to provide a realistic rehabilitation insulation against anything that would threaten it.

I have designed this study, a portion of my graduate research, as a way of exploring the effects of sign language use on information processing strategies for this purpose.

You can help gather valuable information if you are over age 18 and:

__________ are the hearing child of Deaf parents whose first language was ASL, or

__________ learned ASL after the age of 10,

by the time commitment of approximately an hour and a half during which you will watch a film, identify information symbols and complete a short questionnaire. Should you agree to make this voluntary contribution please contact me:

Ms. Rita Rogan Hull
Department of Psychology
Michigan State University
East Lansing, Michigan

Phone: 517 355-9564

It is understood that your participation is totally voluntary and there will be complete freedom to withdraw at any time.

Thank you for your time and interest,

Sincerely,

Rita Rogan Hull
Graduate Student

Appendix D

Subject Information Questionnaire

Subject Number

Sex ________________
Age ________________ Birthdate ____________________

Handedness Information
Self: ______________ Mother: ____________________
Writing __________ Grandmother: ______________
Throwing __________ Grandfather: ______________
Father:
Grandmother: ______________
Grandfather: ______________

Hearing Status:
Mother ______________
Father ______________

Birth Order: ____________

First Language ____________________
How learned ____________________
Second Language ____________________
Age learned ____________________ Method learned ______________
Competency Achieved ____

Education:
Highest grade completed _________________________
Grade point average _________________________
Other specialized training _________________________

Occupation: ____

Employment Status:
Employed, Full-Time ___________
Employed, Part-Time ___________
Unemployed ___________
Never Employed ___________

Vision:
Do you wear glasses? ___________
Vision when corrected ___________
Do you have a restriction on your Driver's License for vision? ___________

Have you ever had problems learning to:
Read ______________ If yes, describe ________________________________
Write ______________ If yes, describe ________________________________
Do Math ______________ If yes, describe ________________________________

Do you sometimes not understand the things you read? ________

Has a doctor ever told you that you had Epilepsy? ___________

Have you ever had blackouts? ________________________________

Appendix E

Experiment I - Words

	Word	Visual Field			Word	Visual Field	
1.	PAN	R		21.	LEG	R	
2.	RAY	R		22.	PUT	L	(?)
3.	PAN	L	(?)	23.	LEG	L	
4.	ROW	R		24.	SKY	L	
5.	WHO	L		25.	WAY	R	
6.	SUM	R		26.	TEN	L	
7.	LOW	L	(?)	27.	MAP	R	
8.	WAY	L		28.	ACT	R	(?)
9.	NOD	R		29.	JOY	R	
10.	BOW	L	(?)	30.	ACT	L	
11.	RAY	L		31.	MAP	L	
12.	SKY	R		32.	ALL	L	
13.	ALL	R		33.	TEA	R	(?)
14.	CRY	L		34.	CRY	R	
15.	NOD	L		35.	SUM	L	
16.	TEA	L	(?)	36.	OUT	R	
17.	LOW	R		37.	ROW	L	(?)
18.	JOY	L		38.	OUT	L	
19.	TEN	R	(?)	39.	WHO	R	
20.	PUT	R	(?)	40.	BOW	R	

Appendix F

Experiment II - Static Signs

	Sign	Visual Field			Sign	Visual Field	
1.	MEET	R	(?)	21.	RAIN	L	
2.	SELL	R		22.	ASK	L	(?)
3.	MEET	L		23.	LOOK ME	R	
4.	HEADACHE	R	(?)	24.	AFRAID	R	
5.	TEACH	L		25.	VACATION	R	
6.	MORE	R		26.	LOVE	L	
7.	CELEBRATE	R		27.	EQUAL	R	(?)
8.	LICENSE	L		28.	SELL	L	
9.	MISCHIEVOUS	R	(?)	29.	TEACH	R	(?)
10.	MORE	L	(?)	30.	WANT	R	
11.	LICENSE	R		31.	HAVE	L	
12.	MISCHIEVOUS	R		32.	VACATION	L	
13.	HEADACHE	L		33.	LOOK ME	L	
14.	AFRAID	L	(?)	34.	HAVE	R	
15.	PLAY	R		35.	EQUAL	L	(?)
16.	CONTINUE	R		36.	PLAY	L	
17.	WANT	L	(?)	37.	CONTINUE	L	
18.	CAT	L		38.	RAIN	R	
19.	CELEBRATE	L		39.	CAT	R	
20.	ASK	R		40.	LOVE	R	

Appendix G

Experiment III - Moving Signs

	Sign	Visual Field			Sign	Visual Field	
1.	RESTRAIN	R		21.	QUIET	L	
2.	ADDRESS	R	(?)	22.	ANGRY	R	(?)
3.	DARK	R		23.	FREEZE	L	
4.	FEELINGS	L		24.	ANGRY	R	
5.	MACHINE	R		25.	SHOES	L	
6.	DARK	L	(?)	26.	NOW	R	
7.	FREEZE	R		27.	LOSE	L	
8.	ABANDON	R		28.	FEELINGS	R	
9.	FINISH	L	(?)	29.	INTRODUCE	L	(?)
10.	FIRE	L		30.	ADDRESS	L	
11.	ANGRY	L		31.	HERE	R	
12.	QUIET	R		32.	EVERY SUNDAY	L	
13.	ABANDON	L	(?)	33.	SHOES	R	
14.	CLEAR	R		34.	FIRE	R	(?)
15.	EVERY SUNDARY	R		35.	MACHINE	L	
16.	CAN	L		36.	HERE	L	
17.	NOW	L		37.	INTRODUCE	R	(?)
18.	FINISH	R		38.	LOSE	R	
19.	CAN	R		39.	WITH	L	(?)
20.	RESTRAIN	L		40.	CLEAR	L	

Appendix H

Experiment IV - Oriented Lines

	Orientation	Visual Field			Orientation	Visual Field	
1.	8	R		21.	2	L	
2.	5	L	(?)	22.	3	R	
3.	7	L		23.	1	R	
4.	5	L		24.	3	L	
5.	5	L		25.	6	L	(?)
6.	1	L		26.	2	R	
7.	7	R	(?)	27.	4	L	
8.	2	R		28.	8	L	
9.	4	R		29.	2	R	
10.	1	L		30.	1	R	(?)
11.	7	L	(?)	31.	6	R	
12.	4	R		32.	3	L	
13.	6	L		33.	4	L	
14.	1	R	(?)	34.	8	R	(?)
15.	3	R		35.	5	R	
16.	6	R		36.	7	R	(?)

INFORMED CONSENT FORM

I freely consent to take part in a scientific study entitled, "Hemispheric Specialization as a Function of Unique Bi-Language Acquisition: The laterality patterns of the hearing offspring of deaf parents whose first naturally acquired language was American Sign Language.".

This study is being conducted by Ms. Rita Rogan (Hull) of the Psychology Department of Michigan State University. I agree that the following statements are true:

1) I understand that I am free to discontinue my participation in this experiment at any time, without recrimination.
2) I understand that all results will be treated with strict confidence. Should the results be published the subjects will remain anonymous.
3) I understand that if I so desire I will be given a summary of the results of this experiment upon its conclusion.
4) I am aware that the experiment may not produce results which are to my direct benefit.
5) The experiment has been explained to me, I understand what my participation entails, and that a full explanation of expectation of outcome will be made to me upon completion of my performance.

____

Signature of Subject

____

Date

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