ISBN 0-315-55627-7

DIFFERENCES IN VISUAL HEMIFIELD PROCESSING OF LINGUISTIC MATERIALS BY DEAF AND HEARING ADULT MALES

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in

School Psychology

Department of Educational Psychology

Edmonton, Alberta

Fall, 1989

THE UNIVERSITY OF ALBERTA

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TITLE OF THESIS Differences in Visual Hemifield Processing of Linguistic Materials by Deaf and Hearing Adult Males

DEGREE: ·tor of Philosophy

YEAR THIS DEGREE WAS GRANTED: 1989

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Date:September 25, 1989

Abstract

Research studies on right-handed, hearing individuals suggest that the left hemisphere of the brain is dominant for language functions. Contradictory results (McKeever, Hoemann, Florian, & Van Deventer, 1976) have been found for deaf persons, suggesting a reverse pattern of cerebral dominance with language functions centered in the right hemisphere. These authors proposed that the lack of exposure to the auditory stimulation of spoken language may alter the hemispheric dominance for deaf people. The major objectives of this study were to determine whether auditory and the kind of exposure to language input (oral or manual) influence development of left hemisphere specialization for language.

Four groups of subjects (adult males) comprised the sample for this study; 20 subjects had no known hearing loss and 20 were prelingually deaf (self-reported profound hearing loss). For one-half of each group American Sign Language (ASL) was the first and primary language used (manual groups); spoken English was the primary language of the other half (oral groups).

Eight visual tasks, selected on the basis of the literature as requiring left hemisphere processing, were presented to the subjects' right and left visual fields unilaterally, by means of a tachistoscope. Number of correct responses and time to response were used as dependent measures.

Major directional hypotheses predicted that hearing subjects would identify visual stimuli presented to right visual field (RVF) with greater accuracy and greater speed than deaf subjects, and that similarly within each of the hearing and deaf groups, oral subjects would outperform manual subjects. Using multivariate analysis procedures, all major hypotheses were rejected. Additional methodological research questions addressed the characteristics and appropriateness of the tasks used in the study and the use of the dependent measures.

The results of the study provide support for Ross's (1983) argument that "differences between deaf and hearing individuals in hemispheric advantage may be due to differences in modes of processing, rather than to differences in underlying brain organization" (p. 309). These results raise the possibility that reading and educational lags associated with early prelingual deafness may be a consequence of educational deficits rather than of neurological differences.

Acknowledgements

It is with great thanks and indebtedness that I acknowledge all of the help I have received from the people who willingly agreed to be subjects for both the pilot study and the thesis, those who helped me to find subjects, the many institutions, organizations and conferences for deaf people who gave of their time to assist me and allowed me to set up the equipment for this study in their offices.

A very special thanks to Suzanne Martin who tutored me in sign language instructions in American Sign Language which enabled me to sign to the subjects who were conversant in ASL. Although willing interpreters were often available, it served as a greater bond between researcher and participant to be able to converse with each other even if my signs were less than perfect. Thanks to the participants who were so patient.

A special thanks to parents in the Parent Support Group for Hearing Impaired Children in Lethbridge who willingly participated in the pilot study, thereby helping to iron out a lot of the wrinkles. Thanks too, to the members of the ASL sign language course at the Lethbridge Community College who willingly gave of their time to be tested in the pilot study.

Without the assistance of the following groups, this research would not have been possible. As deaf people are quite isolated in the province of Alberta and few live in Lethbridge, finding deaf people and grown hearing children raised by deaf parents appeared to be an almost insurmountable task at the beginning of the project.

Special thanks to the following organizations:

1. Faculty of Education, The University of Lethbridge, Lethbridge, Alberta.
2. Rev. Harold Ziprick, Calgary Church for the Deaf, Calgary.
3. Calgary Deaf Centre, Calgary.
4. Alberta Vocational Centre, Calgary.
5. Alberta College Interpreter Services for the Deaf, Edmonton, Alberta.
6. Jacques Plamonden, Counseling Centre, NAIT, Edmonton.
7. Rev. Robert Bauer, Cross of Christ Lutheran Church of the Deaf, Edmonton.
8. Gary Whyte, Terry Tang, and Dr. K. L. Bowers, Instructional Technology Centre, Faculty of Education, The University of Alberta.
9. Canadian Cultural Society for the Deaf Conference, Edmonton, August, 1984.

10. Alberta School for the Deaf, Edmonton, Alberta

11. Psychology Department, University of Alberta

12. Western Institute for the Deaf, Vancouver, B.C.

13. A. G. Bell Association for the Deaf Conference, Portland, Oregon, June, 1984.

For her time and willingness to serve as the model for the ASL sign photographs, my very special thanks to Sue Bailey, teacher at the Alberta School for the Deaf.

A very special thanks to my Thesis advisor, Dr. H. Janzen, and doctoral committee, Dr. Steve Hunka, Dr. G. Kysella, and Dr. H. Ilott for all their assistance and advice. I acknowledge the assistance given by Dr. M. Rodda and Dr. S. Haske.

I have learned a great deal about statistical programming from Dr. Bruce Schaalje, Statistician at Agriculture Canada Research Station, Lethbridge, and am grateful for his invaluable assistance with programming and using BMDP, and to Dan Ethier for his creation of the timer.

The Deans in the Faculty of Education at The University of Lethbridge have been very supportive. Thanks to Dr. Eric Mokosch, and Dr. R. N. Anderson who encouraged me even when finishing the thesis, working full-time, and raising my own family seemed beyond the realms of the possible. And to my colleagues Dr. Myrna Greene and Dr. Carolie Coates a special thanks for their friendship and support.

I dedicate this thesis to my children Martin, Stephanie, and Veronika, who began to believe that working on a Thesis was a normal part of family life; and to my friend and helpmate, my husband, Henning, without whom I would have given up on this project long ago.

The Alberta Heritage Trust Fund, for choosing me as a recipient of the Wilfred R. May and the Ralph Steinhauer doctoral fellowships, my deepest gratitude.

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Chapter 1

INTRODUCTION

Research studies on hearing individuals indicate that the left and right hemispheres of the brain have separate processing capacities. The left hemisphere is often described as the speech hemisphere whereas the right hemisphere has often been associated with non-verbal visuospatial functions (Diamond & Beaumond, 1974). Other studies indicate that the left hemisphere appears to be more specialized in analytic and sequential processing whereas the right hemisphere appears to be more specialized for holistic and parallel processing (Bever & Chiarello, 1974; Cohen, 1973). There has been much speculation about the relationship between language acquisition, in particular its analytical sequential properties, and left hemisphere development.

Two major theories have been developed to explain the asymmetry of the human brain, but they appear to be contradictory in their explanation of left hemispheric dominance. Witelson (1977), Young (1977) and Kinsbourne and Hiscock (1977) suggest that hemispheric specialization is present at birth. Other studies have indicated that hemispheric specialization occurs concomittantly with brain maturation and is completed between the ages of five and puberty (Dorman & Geffner, 1974; Geffen, 1976). Lieberman (1975) suggests that left hemisphere specialization for language develops as a result of processing the complex grammatical codings involved in speech perception. If speech perception is an important factor in the development of the left hemisphere, its absence may alter the distribution of functions between the two hemispheres. This possibility has led to interest in hemispheric specialization of people deprived of all or most auditory perception from birth (congenitally profoundly deaf people).

The Problem

Some studies of hemispheric specialization comparing deaf and hearing subjects appear to support Lieberman's contention. Findings by these researchers (Manning, Goble, Markman, & LaBreche, 1977; Phippard, 1977; Tomlinson-Keasey, 1978; Scholes & Fischler, 1979) seem to indicate that deaf people do not develop left hemisphere dominance for verbal processing of information, dominance which has been characteristic of hearing populations. Conversely, results of research by Neville and

Bellugi (1978) suggest that left hemispheric specialization can be acquired through the visuo-haptic modalities. (A glossary of technical terms used in this study in included in Appendix 1).

Some researchers (Kelly & Tomlinson-Keasey, 1978; Scholes & Fischler, 1979) found evidence of a reversed cerebral asymmetry in deaf people. Deaf subjects received higher scores for signed linguistic materials presented to the Left Visual Field (LVF) whereas hearing subjects had higher responses to visual language materials presented to the Right Visual Field (RVF). In Poizner's (1980) review of studies using American Sign Language (ASL) signs, he noted that deaf subjects received higher scores for left visual field presentations of the ASL signs. However, the ASL signs were not presented to hearing subjects, raising the question of whether it is the visuospatial properties of the task that result in a right hemisphere response, or whether it is a difference in hemispheric asymmetry of the deaf and hearing subjects as suggested above. In view of these findings, it has been suggested that the deaf subjects might have a lateralization for language functionally different from that of the hearing subjects. The contradictions in these findings clearly suggest the need for more research in this area.

The visual modality provides an avenue for assessing cerebral asymmetries and has been successfully used in laterality research with deaf subjects. Images received by the left visual hemifield (LVH) of each eye are transmitted to the right hemisphere (RH), and the images received by the right visual hemifield (RVH) are transmitted to the left hemisphere (LH) (Bryden, 1982). This method involves tachistoscopic presentation of visual materials to the left and right visual hemifields either at the same time (bilateral) or to one hemifield at a time (unilateral). In order to ensure that the visual images are presented to only one visual hemifield, the stimuli must be presented so rapidly (in less than 200 ms stimulus duration) that the eyes cannot fixate on a new position. Thus if subjects respond more rapidly or accurately to stimuli presented to one hemifield it is inferred that this indicates that the contralateral (opposite) hemisphere is more successful or more specialized for processing that particular kind of stimuli (Bryden, 1982). In fact, the hemispheres do have inter-connecting fibers, but crosslateral (cross hemisphere) transmission takes time and images or messages received in this way are less clear than direct images (Bryden, 1982). Therefore, images received first are received in a less disintegrated form, which should result in more accurate identification of information.

McKeever, Hoeman, Florian, and Van Deventer (1976) tested the theory that the reduction in auditory stimulation in congenitally deaf people might alter the lateralization for language. They reasoned that if left hemisphere specialization for language is primarily a result of a superior left auditory association cortex, then people deprived of such auditory experience should not develop the left hemisphere "dominance" for language characteristic of research studies of normally hearing subjects.

In the McKeever et al. (1976) study, half of the subjects were oral deaf and half were hearing subjects trained in ASL. Materials presented tachistoscopically consisted of print words and letters, and line drawings of ASL signed words and finger-spelled letters. They found that congenitally deaf persons showed smaller visual-field differences for linguistic stimuli presented visually than did the hearing subjects. Based on the reduced asymmetry found in the deaf subjects, the authors concluded that auditory sensory deprivation does in fact alter or reduce LH specialization for language. Whether or not that is in fact the case is the problem addressed in this study.

Methodological Concerns

Some of the differences in the findings of previous research may be attributed to methodological concerns, in particular the selection of subjects. Very few researchers have attended to or included questions about subjects' language acquisition background and educational training, such as: age of hearing loss, degree of hearing loss, and age of entry into early language programs for deaf subjects. Some studies have included deaf subjects from one particular program of language instruction (Phippard, 1977) and generalized to all deaf people from that group. Subject groups have been small with little attention paid to comparison groups of deaf and hearing subjects.

The lack of ability of hearing oral speech demands that language will be acquired differently in deaf people than in hearing people. The two major instructional techniques used to teach deaf people language have been the oral method (lip reading, use of residual hearing, reading) and the manual method (sign language). A combination of the two methods, called Total Communication, is currently used widely in schools, along with a variety of signed systems which parallel English syntax, including signs for word endings. Careful attention must be paid to how language has been acquired when comparisons among groups of deaf people are made, as well as in comparisons of deaf and hearing individuals.

Researchers also believe that the nature of lateralization of brain function may differ in men and women. Kimura and Hurshman (1984) reviewed a number of studies of recovery of function following left hemisphere strokes in men and women; the evidence indicates that recovery of speech is better in women than it is in men with similar left hemisphere lesions. These results seem to support the suggestion that expressive language ability may be more symmetrically represented in females than in males.

Because of the question of bilateral representation of expressive language in females and the consistent findings that following left hemisphere strokes women do recover speech better than men, it would appear that at this time subject selection for laterality studies of language should either be restricted to one sex, unless the studies are specifically comparing men and women. Moreover, if using one sex only, because of the apparent asymmetrical representation of expressive language skills in the left hemisphere of men, then single subject selection could be limited to men in order to maximize the differences between the two cerebral hemispheres. Kimura and Hurshman (1984) suggest that since the nature of the asymmetrical brain organization of each sex is still being investigated, selection of subjects should be limited to one sex. The findings in the McKeever et al. (1976) study with all female subjects might therefore not be generalizable to all deaf subjects.

Another difficulty with generalizability of the McKeever et al. (1976) research is that deaf undergraduates are not very representative of deaf people as a whole. Research on the educational progress of deaf children has shown that even minimal degrees of hearing impairment can have far-reaching effects in terms of reading retardation and subsequent delay in other areas of academic achievement (Conrad, 1979). Thus, few deaf people reach the level of education of McKeever's subjects (Rodda, 1970).

Generalizations have been made from the studies just described (McKeever et al., 1976; Phippard, 1977) using deaf subjects to deaf people in general, but deaf people are not a homogeneous group. Age at onset of deafness, whether congenital, prelingual or postlingual is an acknowledged factor. Just as important is information about how early language training was carried out. Whether sign language was taught by deaf parents fluent in sign language or was learned in school at some later date is also an important variable. All of these components of language development may be critical variables influencing hemispheric specialization.

Methodological Improvements

Sweeping generalizations have been made about the hemispheric specialization in deaf people, without inclusion of comparable groups of hearing people. In this study an attempt has been made to minimize confounding of results by inclusion of both hearing and deaf subjects with exposure to similar types of first language instruction. Equal numbers of both hearing and deaf people whose first exposure to language was oral, as well as comparable groups whose first exposure to language was manual (ASL) are included. All subjects were presented with all materials in order to compare responses by both deaf and hearing subjects. In order to minimize the problems with recognizability of signs encountered by subjects in the McKeever et al. (1976) study, actual photographs of ASL signed by a deaf person were created.

Two dependent variables have been used as measures of hemispheric differences in both deaf and hearing subjects. They are the number of correct responses reported, designated as Score (McKeever et al., 1976), and Time to Response, designated as the time from presentation of visual stimulus to the instant of subject response to the stimulus. Both these dependent variables were included as each has been used independently in previous research studies, with an implicit assumption that they are different measures of an underlying process. The use of both variables allows for the possibility of determining whether this assumption is correct. Furthermore, to minimize a possible left hemisphere effect by use of either verbal or written report, a multiple choice board with pointing was used.

Purpose of the Study

The overall purpose of this study was to determine whether there is a difference in left hemisphere domination for language between hearing and deaf people taught language by either an oral (speaking) method or a manual (sign) method.

General Objectives

This study had two major objectives:

1. to determine whether auditory experience affects development of left hemisphere specialization for language, and
2. to determine whether type of exposure to language input, that is oral or manual, influences development of the left hemisphere specialization for language

Hypotheses

Each of the two major objectives was translated into three diretional hypotheses for the purposes of data collection and analyses. It should be noted that although the visual stimuli were presented to both right and left visual fields, current research indicates that left hemisphere specialization for language is identified through more accurate and faster responses to presentation to the RVF. Thus the hypotheses have been stated in terms of RVF presentations; LVF Scores and Times to Response were used to check the accuracy of the assumptions underlying the hypotheses.

Accuracy of Identification (Score). Using Score as the measure of hemispheric specialization as indicated by response to visual stimuli presented to the right and left visual fields, these hypotheses are:

1. Hearing (Oral and Manual) subjects will not differ significantly from the Deaf (Oral and Manual) subjects in the accuracy of correct responses to tasks presented to the right visual field.

2. g (Oral) subjects will not differ significantly from the Hearing (Manual) subjects in the accuracy of correct responses to tasks presented to the right visual field.

3. Deaf (Oral) subjects will not differ significantly from the Deaf (Manual) subjects in the accuracy of correct responses to tasks presented to the right visual field.

Time to Response: Speed of Identification Response. Using Time to Response as the measure of hemispheric specialization as indicated by response to visual stimuli presented to the right and left visual fields, these hypotheses are:

4. Hearing (Oral and Manual) subjects will not differ significantly from the Deaf (Oral and Manual) subjects, in time to response to tasks presented to the right visual field.

5. Hearing (Oral) subjects will not differ significantly from the Hearing (Manual) subjects in time of response to tasks presented to the right visual field.

6. Deaf (Oral) subjects will not differ significantly from the Deaf (Manual) subjects in time of response to tasks presented to the right visual field.

Methodological Questions

In addition to the specific hypotheses tested in this study to address the major study objectives, other methodological issues were also addressed. These issues were framed in the form of research questions:

1) What is the relationship between the visual stimuli (their nature and

characteristics) and the two dependent variables of Score and Time to Response?

2) What is the nature of the relationship between the two dependent variables of Score and Time to Response?

Limitations

For ease of statistical analysis with groups of equal size, although "there are a number of methods for making adjustments to the data when cell frequencies are unequal and disproportional" (Fergusen, 1976, p. 256), it was decided to keep all groups of equal size, with the availability of numbers of subjects in the smallest group (hearing manual) determining the group size.

The group most difficult to find were hearing sons of deaf parents, for whom manual communication was their first language. Subjects for this group, as well as deaf subjects, were located through contacts with local, regional, and national associations for the deaf in both Canada and the U.S. As some of the subjects had traveled specifically to some of the sites used for testing to attend conferences, workshops, or other activities for deaf people, the subjects in this study came from many areas of the U.S. and Canada. For this reason subjects do not represent any one specific geographical area of North America.

One of the difficulties facing research using sign language is the technique of tachistoscopic presentation of visual materials. It is difficult to capture the movement of signs within the time limits of tachistoscopic exposures. Some researchers (Boshoven, McNeil, & Harvey, 1982; Wilson, 1977) have used line drawings of signs without the characteristic movement of signs. In a study using brief projections of moving signs, Poizner, Battison, and Lane (1979) found no hemifield differences. The static signs do not include the temporal movement properties which may be critical both to the sign language and left hemisphere specialization. The use of photographs of signs with the key features of the first and last positions of the sign and a black arrow to indicate direction of movement, has been an intermediate solution to the problem of using static photographs to represent moving signs.

Although the subjects were asked to read the Instructions prior to beginning the visual presentation of tasks, there was no record of how well the subjects understood the instructions. Also there is no record of the reaching achievement levels for the subjects in the various groups. Different interpreters for the deaf were used at different sites as it was beyond the means of this researcher to hire an interpreter for this study.

There is no record of decibel loss at birth of the deaf subjects, nor any indication of the stability of this loss over time. Furthermore, no data were collected on the use of amplification equipment, whether ear-level hearing aids or FM equipment or other devices which may have been used at home or in school. Response hand to the visual stimuli was not controlled.

Self report was used to determine hearing loss in the deaf subject groups. The Schein and Delk (1974) hearing scale was normed for use in groups; in this study responses to the scale were used for assignment to the deaf groups. To truly determine the extent of hearing loss of the individuals in each group audiometric testing would have been required. It is also possible that within the hearing groups, slight hearing losses may have been detected.

One major limitation of the study was in the assignment of each subject into the four groups by hearing and language experiences. Certainly the Hearing Manual group was different from the Deaf Manual group in that the Hearing subjects were exposed to spoken language as well as to signed language. Also no data was available on the degree of proficiency of the Hearing Manual subjects in sign language at comparable ages to the Deaf Manual subjects. In none of the four groups were audiometric data collected; nor were data available on the degree of hearing loss over time for any of the deaf subjects. In this study an attempt was made to find comparable groups of subjects, although some of the limitations of comparability have been described.

Significance of the Study

Results of this study may contribute to the theoretical and practical understanding of the development of language in deaf persons. The results may help to determine the relative importance of spatial linguistic characteristics in determining cerebral asymmetry; they may contribute to theories of cerebral asymmetry and the relationship between left hemisphere involvement in language when language is not auditorily perceived. Results of this study may contribute to resolution of the issue of whether auditory experience is a necessary condition for the development of the left hemisphere. The study results may help to provide the impetus for creating strategies for stimulating development of the left hemisphere in deaf children. Results may indicate strategies or language systems which stimulate the right hemisphere, and enhance knowledge and understanding of right hemisphere expressive language capability.

It is anticipated that the long term effect of this study will be the promotion of the enhanced sensitivity to ways in which deaf children learn language. If it can be shown that the differences between deaf and hearing people are not a result of laterality or left hemisphere development, thus nullifying the argument that deafness per se precludes the normal development of left hemisphere and subsequent language development, then there are strong implications for education of deaf children. No longer would the artificial ceiling on the abilities of deaf children be a viable explanation for low reading scores and lack of educational advancement. Instead, effort could be more appropriately channeled into the creation of educational programs and appropriate learning strategies for working with deaf children.

Chapter 2

LITERATURE REVIEW

Theories of Laterality and Language Development

The asymmetry of the cerebral hemispheres has been extensively documented in the literature. Studies on brain-injured and commissurotomy patients demonstrate a left hemisphere lateralization for language functions and a right hemisphere lateralization for processing visual and tactile spatial information (Gazzaniga & Sperry, 1967; Luria, 1973; Nebes, 1974; Sperry, 1974).

Recent studies in language lateralization in normal subjects have brought about the realization that the right hemisphere has some receptive speech comprehension (Gazzaniga, 1970; Kinsbourne, 1974). However, in Searleman's (1977) review of linguistic capabilities in the right hemisphere, he indicates strongly that speech and writing production in the right hemisphere are limited.

A clear relationship between linguistic function and cerebral dominance has been shown by Cohen (1972) in experimental psychology and Whitaker (1971) in neurolinguistics, as well as by behavioural researchers whose results have been summarized by Kelly (1978) (See Table 2-1). The regularity of this relationship in most individuals has led to interest in hemispheric specialization in individuals with abnormal or delayed linguistic experiences (See, for example, Curtiss, 1977, in his study of Genie, a child raised in communication isolation.)

Lateralization Complete at Birth

Kinsbourne (1975) argues that brain specialization (lateralization) is complete at birth. Certainly there appears to be anatomical as well as behavioural evidence of cerebral asymmetry present at birth to support his theory. Anatomical studies indicate that the left planum temporal, which would appear to include Wernicke's area and is known to be crucial to normal language functioning, is larger than the right planum in adults (Geschwind & Levitsky, 1968); this area has also been found to be larger in newborns (Witelson & Pallie, 1973). Dichotic listening studies by Entus (1977) resulted in a right-ear (left hemisphere) advantage for processing verbal material and a left-ear (right hemisphere) advantage for nonverbal material in infants a few weeks of age.

Table 2-1: Summary of Functions of Left and Right Hemispheres

Left Hemisphere Function		Right Hemisphere Function
Words	letters	non speech sounds
calculating	rhythm	melodic patterns
stress	intonation	visuospatial tasks
syntax	speaking	face recognition
lexical decisions	reading	parallel processing
phonemic analysis	writing	some speech perception and comprehension (no speech production)

(adapted from Kelly, 1978, p.641)

Lateralization Continues Throughout Life

The opposite view posed by Brown and Jaffe (1975) is that cerebral dominance is a continuous process which evolves throughout life. They suggest that the right hemisphere may be dominant during the "prelinguistic" period with left hemisphere skills being developed as speech is acquired. Results of several studies favour the developmental process for hemispheric lateralization (Satz, Bakker, Teunissen, Goebel, & Van der Vlugt, 1975; Tomlinson-Keasey, Kelley, and Burton, 1978).

Critical Period Theory

An intermediate view is a developmental model postulating that lateralization may be completed sometime before adulthood. Myklebust (1964) was one of the earliest researchers to suggest that cerebral lateralization of the hearing impaired could differ from that of the normal hearing person. He reasoned that the absence of a sensory modality could alter the integration and functioning of the other senses.

Lenneberg (1967) was concerned with the possible detrimental effect of lack of auditory exposure to the developing brain. He believed that lateralization of function in the brain develops over time but is not complete until puberty. Based on clinical data (collected by Basser) of evidence of recovery from aphasia and language acquisiton after hemispherectomy for infantile hemiplegia, he concluded that lateralization was complete at puberty. His research indicated that puberty marks a crucial turning point in the ability to learn new languages through exposure, without signs of a foreign accent. He believed that lateralization was the biological basis of language-learning ability.

From Lenneberg's research, grew a concept of a "critical period", that is essential to language development. Thus, if through lack of exposure to language (through, say, deprivation, illness, deafness) development does not take place during the critical period language will not develop to its potential. In view of Lenneberg's hypothesis, the pattern of cerebral asymmetry identified in hearing subjects cannot be assumed to be the same as that found in subjects who have acquired language through other than auditory means.

Effects of Strokes on Language

Whether or not deaf populations exhibit the same left hemispheric dominance for expressive language as do hearing populations is open to dispute. Lieberman (1974a, 1974b) attributes hemispheric specialization directly to the processing of grammatical codings involved in speech perception. However, the question of whether deaf people could develop hemispheric specialization without access to auditory processing of speech perception is still unresolved. Studies of deaf adults who became aphasic and exhibited a communication impairment following a stroke would suggest that lateralization of language for deaf people is similar to that of hearing people (Sarno, Swisher, & Sarno, 1969).

Kimura, Battison and Lubert (1976) analysed seven cases of aphasia in deaf adults. They noted an association between left hemisphere damage and manual communication disorders. They suggested that the interference of a deaf aphasiac's ability to sign may be interpreted as a disorder of motor sequencing, rather than a language deficit. They suggest that the left hemisphere's specialized functions may be related primarily to control of complex motor behavior; the disturbances of sign language and speech may be interpreted as motor dysfunctions in which linguistic impairment is secondary.

More recently, Poizner, Kaplan, Bellugi, and Padden (1984) studied three women and one man, all of whom were fluent in ASL prior to their strokes. All subjects were right-handed. Results of a series of visuo-spatial tests suggest "that deaf signers show hemispheric specialization for nonlanguage visuo-spatial processing that is similar to hearing speaking individuals" (Poizner et al., 1984 p. 281). The three patients who had left-hemisphere damage presented different difficulties with sign language. Testing these same patients, Bellugi, Poizner, and Klima (1983) suggest that hemispheric asymmetry can develop in deaf signers, with resulting separation of linguistic and visuo-spatial processing. The authors further noted that "differential damage within the left hemisphere appears to lead to selective impairment of the structural layers of sign language" (Bellugi et al., 1983, p. 168).

Measures of Laterality

Many different measures have been used to study lateralization of language. Some of these have included neuroanatomical asymmetries (Witelson & Pa" , 1973), nuclear blood flow (Risberg, Halsey, Wills & Wilson, 1975), event-related potentials (Neville, Kutas, & Schmidt, 1984), dichotic listening (see reviews by Berlin & McNeil, 1976; Krashen, 1976), dichaptic techniques (Witelson, 1976; Cranney & Ashton, 1980; Vargha-Khadem, 1982; Bryden, 1982), and dioptic techniques (see reviews by Bryden, 1982, and White, 1972).

Electrophysiological Measures

Electrophysiological measures would appear to be the most direct measures of hemispheric asymmetry, yet cautions are sounded by various researchers. Uttal (1973) indicates that interpretation of such data may be confused with the fact that the changes observed may be correlated with a particular stimulus event, which in fact may have nothing to do with the process under investigation. Bryden (1982) summarized the literature to date, stating that "physiological studies have generated almost more confusion than knowledge" (p. 155); he cautions that "before these measures can be truly useful, greater behavioral sophistication is required in the physiological experiments" (p. 155). Bryden (1982) is leery of researchers relying on these measures since a proper understanding of electrophysiological changes depends on a comprehensive theory of brain activity which is yet to be developed.

Some researchers are using the event-related potential to corroborate findings of behavioural studies. Neville, Kutas, and Schmidt (1984) compared ten hearing with eight congenitally deaf adults. Unfortunately the authors included no information about mode of first language of acquisition for the deaf subjects, although they allude to the fact that for deaf people whose native language is a signed system, English may be processed more as a second language, the processing of which Bentin (1980) suggests may involve the right hemisphere more than the left.

Homan, Criswell, Wada, and Ross (1982) studied the neurology of manual communication in a patient who had learned speech and manual communication (signing) simultaneously. Based on their study, in which they used intracarotid injection of amobarbital sodium, they concluded that hemispheric dominance for the propositional components of manual communication and spoken language were the same, except that lateralization was less complete for the manual language. Furthermore, they suggested that the right hemisphere contributed to both propositional and emotional components of manual communication.

Behavioural Measures

A number of behavioural measures have been used to measure hemispheric functioning. Among these have been dichotic listening (Kimura, 1963), dichaptic studies using the tactile modality (Gibson & Bryden, 1984), simultaneous finger-tapping/vocalization or dual task paradigm (Kinsbourne, 1975), and dichoptic or tachistoscopic measures (Kimura, 1973). The dichotic and dichoptic measures have been used widely in research with both hearing and hearing-impaired subjects. The dichaptic measures appear promising; however, this is a new area of research with many methodological concerns (Bryden, 1982). The dual task paradigm offers a non-invasive measure of children's laterality; however, some of the current contradictory findings render it a less preferred method of research.

Auditory:Dichotic Listening

Dichotic listening procedures were the first behavioural techniques to be developed and have been used extensively to study laterality in brain function and cerebral asymmetry (see a major review by White, 1972). Dichotic listening was introduced by Broadbent (1952) and has been a favoured method of determining hemispheric specialization. This method involves the synchronous presentation of two auditory stimuli to a subject through stereo headphones. Dichotic studies (Berlin et al., 1973; Kimura, 1963) have shown a differential performance between the left and right ears in identifying verbal and nonverbal stimuli. Inferences concerning hemispheric functioning can be made from ear performances on dichotic tasks, because the contralateral neural pathways for the auditory system operate more efficiently than the ipsilateral pathways when the ears are required to process simultaneous input (Kimura, 1973). Thus, a right ear superiority for identifying words on a dichotic task would indicate left hemisphere processing.

Kimura's (1961) early work indicated that simultaneous presentations of paired words to both ears would result in more words accurately identified by the right ear; presentation of nonspeech sounds resulted in a left ear advantage. This method has been studied by many investigators and has yielded similar results. However, as half of the subjects in this investigation were deaf, the dichotic listening procedure could not be used.

Tactile:Dichaptic Studies

Few researchers have attempted to use the tactile modality in the study of cerebral representation of linguistic and non-linguistic stimuli. Kimura (1966) compared the performance of each hand tested singly. This procedure would appear analogous to the unilateral visual presentation technique; however, in tactile studies, subjects know which hand is being tested. Such a procedure permits the subject to devote his attention entirely to the hand in question, which is, therefore, different from the visual test situation.

Some researchers impressed with the dichotic listening procedure have developed tactile analogies. One of the first was Witelson (1974) whose young subjects palpated simultaneously three-dimensional forms, one with each hand, for 10 seconds. Subjects selected the forms from six alternatives; boys in grades one to eight showed a left-hand advantage. When tested on a letters task, and recalling the letters, the same subjects showed a right-hand advantage. The subjects responded verbally to the task by naming the letters, which may have involved the left hemisphere and influenced the right-hand advantage. Witelson's results have yet to be replicated. Cranney and Ashton (1980), using Witelson's dichaptic task on adults and hearing and deaf children. found right-hand superiority for both adults and children on all tasks. The lack of task differences may be attributed to the inclusion of both females and males in the study.

Similar results were found by LaBreche, Manning, Goble and Markman (1977) in their study of hearing and congenitally deaf teenagers. They found no differences in their subjects' responses to Witelson's dichaptic task, although they showed a right-hand superiority overall, again a finding opposite to Witelson's. Order of presentation would seem to affect results, as subjects exposed to the letters prior to shapes had significantly superior right tactile field performance. The right tactile field effect may have been produce a left tactile field effect.

Vargha-Khadem (1982) argues that the tactile task requirements must be sufficiently compex to ensure that a subject cannot use a pattern-matching strategy as this would bias the processing of the stimuli by the right hemisphere. In Vargha-Khadem's (1982) study of right-handed, junior high deaf and hearing subjects, subjects palpated either two shapes or two letters for each trial. Subjects identified the two palpated figures from a multiple choice card of six items by pointing. Overall, right hand accuracy was greater than left. Deaf subjects performed better on nonverbal tasks (shapes), whereas hearing subjects performed better on verbal tasks (letters).

It is essential with somatosensory laterality research, as with other behavioural measures to avoid the development of strategy effects with anticipation of presentation visual field order by ensuring randomization of presentation to control for strategy effects. Gibson and Bryden (1984) used a very simple dichaptic procedure using cut-out sandpaper letters and shapes which were mounted in pairs on cards. Subjects were cued as to which of the two stimuli they were to identify first. Order of identification of stimuli was randomly assigned. Their ten year-old subjects showed the anticipated right-hand advantage for identifying letters and a left-hand advantage for identifying nonsense shapes.

The use of somatosensory research with subjects with whom the dichotic listening procedure is inaccessabile due to deafness, is appealing. Some of the research currently being conducted shows some interesting trends. However, there is not a substantial body of research in this area which could provide a baseline for research with more specific populations.

Sensori-motor:Dual Task Paradigm

The dual task paradigm of finger-tapping with left or right forefinger while simultaneously vocalizing is another behavioural task used in the measurement of laterality. Kinsbourne (1975) used this method to assess cerebral laterality for speech production in young children. This task has been found to be useful with tests of very young children as an alternative to the visual task, since it is difficult to control for children's fixation in the visual tasks.

Ashton and Beasley (1982) studied congenitally deaf and hearing children using a concurrent processing of the non-verbal task. However, with the concurrent verbal task, both deaf and hearing children showed impaired right-hand performance. Deaf subjects showed a greater bilateral decrement than the hearing children, although the pattern of hemispheric asymmetry was found to be similar and in the same direction in both groups. The authors suggest that these data support the progressive lateralization hypothesis (Lenneberg, 1967) among the normal hearing. Furthermore, they caution that hemispheric specialization may be less apparent in deaf children as exemplified by the decrement in performance of both hands.

Marcotte and LaBarba (1985) found the predicted left hemisphere dominance for speech production in their dual task paradigm test of normal hearing children, whereas more symmetrical patterns of cerebral control for speech production were found for the deaf children. The authors reject Lenneberg's (1967) progressive lateralization hypothesis in that they found left hemispheric control for speech production across age groups from three to 14 years of age. Furthermore, they suggest that the bilateral interference with finger-tapping evidenced across age groups by the deaf children supports the notion that early linguistic deprivation leads to differential cerebral organization. Results such as these must be validated across other areas of behavioural research.

Visual:Dichoptic Measures

Visual half-field or dichoptic techniques employ a technique somewhat analogous to dichotic listening. Visual stimuli (pictures, dots, words, etc.) are presented rapidly to the left and/or right visual fields. The very rapid presentation of visual stimuli should be less than the latency of saccadic eye movements (Woodworth, 1938) in order to ensure that the stimulation is restricted to one visual field and is thereby transmitted to the contralateral hemisphere of the brain (Berlucchi, 1974). The rationale for use of this behavioural measure is that differences in performance as indicated by accuracy or reaction time in the two hemifields reflect greater efficiency in the contralateral hemisphere for processing that information.

It is interesting to note that the visual dichoptic measure has now become the preferred procedure for behavioural research. Bryden (1982) acknowledges the validity of using this technique for studies of verbal laterality, indicating that using this measure "there is little doubt that verbal laterality effects are dependent at least in part on the specialized language functions of the left hemisphere". He cautions that it is difficult to ascertain how much of the effect is the "result of the functional asymmetry and how much is due to extraneous factors". Although there is some evidence that the "tasks that broadly tap visuo-spatial abilities show a right hemispheric superiority", Bryden (1982, p. 87) cautions that these effects are more elusive than the verbal laterality effects.

The visual system is also crossed, but its connecting pathways to the cortex are different from those of the auditory system. Stimuli perceived in the visual hemifields project exclusively to the contralateral hemispheres (Bryden, 1982). When the eyes are fixated on a point, all of the stimuli to the left of the fixation point excite the visual cortex in the right hemisphere and stimuli from the right visual field excite the left visual cortex (Kimura, 1973). In order to overcome the possibility of the eyes shifting, the stimulus items must be projected to the visual hemifields at speeds of less than 200 ms. (since the latency of eye movement is thought to be about 200 ms.).

Of the behavioural measures, dichotic listening and dichoptic (visual--tachistoscopic studies) have been used the most extensively, with the results from the tachistoscopic (visual) studies paralleling results of research in other areas (Bryden, 1982). The non-invasive nature of the tachistoscopic (visual) measure and its visual nature makes it an obvious choice for comparative research with deaf and hearing people. Non-invasive measures as explained by Miran and Miran (1984), are "measures which do not require surgical or biochemical interventions. They are behavioural and perceptual motor tasks. They offer less risk to human subjects and re relatively inexpensive to administer. Non-invasive methods can be used in conjunction with biological, biochemical and electroencephalographical methods" (295).

Selection and Presentation of Visual Tasks

Researchers have attempted to create visual stimuli (visual tasks) that would engage one specific hemisphere, by separating stimuli into the dichotomous theoretical constructs describing hemispheric function (Bryden, 1982). Stimuli for visual studies have been referred to and catagorized as verbal and visuospatial (Bogen & Gazzaniga, 1965). It was assumed that verbal stimuli would be processed by the L.H. and visuospatial stimuli by the R.H. However, Bryden (1982) cautions that it may be difficult to correctly catagorize all stimuli along the lines of a single dichotomy, as is evident in and music appear to be almost randomly assigned to the hemispheres. Syntax, intonation, and stress appear to be associated with L.H. functions, whereas melodic patterns and some speech perception and comprehension have been identified with R.H. function. Therefore, selection of stimuli must be carefully undertaken.

Other researchers are cautious about assigning tasks to specific hemispheres and, like Cohen (1973), suggest that the process that a particular task engages may be a more appropriate descriptor than whether the task itself appears to be verbal or non-verbal task. Cohen (1973) suggests another dichotomy for explaining the functional differences found: verbal tasks appear to be predominantly successive (or serial) processes, whereas non-verbal tasks appear to be simultaneous (or parallel) processes. Besner, Daniels, and Slade, (1982) sound similar cautions in regard to interpretation of ideographs and morphemes as right hemisphere tasks. They indicate that "it is not the direct mapping between ideographs and the morphemes of a language which yields a left visual field advantage, but associated incidental stimulus characteristics which make demands upon preprocessing operations that are carried out more efficiently in the RH" (Besner, Daniels, & Slade, 1982, p. 21).

Correct recognition of various verbal (alphabet signs, words, letters, ASL words) and visuospatial (dot enumeration, facial recognition) stimuli have been used to study hemispheric specialization in deaf individuals. Methodological problems have made comparisons of visual field effects between deaf and hearing subjects difficult. Deaf subjects often respond by signing, whereas hearing subjects responded verbally (McKeever et al., 1976; Manning et al., 1977). This difference in mode of response is important as it has been associated with altering hemifield effect (Geffen, Bradshaw, & Wallace, 1971). Furthermore, hearing and deaf subjects have not always been tested on all tasks (Phippard, 1977). Thus, careful task selection and task creation are critical to studies using visual presentation of tasks.

Visuo-spatial Tasks

Dot Enumeration

The dot localization task is considered to be a non-verbal visuo-spatial task and has shown rather consistent LVF superiority in hearing adults (Kimura, 1969; Kimura & Durnford, 1974; Levy & Reid, 1978; Boshoven et al. 1982). In a study by Neville and Bellugi (1978) comparing congenitally deaf and hearing subjects, deaf people showed an unanticipated and significant RVF advantage for the dot enumeration task, whereas hearing subjects showed the expected LVF advantage. The authors suggest that perhaps responses by the deaf subjects reflect evidence of a hemispheric asymmetry reverse to that of the hearing subjects. They reason that since they found RVF superiority for visuo-spatial tasks that would usually be associated with LVF responses in hearing subjects, it would follow that the Right Hemisphere of deaf people might be specialized for some function such as time (temporality) normally found to have RVF superiority in hearing people.

Facial Recognition

Facial recognition has been considered a LVF task as this effect has been demonstrated by numerous researchers (Rizzolatti, Umilta & Berlucchi, 1971; Pirozzolo & Rayner, 1979). It has persisted despite presentations of very different stimuli ranging from black and white photographs (Hilliard, 1973) to cartoon faces (Ley & Bryden, 1979), to stylized line drawings (Patterson & Bradshaw, 1975).

However, it appears that mode of response can alter even these consistent responses. Such an instance is reported by Geffen et al. (1971) whose subjects' manual response to faces yielded LVF effects, but vocal response produced no field effects. It may be assumed that the RVF effects of verbal response cancelled out the LVF effects of facial recognition. In another study (Phippard, 1977), deaf (manual) subjects showed no field effects in response to black and white photos of male faces. No comparable data are available on the oral deaf subjects as they did not participate in the facial recognition task in this study.

Corina (1987) compared the ability of deaf ASL signers and hearing persons to correctly identify affective (emotional) content and linguistic facial expressions. Hearing people showed better recognition of both facial expressions for the LVF presentations. Deaf people, for whom the authors note facial expressions are meaningful linguistic displays, responded with more correct RVF than LVF scores. Thus, presentation of ASL signs with the accompanying facial expressions, could alter visual field responses. A neutral expression by the signer would tend to convey little affective or linguistic information for mediating information.

Verbal Tasks

Letters

A RVF superiority has been found for letters per se (Bryden, 1965; McKeever & Gill, 1972). However, as letters become less identifiable as letters (e.g. elaborately scrolled and embellished letters), they appear to be processed more visuo-spatially. The script (font) of a particular letter or word appears to exert a strong influence on whether the letters will be processed as a left hemisphere or right hemisphere task. Some researchers (Bryden & Allard, 1976) suggest that it is the configuration of the stimulus itself which determines which hemisphere will be involved in the processing of a letter. They propose that it is the relative difficulty of the visuo-spatial versus the verbal-analytical mode of processing imposed by the stimulus which will determine whether there will be a right or left hemisphere advantage for written linguistic material.

Bryden and Allard (1976) found that letters in certain non-standard typefaces (more convoluted script) yielded a reliable LVF effect, whereas more regular typefaces resulted in the anticipated RVF superiority. Similar findings were reported in a study using visual presentations of pictorial and non-pictorial Chinese characters (letters) to Chinese subjects. Non-pictorial characters yielded the predicted RVF effect while no effect was found for the more complex picture-like characters (Nguy, Allard & Bryden, 1980).

Words

A significant RVF advantage for accuracy of identification of words presented to hearing individuals has been found by numerous researchers (Hines, 1975; McKeever, 1971; McKeever et al., 1976; Manning et al., 1977). But when words have been presented to deaf individuals either LVF responses (Tomlinson-Keasey, 1976), slight trends to RVF advantage (Manning et al., 1977) or no visual field differences (McKeever et al., 1976) have been reported.

Tomlinson-Keasey (1976) studied 42 hearing impaired children in grades three to five by presenting gothic style words tachistoscopically and found a LVF specialization. They concluded that early hearing loss precludes left hemisphere language asymmetry for deaf people because of the lack of auditory input. Bryden and Allard's (1976) findings in regard to typeface may be applicable to the interpretations of this study in that the gothic script is a non-standard typeface. It is also of concern that no hearing children were included in this study for comparative responses to the visual materials.

In a study by Boshoven et al. (1982), in which concrete picturable nouns were presented to congenitally deaf subjects, hearing subjects, and interpreters for the deaf, a significant LVF advantage was found for all three groups. The LVF finding appears to be contradictory to the findings for hearing subjects mentioned above which might be explained by the inclusion of both male and females in the subject groups. It is also possible that picturable nouns are treated more like pictures than words, thus being processed more efficiently in the right hemisphere.

Kelly and Tomlinson-Keasey (1978) conducted a very sophisticated study comparing lateralization in hearing and congenitally deaf nine and ten year old children. High and low image words and concrete and abstract pictures were presented unilaterally to each hemifield. Subjects responded manually whether or not the two stimuli presented in succession matched. Of greatest interest is the differential hemispheric lateralization. Deaf children showed greater efficiency for LVF presentations while hearing children showed RVF superiority. The deaf children outperformed the hearing in speed and overall processing efficiency. The authors suggest this LVF superiority may indicate that young deaf children tend to process all visually presented stimuli in a similar manner, perhaps using right hemisphere matching strategies.

In an attempt to determine whether the picturability of nouns might in some way trigger LVF responses, Lambert and Beaumont (1983) studied concrete and abstract nouns. They found that imageability of nouns (the association of the noun with a visual representation) does not interact with visual field.

Horizontal or Vertical Orientation. A potential difficulty associated with tachistoscopic presentation of words in the usual horizontal position is that it may result in important letter cues essential to word identification being closer to the fixation point in the RVF than in the LVF (Fudin, 1976). Bruner and O'Dowd (1958) found that the first part of a word contains the most important information required for identification of a word, the middle of a word is the next most informative section, and the end of the word is the least informative part.

In a similar study with elementary children, of increased length of array of horizontally presented letters, Butler and Miller (1979) noted that as words increased in length, the distance of the first letters from the fovea became more critical. Five-letter words presented to the LVF were less accurately identified than three-letter words presented to the same hemifield. These results seem to support Fudin's (1976) work, indicating that subjects can retain more of the features of a shorter word presented to the LVF which favors the letters at the end of the word which are closer to the fixation point.

In order to reduce a possible left to right scanning effect of horizontal presentation of words on hemifield response, some researchers have chosen the vertical presentation mode and although the RVF advantage remains, there is a reduction in accuracy which may be due to the novelty of vertical presentation (McKeever & Gill, 1972; MacKavey, Curcio & Rosen, 1975). Since the right visual field effects for vertically displayed words in the McKeever and Gill (1972) study were smaller than those obtained with horizontal words, the authors suggest that some property of horizontally aligned words enhances the RVF effect. Bryden (1970) arranged non-word approximations to English vertically which did not alter the RVF effect. At that time, Bryden concluded that the directional scanning processes did not, therefore, produce a RVF superiority. In a more recent study Bryden (1986) concludes that although first letters appear to be more important visual clues for word association in horizontal presentations, it does not follow nor would he advise that vertical presentations of words be used in their stead.

Since words in the English language are read from left to right, with rather consistence RVF effects, would the same results be found if subjects scanned from right to left? Carmon, Nachshon, and Starinsky (1976) conducted a study on scanning effect using Hebrew words which are read from right to left. They presented two and four-letter Hebrew words (read from right to left) and two and four-digit numbers (read in the opposite direction, from left to right) in horizontal orientation, both in unilateral and bilateral presentations. They found a significant RVF superiority for all these materials, irrespective of left or right scanning. The authors argue that scanning effects must be minimal since the digits and words both produced RVF superiority, even though scanned in opposite directions.

The results in the Carmon et al., (1976) study seem to concur with Bryden's (1970) findings, that it is not the direction of scanning which produces the RVF effect. In each study, with vertical orientation of words, right to left scanning or Hebrew words, left to right scanning of numbers, and left to right scanning of English words, a significant RVF superiority for all materials occurs consistently. It appears that the orientation of words for visual presentation does not alter the RVF effect, except that vertical orientation may be a more unusual respresentation of words perhaps explaining the lower RVF effect in the McKeever and Gill (1972) study.

Tomlinson-Keasey (1976) studied 42 hearing impaired children in grades three to five by presenting gothic style words tachistoscopically and found a LVF specialization. They concluded that early hearing loss precludes left hemisphere language asymmetry for deaf people because of the lack of auditory input.

Thus, in the majority of research studies, presentation of words appears to be associated with RVF responses. However, there appear to be some exceptions with regard to specific groups of people such as those who are interpreters for the deaf or are themselves deaf. The letter style or script appears to be important in terms of which hemisphere is engaged with more convoluted fonts being associated with LVF results. Horizontal presentation of words does not appear to alter responses and appears to be a more familiar representation of words than the alternative of vertical presentation which may result in unnecessary subject confusion. Words used should be of four letter length, representing a variety of parts of speech, with similar frequency of use in the English language, as established by Thorndike and Lorge (1968).

American Sign Language

Central to the question of lateralization of function in deaf people is the issue of hemispheric processing of sign language, a major mode of communication among deaf people, of which American Sign Language is the most widely used. In a review of cerebral lateralization of function (Kelly, 1978), visuo-spatial tasks appear to be associated with the right hemisphere; thus it would follow that sign language, which is received by the visual modality, may also be a right hemisphere task. Tasks associated with understanding language such as lexical decisions, syntax, phonemes, and rhythm and stress, all aspects of ASL, are all associated with the left hemisphere. Thus, it would appear that depending on how subjects respond to ASL, either hemisphere could be engaged.

Certainly American Sign Language meets the requirement of a language composed of complex grammatical codings. It has been suggested by Stokoe (1960) that the linguistic structure of American Sign Language (ASL) parallels that of spoken language. Stokoe argues that, unlike gestures, there are a finite number of visibly distinctive features which compose the signs of ASL. The evidence provided by Klima and Bellugi (1979) in their extensive studies of American Sign Language shows that ASL contains all the properties of a language. They point out that

> a study of the linguistic expression of conceptual catagory levels illustrates that ASL grammar provides not only the possibility of inventing new lexical terms, but also rules for inventing (or deriving) entire sets of terms for which discrete signs do not exist (Klima and Bellugi, 1979, p. 225).

Ross (1983) suggests that processing of signs may be carried out more efficiently in the left hemisphere as the production and comprehension of sign language relies on an analysis of signs into the distinctive features catagorized by Stokoe (1960); the analytical processing appears to be a left hemisphere task (Cohen, 1973; Kelly, 1978). Thus it would appear that the signs of ASL would be processed mainly by the left hemisphere, as is spoken English.

<u>Alphabet Letters Presented in Sign, or Fingerspelling</u>

Fingerspelling is the use of one hand for creating signs representing the letters of the alphabet. Through the distinct hand configurations representing each letter, English words and sentences can be spelled out by hand, letter by letter. Poizner (1980) suggests that the handshapes for manual alphabet which stand in one to one correspondence to letters of the English alphabet are just a more complex spatial representation of English than English orthography. This may make interpretation of cerebral asymmetries to manual stimuli difficult, since aspects of the spoken language may influence the processing of the manual alphabet. Comparing the responses of subjects to the manual alphabet with their responses to English letters he found relatively more LVF responses to the manual alphabet. If the manual alphabet is indeed mediated by aspects of the English language, especially in view of its sequential nature, expectations would be for higher RVF responses, which was the opposite of what was found.

Wallace and Corballis (1973) found differences between deaf and hearing children's recall of four and five letter word sequences. The authors noted that the hearing children relied mainly on acoustic or articulatory coding, while the deaf children made extensive use of visual coding. Within the deaf children's groups, the oral deaf and manual deaf children differed with the manual deaf making primary use of a visual code, and in addition they seem "to have resorted secondarily to a code that was probably based on fingerspelling rather than on acoustic or articulatory features" (Wallace and Corballis, 1973, p. 343).

Many researchers have included fingerspelling in their studies of deaf individuals (Wilson, 1977; Virostek and Cutting, 1979). Neither deaf nor hearing have shown field differences to fingerspelled alphabetic letters presented unilaterally (Phippard, 1977), and only slight LVF trends have been found in the bilateral condition (McKeever et al., 1976).

Virostek and Cutting (1979) conducted a sophisticated study including three groups of eight subjects each: congenitally deaf people whose first language was ASL who had two deaf parents, hearing interpreters of ASL, and hearing subjects who did not sign. Although no significant differences were found between deaf and hearing subjects, the deaf signers showed a RVF advantage for comparison of manual spelling. The authors suggest that signers' RVF advantage for alphabetical stimuli is not likely to be due to a simple naming strategy, but rather they interpreted the results in terms of left hemispheric specialization in focal or analytic processing and right hemisphere specialization in diffuse or holistic processing (Semmes, 1968).

Virostek and Cutting (1979) used Lane, Boyes-Braem, and Bellugi's (1976) analysis of distinctive features, and found on post hoc analyses significant asymmetry in favour of RVF for signed alphabetical pairs differing by one semantic feature. Non-signers showed a nearly significant LVF advantage for those stimuli differing by two features. Virostek and Cutting (1979, p. 507) suggest that "perhaps signers, attuned to the featural dimensions of defining different handshapes, were forced to adopt a more analytic strategy in detecting the minimal differences" between pairs of handshapes that are 'compact', and not 'extended', whereas nonsigners would not have the knowledge to analyze this task resorting to matching the shapes which could explain the LVF or right hemisphere advantage.

Scholes and Fischler (1979) suggest that although hemispheric asymmetry of function does not develop normally in the deaf, they do develop the analytic skills needed to deal with the structure of language. They presented pictures of objects unilaterally to 26 college-aged deaf and 9 hearing subjects. Subjects were shown either written or signed letters. They were to indicate whether the letters were in the spelling of the object's label. The more linguistically skilled deaf subjects responded better to LVF presentations paired with signed letters. Hearing subjects, who responded to letters, received higher scores for RVF presentations. Here again is an example of sweeping conclusions being drawn from comparisons of different materials: finger-spelled letters shown to the deaf subjects were compared with print letters being shown to the hearing subjects. Every subject must be tested on every task (thus using a fully crossed design) to determine whether it is some aspect of the task which is resulting in the visual field differences. Control groups for first language acquisition should be included when signed tasks are included.

Words Presented in American Sign Language

In a comparison of deaf and hearing subjects by McKeever et al. (1976), hearing subjects showed significant RVF advantage for written words presented in both the unilateral and bilateral positions; deaf subjects showed a similar significant RVF for English words presented in the unilateral position only. Hearing subjects responded with a LVF effect for both signed words and the manual alphabet presented bilaterally. Only a slight LVF trend for ASL words and letters was reported for deaf subjects in both the McKeever et al. (1976) and the Manning et al. (1977) studies. Interpretation of these data for the hearing subjects corresponds with previous findings of a RVF specialization for written English and a LVF advantage for line drawings of ASL and the manual alphabet. The authors speculate that the visual hemifield differences might have emerged for the deaf subjects if the line drawings and alphabet signs had been presented in the unilateral positions as well as bilaterally.

Unilateral presentation of ASL signs to deaf subjects has resulted in contradictory findings. Poizner et al. (1979) note significant LVF effects for signs, whereas the opposite (RVF) field effects were found in the deaf by Neville and Bellugi (1978). Hearing subjects showed greater RVF responses in a study by Lubert (1975), whereas both deaf and hearing subjects showed the LVF effect for ASL letters and words in Muendel-Atherstone and Rodda's (1982) study. They suggest that the size of finger configurations may influence visual field response.

Photographs and Line Drawings

A number of researchers (Wilson, 1977, 1983; Neville and Bellugi, 1978; Boshoven et al., 1982) have used line drawings of ASL signs rather than actual pictures of signs. The rationale sometimes cited is that line drawings cut down on the extraneous information presented which might detract from attention to the signs (Boshoven et al., 1982). These authors suggest that there is some evidence that the line drawings of signs create confusion and may be viewed as unfamiliar materials even by those subjects familiar with ASL signs. The results indicate that the degree to which subjects are familiar with tasks may influence hemifield response.

Results of studies of native Hebrew speakers learning English by Silverberg, Gordon, Pollack, and Berlin (1980) have suggested that the right hemisphere advantage occurs for unfamiliar material, whereas a left hemisphere advantage is found when the material becomes more familiar. There is support for this view from dichotic listening studies with musicians and non-musicians (Bever and Chiarello, 1974). The non-musicians received higher right hemisphere recognition scores, whereas the musicians received higher left hemisphere scores for auditory recognition of musical scores. Goldberg and Costa (1981) explain this phenomenon in terms of encodability of the stimulus. They suggest that left hemisphere performance depends on the codability of a task which is dependent on a descriptive system which in turn would make it dependent upon a language-based system.

In order to reduce the possibility of confounding results with LVF responses related to interpretation of line-drawn signs as unfamiliar materials, actual photographs of ASL signs should be used with native signing subjects. Boshoven et al. (1982) expressed the concern that information other than that represented by the signs alone may be present in the task altering the task from one of recognition of hand position and signs to one of recognition by other visual patterns included in the task. In order to minimize inclusion of visual patterns which could be used for visual cueing, one signer could be photographed for all signs, with the photographs presented in black and white only, showing as little difference in body orientation as possible. Even the expression of the signer's face must be uniform. A recent study indicates that subjects can read the affective non-verbal messages (expressions) in the signer's face (Corina, 1989). In Corina's (1989) study, two different types of facial expression, conveying affective or linguistic information, resulted in differential hemispheric asymmetries in deaf and hearing persons.

<u>Features of ASL Signs</u>

Whether the position of signs in front of the body have an influence on the laterality results has been questioned. Neville and Bellugi (1978) studied 14 congenitally deaf subjects who used ASL. They used visual presentation of 22 symmetrical signs placed in front of the torso. Symmetrical signs were used so that identical information would be presented to the retina irrespective of visual hemifield presentation. They also used 20 asymmetrical signs and counterbalanced them with their mirror images. Subjects responded in ASL. The subjects showed RVF responses in the unilateral presentation of both asymmetrical and symmetrical signs in the unilateral presentation, whereas no field responses appeared in the bilateral condition.

Poizner et al., (1979) point out that movement is an integral aspect of ASL signs and consequently must be included in an evaluation of laterality studies. In their comparison of mixed male and female hearing English speakers and deaf native signers, they found no asymmetry in the deaf groups' response to the moving sign stimuli, whereas the deaf subjects' responses to the English words (RVF) and the static ASL signs (LVF) were similar to responses by hearing subjects in other studies (McKeever et al., 1976; Poizner & Lane, 1979). There were no visual field differences between hearing and deaf subjects both of whom received higher scores in response to RVF presentations of English words. The authors conclude that the requirements of spatial processing may be a large determinent of hemispheric asymmetry.

Stokoe (1960) has analyzed the signs of ASL into three classes of functional features (cheremes or manual communication phoneme equivalents) which he feels are essential to convey meaning. They are: 1) location of sign in relation to body and head; 2) type of hand configuration used; 3) type of movement involved. If any one feature is missing or difficult to interpret, as in line drawings of ASL signs, the sign is open to misinterpretation. The major feature missing, even from photographs, is movement. However, if direction of movement can be shown with arrows, again all aspects necessary for interpretation of ASL signs are present.

Visual Presentation

Fixation Control

Studies of cerebral asymmetry using unilateral visual presentation are based on the principle that stimuli presented to the left visual hemifield (LVF) are relayed initially to the right cerebral hemisphere and that stimuli falling in the RVF are relayed initially to the left cerebral hemisphere (Cohen, 1977). LVF or RVF presentation is usually achieved by using brief presentation (200 ms. or less) of tasks. Subjects are asked to fixate a central spot or cross or report verbally a number or letter. If a subject does not fixate centrally when instructed to, stimuli will not fall in the LVF or RVF as intended; obtained data will not relate to the organization of cerebral hemispheric functions. In a recent study by McKeever and Eys (1986), results indicate that the verbal reporting of fixation digits significantly augment RVF superiority. Thus it would appear that the verbal naming of the digit may engage the left hemisphere and produce confounded results.

Exposure Time

In a summary of the presentation concerns, Bryden (1982) states that there appears to be no evidence that exposure duration has any effect as long as it is less than 200 ms. Hulme (1979) has provided evidence that it may take up to 300 ms. to initiate an eye movement when the subject does not know which visual field will be stimulated. This would be justification for unilateral presentation of tasks rather than bilateral as well as complete randomization of tasks by visual field.

Unilateral or Bilateral Mode

To date the many articles citing research on unilateral and bilateral presentation indicate no reason for choosing one over the other. However, Bryden (1982) argues for use of unilateral presentation of materials as it may provide a somewhat better fixation control than presentation of materials bilaterally. The concern remains that with unilateral and bilateral presentation of the same materials, the visual field results are found in the unilateral mode and few or no differences are found in the bilateral presentations, especially with ASL studies. Thus, perhaps the bilateral mode of presentation of ASL provides too much data in the stimulus. Data are lost in short term memory and swiftly irradicated, leaving no useful data for assimilation by the subject. It may not be possible to obtain meaningful results when deaf subjects are exposed to a bilateral presentation of ASL stimuli.

Response Mode

Using either verbal or signed responses to stimuli may affect the laterality of the response. Bryden (1982) cautions that if verbal mediation can aid in the performance of the task, it may destroy any LVF superiority. Geffen et al. (1971) recommend the use of a consistent response mode across all subjects and stimuli since response requirements may alter processing strategies. Field effects were reversed by Gazzaniga and Seamon

(1973) whose subjects visually coded words showing a LVF effect, then used a verbal rehearsal strategy which resulted in reduced RVF advantage. Springer and Deutsch (1981, p. 73) caution researchers that analysis of hemispheric differences in terms of verbal and non-verbal stimuli is inadequate; they feel that the way in which the subject deals with the stimulus is much more important than the nature of the stimulus. Corina (1989) contends that the "determinants of hemispheric specialization reside not in any one single factor but are better characterized as an interaction of stimulus content, task demands and underlying cerebral organization" (p. 22).

Bryden (1982) suggests that in order to avoid hemispheric interference from the last trial on the next trial, materials must be presented in a completely randomized presentation schedule of trials. Various researchers have tried to minimize cross modality contamination of response by having subjects write out responses or point to an array or press a lever. Phippard (1977) used a multiple choice recogniton paradigm containing the entire set of visual stimuli. After each trial, subjects pointed with the right hand only to the response card corresponding to the one just seen.

Similar response modes such as key pressing have been introduced to minimize differences incurred in studies where deaf subjects responded in ASL (Neville & Bellugi, 1978) and hearing subjects used oral report (McKeever et al., 1976; Manning et al., 1977; Poizner et al., 1979).

Reaction Time. Both reaction time and accuracy of response to the stimuli have been used as dependent variables. The rationale provided by Witelson (1977) for this behavioural measure is that differences in performance as indicated by accuracy or reaction time in the two hemifields reflect greater efficiency in the contralateral hemisphere for processing of that information.

The major reason for using reaction time as a dependent measure is that it is a continuous variable and as such allows for stronger statistical analyses. In addition, the finger movement to press a key is a good non-verbal response offering little verbal information to trigger a L.H. response (Bryden, 1982). Corina (1989) recommends the use of a reaction time measure in order to ensure that contamination from hemispheric cross-talk to response strategies may be ruled out.

Accuracy Rate. As Bryden (1982) states, the evidence indicates that accuracy scores and time measures represent the efficacy of the same cognitive process. Very few researchers have used both reaction time and accuracy in a single study (Poizner & Lane, 1979). As indicated earlier, response mode may alter the visual field effect with verbal response resulting in a RVF. Thus the argument for reaction time is that "finger movement is a good non-verbal response" (Bryden, 1982, p. 84).

In order to attend to methodological concerns, visual stimuli should be presented at 200 ms or less. All tasks should be presented in a completely randomized series with a separate randomization for each subject. In order to minimize the possible interference of verbal mediation, a manual response mode should be used, with both time to response and accuracy scores being collected so that each might be used as a basis for assessing their relationship to the visual stimulus.

Subject Selection

Sex of Subjects

Certainly as important as the issue of educational mode or language acquisiton differences is the issue of sex-related differences of the subjects. Bryden (1982) suggests that "the evidence points fairly strongly to a sex-related difference in the representation of language functions, with left-hemispheric representation of linguistic processes being less prevalent in the female than in the male" (Bryden, 1982, p. 239). Males show a greater verbal I.Q. deficit when compared with females with similar left-hemispheric lesions (McGlone, 1978). Kimura and Durnford (1974) indicate that females tend to show less robust patterns of lateralization than men. Evidence from anatomical studies indicates that not only does the left hemisphere develop later than the right hemisphere, but that hemispheric development is completed earlier in females than in males (Goldberg and Costa, 1981).

McKeever et al. (1976) anticipated that deaf individuals lacking auditory experience would exhibit visual half field asymmetry to a lesser degree than hearing subjects having auditory experiences. In fact their deaf subjects, all female undergraduates, showed minimal half field asymmetry for words and ASL stimuli as predicted when presented bilaterally, whereas a RVF advantage was noted for words presented unilaterally. The hearing subjects' responses were similar to those obtained in other studies, with significant RVF advantage for written words and LVF response to sign stimuli.

Boshoven et al. (1982) may have introduced confounding factors by their inclusion of both males and females in their study of three groups of subjects who were referred to as deaf, hearing and interpreters of the deaf. Differences occurred between the deaf and hearing subjects on the line drawings of items, with deaf subjects showing significant LVF advantage for processing drawings which was the opposite of the RVF obtained by subjects in the non-deaf groups.

The authors (Boshoven et al., 1982) indicated that subjects in the deaf group may differ from the hearing group in one or a combination of ways. They suggest that nondeaf subjects may have labeled drawings with a verbal referent while deaf subjects labeled the drawings with a nonverbal referent. Furthermore, they suggest that the LVF advantage in the deaf subjects may be due to the later age of language acquisition; the lack of language stimulation in the early years might adversely affect the ability of the left hemisphere to process language or any other information analytically. The inclusion of both sexes and the resulting overall LVF results for words and RVF for signs are findings which directly contradict the findings of most other studies using these tasks (See Summary by Poizner, 1980), and would tend to bring into question the findings and the inferences drawn by these authors.

Handedness of Subjects

Most researchers in laterality very carefully exclude left-handed subjects because they may be left or right hemisphere dominant for speech. The development of sodium amytal techniques for the assessment of speech lateralization (Wada & Rasmussen, 1960) has made it possible to obtain data on the relation between handedness and speech lateralization for their large samples of subjects. Rasmussen and Milner (1977) found that 96 per cent of right-handers and 70 per cent of left-handers show left hemispherical speech lateralization. It has been found, however, that the incidence of right hemispheric speech is much higher in the left-handers than in the right-handers and that bilateral speech representation is a characteristic almost wholly associated with left handedness. Bryden (1982) states that at present we can conclude only that left-handers are less likely to demonstrate clear cut cerebral organization than are right-handers.

Comparability of Subjects

Conflicting results have been documented in investigations of lateralization for visual linguistic materials with deaf subjects. Tomlinson-Keasey (1976) concluded that lack of audition exemplified by their deaf subjects does preclude left hemisphere language specialization, whereas others (Neville and Bellugi, 1978) interpret their findings as indicative that left hemisphere language specialization can be acquired through a visual-haptic modality. Wilson (1977) suggested that deaf subjects show less evidence of cerebral asymmetry than do hearing subjects.

However, subject variables have not been well controlled. If early language training has an effect on hemispheric specialization, then variables relating to early language acquisition must be attended to in a study of deaf people. Certainly hearing loss must be documented as well as whether the loss is pre or post lingual. Wilson's (1977) caution must be attended to in studies using deaf subjects. Following her study of deaf subjects only, she recommended that since deaf people are no more a homogeneous group than are hearing people, researchers should take care that sub groups within the deaf population be compared.

Independent studies by Meadow (1967), Brill (1969) and Ray (1970) showed that deaf children of deaf parents performed better than deaf children of hearing parents on standardized intelligence tests. These investigators attributed the superior performance of the deaf children of deaf parents to the introduction of sign language as a communication system at an early age, thus giving the children access to information in their environment.

Deaf children educated in oral programs often develop better language skills than do deaf children in the general school population. Quigley and King (in press) conducted a follow-up study of 637 former students of the Central Institute for the Deaf, the Clarke School for the Deaf, and St. Joseph's Institute for the Deaf. They found that over 60 per cent of the respondents were engaged in professional level occupations and 30.6 percent had at least a four year undergraduate college education.

It is possible that these results may be confounded in that parents who value education may also be from a higher socio-economic background and hence may be able to afford to send their children to private schools. It is pssible that better-educated parents ferret out oral programs for their children which will provide access to institutions of higher education. In the past there have been few college or university programs such as the newly accredited Gallaudet University in Washington, D.C., for students who use sign language.

Ogden (1979) suggests that selection factors such as socioeconomic status and I.Q. have often been associated with the high academic and occupational accomplishments of graduates of oral programs, thus giving credence to the posibility raised earlier of confounding variables.

A study by Schein and Delk (1974) of deaf people, irrespective of their language training (oral or manual), revealed that approximately 46 percent of the deaf population was employed within the manufacturing industry and 60 percent of all deaf persons were employed in either skilled or semiskilled trades. They also found that the income of families with deaf heads of households were lower than for families in the general population (deaf and hearing). Thus the deaf professionals trained in oral programs studied by Quigley and King (in press) represent only a small percentage of the large population of deaf people who are working. Therefore, selection of subjects should take into account socioeconomic factors to ensure comparability of groups.

Effects of Early Language Exposure

Vernon and Koh (1970, p. 536) suggest that "early manual communication markedly facilitates educational achievement and linguistic development for deaf children". Parental preference plays a large role in the kind of educational system chosen. Children of hearing parents are more likely to be given an oral education, whereas children of deaf parents who use a signed communication will most likely be educated in a similar system. A study by Kusche, Greenberg, and Garfield (1983) corroborates these findings comparing deaf children of deaf parents with deaf children with hearing parents. Early sign language acquisition and I.Q. were highly correlated, and achievement scores for the deaf children of deaf parents were higher than those of the deaf children of hearing parents.

Differences in educational achievement and intelligence test scores for deaf children have often been associated with early use of manual communiction in the families. In fact, some studies have shown that deaf children of deaf parents enter school more advanced than deaf children of hearing parents and maintain this advantage throughout their school years (Stuckless & Birch, 1966).

It has also been noted that deaf children may outperform their hearing peers on items which are sometimes referred to as "performance items" such as "Block Design" and "Picture Arrangement", two of the subtests of the Wechsler Intelligence Scale for Children-Revised (Wechsler, 974); these are items which require a manual rather than a verbal response by the subject.

Conrad and Weiskrantz (1981) compared two groups of English deaf children on three subtests of the British Ability Scale. One group had two deaf parents while the other group had two hearing parents and at least one deaf sibling. Although there were no differences between the scores of the two deaf groups on the scales, the researchers found that on two of the subtests (Block Design and Recall of Digits) the scores of both groups were far above the means for the hearing children.

Results of many studies of deaf people have shown that reading difficulties are associated with deafness, often resulting in restricted access to further education (Rodda, 1970). For this reason comparison of deaf and hearing groups, by the usual methods of either years of schooling attained or socio-economic indices, provide only partial information for comparison. Some deaf children do poorly in school, thus years of schooling per se may not measure the same thing as it does for hearing children. This information needs to be collected along with additional information in regard to the individual's abilities rather than achievements. Therefore comparability of groups must be measured in another way, such as native ability or aptitude. Thus, a nonverbl measure of aptitude could be used to ensure that groups do not differ significantly.

In order to select an appropriate matched control group for the deaf subjects Vargha-Khadem (1982) administered the Raven's Progressive Matrices to both hearing and deaf subjects. Deaf children often have difficulty with verbal tests and, as mentioned above, may outperform their hearing peers on the performance items of various tests. Vargha-Khadem selected the Raven's Progressive Matrices, a non-verbal test as a means of selecting the control group.

The Advanced Progressive Matrices Test (Raven, 1960) is an economical substitute for estimation of global nonverbal intelligence quotients with the Progressive Matrices raw scores correlating .83 (N=83) with the Full Scale Wechsler Adult Intelligence Scale I.Q. scores (Shaw, 1967).

In order to attend to the pre-school influence of mode of language acquisition, it is essential that the hearing subjects not only be fluent in ASL, but should have learned ASL as their first language like their deaf counterparts. Poizner (1980) suggests that "the clearest interpretation of cerebral asymmetries for sign language comes from presenting forms from an autonomous sign language to native signers of that language" (p. 3).

Deaf Subjects

Definition of terms and who is to be included in the group of deaf subjects may have contributed to some of the inconsistencies in the literature of asymmetry of hemisphericity in deaf subjects. Studies with deaf subjects have not attended to the multiple background factors which may have a profound effect on language development and subsequently on hemispheric specialization. Some researchers have focused entirely on deaf people who primarily use sign language (Scholes & Fischler, 1979; La Breche et al., 1977). Others have compared oral and manual subjects (Phippard, 1977). Still other researchers have included only congenitally deaf subjects (Manning et al., 1977; McKeever et al., 1976) thus avoiding the developmental issue of pre and postlingual deafness.

Kelly and Tomlinson-Keasey (1977) consider degree of hearing loss and pre or post lingual loss to be important factors contributing to language lateralization in deaf subjects. Important subject variables such as first language acquired (oral or manual), age of language acquisition, and degree of ASL skill have rarely been documented in studies of brain asymmetry. Eight congenitally deaf signers, all of whom had deaf parents and had learned ASL as their first language, were included in the Virostek and Cutting (1979) study. Boshoven et al. (1982) do mention that most of the deaf subjects in their study had acquired no language until age five and only one subject had deaf parents.

Virostek and Cutting (1979) concluded that deaf children with two deaf parents comprise only one out of 10,000 people in the U.S. It is only with this group that one can be sure that sign is the native language. Thus, although deaf subjects have generally been treated as homogeneous groups of people, it can be seen that the role of language training creates at least two separate and distinct groups.

Phippard (1977) examined the laterality of deaf subjects who used either total communication or oral commmunication. Her subjects had a hearing loss of at least 70 decibels (dB) in the better ear. She found that the deaf subjects whose communication system was oral only showed a LVF advantage for the perception of both verbal and nonverbal stimuli, while no hemifield differences were observed for those people whose communication was primarily manual. In a study of young, right-handed, deaf children by Kelly and Tomlinson-Keasey (1977) all children had hearing losses greater than 60 dB and were attending a Total Communication program. They showed a LVF preference for processing verbal and nonverbal stimuli, a finding similar to Phippard's (1977) oral group, but did not replicate her findings with the manual subjects. Perhaps children in the Total Communication program were more similar to those in Phippard's oral group than the manual group and the receipt of oral training in addition to manual, may be an indicator of greater residual hearing. Thus degree of hearing loss is a factor which also must be included in description of deaf subjects.

Hearing Subjects

Subject selection is a vital aspect of laterality research, especially in research comparing deaf and hearing subjects. Some researchers (Neville & Bellugi, 1978; Wilson, 1977) have avoided the issue by testing deaf subjects only; others have not tested the hearing and deaf subjects with the same materials (Poizner, Battison & Lane, 1979; Manning et al., 1977).

In order to overcome the concern that deaf manual subjects were more familiar with ASL signs, some researchers (Virostek & Cutting, 1979; Boshoven et al., 1982) included hearing interpreters of ASL as controls in their studies in order to test all subjects on all tasks. The hearing control group in the McKeever et al. (1976) study were not native signers; their experience with ASL ranged from one to 20 years. Few researchers have included native signers. Boshoven et al., (1982) included interpreters for the deaf as a hearing control group. In their study eight of the 12 interpreters were hearing children of deaf parents (native signers).

It is essential that the hearing subjects be not only fluent in ASL, but have learned ASL as their first language like their deaf counterparts in order to attend to the pre-school influence of mode of language acquisition. Poizner (1980) suggests that "the clearest interpretation of cerebral asymmetries for sign language comes from presenting forms from an autonomous sign language to native signers of that language" (p. 3).

If early language acquisition is the most important factor in hemispheric stimulation, then the hearing subjects who learn a signed language (e.g. ASL) as their first language would more closely approximate the deaf subjects who learned ASL as their native language. Boshoven et al. (1982) included interpreters for the deaf in their study. Eight of the 12 interpreters were raised by deaf parents and had learned ASL as their native language. Deaf subjects showed a LVF superiority for processing line drawings of objects, a finding opposite to the higher RVF scores of the hearing adults. Otherwise, laterality differences between hearing and deaf adults were nonsignificant. A significant LVF advantage for words and dots was found compared with the RVF advantage for ASL signs across all subjects, indicating similar asymmetry for deaf and hearing subjects. Results of this study certainly give credence to the notion of including subjects in both hearing and deaf groups with similar language training so that a more valid, nonconfounded comparison can be made.

Muendel-Atherstone and Rodda (1982) included 20 hearing and 20 profoundly deaf subjects in their study. Ten of the deaf subjects had learned English orally as had ten of the hearing subjects (Deaf Oral and Hearing Manual) and ten of the deaf subjects had been raised with ASL (Deaf Manual). A hearing comparison group to this group were a group of ten ASL interpreters for the deaf (Hearing Manual). Six different visual stimuli, letters, words, ASL words, ASL signs, Road signs, and ASL Iconic signs were presented unilaterally on a tachistoscope. Hearing subjects had significantly higher scores than deaf subjects for all six visual stimuli. Subjects received higher scores for LVF than RVF presentations of fingerspelled letters and ASL words with higher scores for RVF presentations of ASL idioms with Arrows and Road Signs. The authors suggest that careful attention should be paid to subject selection and educational background as some of the differences between hearing and deaf groups in this study could be attributed to educational level as many of the deaf subjects were attending vocational colleges. The authors also point out that the manual groups were not comparable in that the interpreters had learned ASL as adults unlike the Deaf Manual group.

Summary

As has been indicated, the literature is still unclear in regard to many aspects of the question of lateralization generally and hemispheric specialization for language for deaf people in particular. The theoretical question of when hemispheric lateralization occurs is crucial to the question of hemispheric specialization for language of deaf people in that language acquisition for hearing people occurs after birth, whereas auditory access to language acquisition is minimally if at all possible for deaf people. It is however, beyond the scope of this study to seek to determine when lateralization occurs.

The question is whether, given the contraditions in the literature, hemispheric performances of deaf people as indicated by responses to visual presentations of linguistic stimuli to left and right visual fields, are in fact different for hearing and deaf populations when language development conditions are similar. Although there is overwhelming evidence "that verbal laterality effects are dependent at least in part on the specialized language functions of the left hemisphere", (Bryden, 1982, p. 87), Bryden has cautioned researchers not to think in terms of single dichotomies of verbal/visuospatial characteristics.

Behavioural measures have been used extensively with results from tachistoscopic studies paralleling research in other areas. These non-invasive measures, which are behavioural rather than physiological, have been used extensively with normal populations. Great care must be taken in selection of, presentation of, and response to visual stimuli to ensure that visual stimuli are in fact processed as predicted. Use of either unilateral or bilateral presentations in the visual modality would appear to be equally acceptable, although it appears that selection of the unilateral presentation for ASL signs would reduce the conflict of competing images.

It is clear that some visually presented stimuli such as faces result in almost consistent LVF responses for hearing people with some evidence of an opposite RVF response for deaf people. Written letters and words tend to be perceived better in RVF presentations except when script becomes more unclear or convoluted, in which case LVF results are higher. Results from deaf groups have been equivocal. Concrete nouns have not been found to interact with visual field (Lambert & Beaumont, 1983). Horizontal presentation of words does not influence scores.

Responses to signed visual stimuli and signed letters have been equivocal. Rationale exists for either hemisphere to be involved. Certainly Poizner's (1980) statement that the manual alphabet signs are a spatial representation of English orthography would tend to confirm a RVF expected response to signed letters. Responses to signed ASL words have been varied. Arguments have been made and defended for both RVF and LVF responses. ASL words can be characterised as visuospatial visual stimuli thus anticipating LVF results. However, due to the complex linguistic analysis underlying comprehension of ASL, such as lexical decisions, phoneme analyses, attention to syntax, rhythm and stress, an equally convincing argument can be made for higher RVF scores. The complex findings by Bellugi et al. (1983) of deaf manual subjects who have suffered left hemisphere damage suggest that specific damage to parts of the left hemisphere may result in "selective impairment of structural layers of sign language" (p. 168). These findings raise questions in regard to the complexity of specialization for left hemispheric function which may be obscured by dichotomous reference systems such as verbal/visuospatial (Gazzaniga & Sperry, 1967) or serial/parallel (Cohen, 1973). Ross (1983) provides another view of hemispheric advantage, in her discussion of processing strategies, she suggests that "differences between deaf and hearing individuals in hemispheric advantage may be due to differences in modes of processing, rather than to differences in underlying brain organization" (p. 360).

In view of the findings in the literature, subjects included in laterality studies, whether hearing or deaf, must be carefully selected. Some of the variables which must be attended to are: sex (male), age (beyond puberty), handedness (right-handed), and with the employment of the visual laterality task, good vision is also critical. If hearing and deaf subjects are to be compared, attention should be paid to subject variables which may differentiate these groups. Important language and educational subject variables which should be considered are pre or post lingual loss of hearing, degree of hearing loss, initial mode of language acquisition, age of language acquisition, parental language, early educational program, learning ability and socioeconomic status.

Chapter 3

METHOD

The basic method used to address the study hypotheses was to present rapid visual stimuli to the RVF (left hemisphere) and LVF (right hemisphere) of hearing and deaf (oral and manual) subjects and to record accuracy of responses and times to response for each group. The methods employed in this study were developed and subsequently refined in a pilot study (Muendel-Atherstone & Rodda, 1982), which is described in Appendix 2. On the basis of that pilot study considerable attention was paid to sample selection; also, a number of visual stimuli were modified, excluded, or new ones were added, and procedures were refined.

Sample Selection

Results of the pilot study had raised cautions in regard to subject selection (Muendel-Atherstone & Rodda, 1982). In that study Interpreters were used as a comparison group with the deaf subjects who learned ASL as their first language. However, the ASL Interpreters had learned ASL after they had already acquired language. Thus in this study in order to more closely approximate the language acquisition conditions of the deaf subjects who learned ASL as their first language, hearing subjects who had learned ASL as their first language were included as the comparison group. Every attempt was made to select subjects who differed only in respect to the two main selection criteria: Hearing status (deaf/hearing) and language acquisition modality for first language learned (oral/manual). Hearing status was determined by subject responses to Hearing Scale II by Schein and Delk (1974) in Appendix 3. Language acquisition was determined by subject response to questions posed in the Background Questionnaire (Appendix 4) which related specifically to early language acquisition in the family and school.

The same procedure was followed for finding subjects for the hearing manual group as the for deaf groups. Letters were sent to organizations for the deaf, phone calls were made to colleges, and organizations for the deaf were visited. In addition, the researcher attended two major conferences for the deaf and spoke to many of the conference participants asking for volunteers. People who were contacted in turn contacted others.

Volunteers for this study contacted this researcher. Searching was concluded when this researcher felt that all contacts had been exhausted and that any further questioning or telephone calls would be counterproductive.

Subjects came from five states in the U.S.A.: Florida, Alabama, Illinois, Iowa, and New York and five provinces in Canada: British Columbia, Alberta, Saskatchewan, Ontario, and Quebec. Thirty of the subjects came from Alberta. Even within Alberta the geographical distribution of the subjects was broad with subjects from the following cities: Lethbridge, Calgary, Edmonton, Red Deer, Barhead, Burdett, Taber, and Winterburn.

Screening of Subjects

Five instruments were used to determine subject eligibility for this study and to assist with group assignment of subjects as well as to assess group comparability.

The Edinburgh Inventory. As it was essential to this study to ascertain that every subject was right-handed, this was determined first by giving each subject Oldfield's (1971) handedness questionnaire, The Edinburgh Inventory (See Appendix 5). This test is short, easily understood, and easily scored. Bryden (1977) assessed handedness of 620 men and 487 women, using both the Crovitz-Zener and Oldfield questionnaires. Results of his factor analyses revealed three factors: a primary handedness factor and two factors that are idiosyncratic to the wording of the questions. Bryden concludes that shortened versions of these two tests are both reliable and valid and show significant correlations with parental handedness. On the basis of the results of his 1977 study, Bryden recommends the use of the short forms of these tests for determining handedness.

Schein Hearing Inventory. In order to determine the severity of hearing loss of the deaf subjects, subjects were asked to fill out the Schein Hearing Inventory (Schein & Delk, 1974) which has been found to be a reliable measure of degree of hearing loss (See Appendix 3). Subjects were asked to read the scale and check the appropriate box.

Background Questionnaire. A questionnaire (See Appendix 4) was designed to gather information on a number of variables for each individual in order to assess group comparability. Data were collected on variables which have sometimes been associated with differences in achievement in studies of deaf and hearing subjects: a) age of school entry, 2) age of reading, 3) years of schooling, 4) educational program (oral/manual), 5) parental language, and 6) occupation. This information was collecte in order to determine whether the groups were comparable in terms of access to educational programs.

Subjects were given the option of filling ou. he questionnaire on their own or talking through the items with the researcher. Answers to questions regarding early schooling and early language training determined group assignment (oral or manual) of each subject.

Socioeconomic Status. In order to compare the occupational status of the subjects in the four groups of this study, the socio-economic index for occupations in Canada (Blishen, 1967) was used. Blishen's (1967) index is based on the two variables of income and education for 320 occupations taken from the 1961 census of Canada. Scores from the above scale were assigned on the basis of each subject's response to to the question about occupation on the Background Questionnaire.

Visual Assessment. All subjects reported that they had good vision either uncorrected or with the use of corrective lenses. A vision test, such as the Snellen Eye test, was not given to the subjects as the Snellen test measures visual acuity of letters of the height of those used in this study measured at a distance of three m from the subject; in this research the subjects were viewing letters presented to them from a distance of only 55 cm. On the Snellen chart 20/20 vision is determined by correctly identifying four mm high letters of the alphabet from a distance of ten feet. Subjects were identifying letters from two to three cm height from a distance of 55 cm. Subjects did not complain about the size of the words, nor did the researcher note any problems with correct identification of either letters or pictures by any subject. According to self-report, none of the subjects had any handicaps other than deafness.

Advanced Progressive Matrices Test. After the subject had complied with the above tasks, and it was ascertained that in fact he was right-handed and was suitable for inclusion in one of the four comparison groups, the subject was asked to complete the Advanced Progressive Matrices Test, Part I (Raven, 1960). When subjects had completed Part I, they were requested to continue to Part II. This test was selected as a measure of nonverbal intelligence (Orme, 1968) to determine comparability of the four groups. No individual scores are reported. Shaw (1967) has indicated that the Progressive Matrices can be used as a valuable and economical substitute for the Wechsl r Adult Intelligence Scale for estimation of global nonverbal intelligence quotients citing high (.83) correlations between the scores on the Progressive Matrices scores and the W.A.I.S. full scale scores.

For the purposes of this study it was important to establish comparability of the four groups. Since the major comparison is between hearing and deaf adults, the use of a nonverbal test was indicated. Printed instructions were given to the subject (See Appendix 6). Instructions were explained to each subject and the first question was worked through as an example with each subject. All subjects completed Part I, the short form. After the subject had completed Part I, he was asked to continue with Part II. Because the testing procedure was time consuming, some subjects were not able to complete Part II due to time constraints, frustration, or other committments. Part II was sent to these subjects, and most were returned leaving seven subjects who did not complete Part II.

Intercorrelations between results of the scores of the 33 subjects who completed both short and long forms were positive (r=.76). Mean results of the short form completed by all subjects are reported. None of the subjects received a score of five or less on Set 1, which indicates that all scores are within the range of average or above average intelligence (Raven, 1960).

Screening Procedures

Screening of subjects took place in took place in settings familiar to the deaf subjects. These facilities (convention centres, counseling offices in colleges, community centres) were essential as they were settings familiar to members of the deaf community, places they normally frequented, and places where there were people who were known to them. The facilities were equipped with TTY (teletypewriters) or similar equipment for receiving calls from deaf subjects. Of greatest importance was the fact that the researcher, who was an outsider, could be associated with a trusted organization.

Each subject was welcomed to the session. The researcher gave a general explanation regarding the nature of the research in English or in American Sign Language. Experimental instructions were in written form and were individually read by each subject. Instructions were signed to the deaf manual group by the researcher or interpreter. In each setting, locally available interpreters who worked at the college or centre, who were hired because of their signing ability, were available for ASL interpreting.

Subjects were asked to fill in the Edinburgh Inventory. Only right-handed subjects were included in this study. If a subject was left-handed, the examiner explained that only right-handed people were being included. He was thanked for his participation. If the subject was right-handed, he filled in the Schein Hearing Inventory. If the subject responded "no" to the first five items, he was included in the Deaf group.

All subjects were then requested to fill in the Background Questionnaire. In order to clearly separate subjects by mode of language acquisition, subjects gave a brief history of their acquisition of language and mode of language of instruction in school (See Appendix 4). In order to be assigned to the Oral group subjects could not have used any form of signed language previously. In order to be assigned to the Manual group, subjects must have been exposed to ASL from birth. There was no way to determine how much "oral" language the Deaf Manual group may have been exposed to. Questions in regard to hearing aid use were not asked.

Screening of subjects was a many leveled process beginning with making initial contacts with subjects to meeting subjects in the testing room. Initial contacts were made with over 100 individuals at conferences and associations of deaf people. Many subjects did not meet the initial screening criteria as they were left-handed, were not prelingually deaf, had vision difficulties, did not want to participate in the testing, could not meet during the testing session due to other commitments, or did not meet the stringent language parameters of being raised by two deaf parents who used ASL for inclusion in the two "manual" groups. At the associations and conventions for deaf people, this researcher talked to hundreds of people, asking the hearing people if they had been raised by deaf ASL signing parents, and asking deaf people if they had been born deaf. Only the people who answered "Yes" to these questions were asked if they would be interested in participating in the study. Thus the initial screening involved hundreds of people.

Final Sample Selection

The final sample consisted of 40 subjects, half of whom were prelingually deaf (on the basis of self report, See Appendix 3) and half of whom were hearing (self report of no known hearing loss). Within each group of deaf and hearing subjects, half had been raised in an oral language environment and learned language orally and half had been raised in a signing environment and learned ASL as their first language. All subjects were adult males, right-handed, had good vision, and had no other handicaps.

Hearing-Oral Group. Group 1 consisted of ten normally hearing adult males who as children learned the English language in the usual way by hearing and practicing speech with their parents, siblings, and members of the speaking/oral community. These were people who were naive of sign language. Some of these people were participating in the Canadian Government sponsored Katimavik project located in Lethbridge, Alberta. These people were from all over Canada. Other members of the group were people working in the community.

Hearing-Manual Group. Group 2 were ten hearing adults whose first language was a manual or signed communication system (in most cases, American Sign Language). These adults were raised by two deaf parents whose primary mode of communication was ASL as indicated by subject response to the Background Questionnaire. Most of these subjects mentioned that their parents and grandparents made an extra effort to ensure that they had sufficient opportunity to hear spoken language and to learn to speak English. Many subjects were able to recall visits to relatives or special concerns of grandparents or uncles and aunts who would ensure that the subject spent time with hearing/speaking people. Other subjects mentioned that learning to speak was no problem as they had older siblings with whom they spoke, or that they simply played with other children in the neighbourhood, thus acquiring spoken English in this manner. Others indicated that they had to take speech therapy in order to improve their spoken English. Therefore, although for these subjects manual communication was their primary early mode of communication, they were exposed to oral language because they could hear. No information has been gathered on either their ability to use sign language or oral speech during their formative years or at the time of testing.

Deaf-Oral Group. Group 3 were ten prelingually deaf male adults, (nine congenitally deaf and one prelingually deaf) who according to their answers to questions on the Schein Hearing Scale (finalized by Schein & Delk, 1974, Appendix 3) were within the profound range of hearing impairment for both ears. According to Schein and Delk (1974), "satisfactory results" were found when comparing scaled scores and audiological measures of respondents. In the Schein and Delk Scale scores 5 through 8 (lumped together because of the rarity of persons with this level of hearing) average 81.8 dB ISO (Schein and Delk, 1974, p. 139. The primary mode of communication for these subjects was oral speech. These subjects were asked specifically whether they had ever used sign language to which they answered "no" to be included in this group. These subjects were naive of manual signs.

Deaf-Manual Group. Group 4 consisted of ten prelingually deaf adult males (nine congenitally deaf and one prelingually), who, acc ·ding to self-report on the Schein Hearing Scale, had losses equivalent to profound hearing impairment in both ears (above 90 dB DBA). Their primary mode of communication was a manual or signed system (ASL). As with the deaf-oral group, only subjects whose hearing loss was acquired before age one were included in this group.

Final Sample Characteristics

Two way Analyses of Variance were used to determine whether there were significant differences between the subject groups, on the basis of hearing status (hearing/deaf) and mode of learning of first language (oral/manual), for a number of characteristics.

Since the six ANOVA's came from the same groups of subjects, the alpha level was set at .05 for the family of hypotheses and an alpha level of .01 was set for the individual tests, with the result that none of the variables are significant. Therefore, the four groups of subjects did not differ significantly on any of the variables collected. All subjects scored within the range of average or above intelligence on the Ravens Progressive Matrices test Part I. A summary of final sample characteristics is presented in Table 3.1.

Simple correlations for all subject groups (See appendix 7) were run for each of the above independent variables with the dependent variables of scores and times for each of the eight tasks. No significant relationships between any of the independent variables and any of the dependent variables were found. On the basis of these tests it was determined that none of the independent variables would be used as a covariate.

Study Procedures

Following the completion of the screening instruments, if a subject met all the criteria for inclusion in the study and for group assignment, the researcher continued with tachistoscopic presentation of the visual stimuli for testing the study hypotheses.

Selection of Visual Stimuli

Table 3-1: Description of Sample Characteristics by Subject Group

Characteristics	HEARING		DEAF	
	ORAL N=10	MANUAL N=10	ORAL N=10	MANUAL N=10
Actual Age				
mean	21.8	26.6	29.0	30.7
s.d.	8.2	6.0	7.9	10.4
School Entry Age				
mean	5.7	5.4	4.1	5.2
s.d.	0.7	1.0	1.7	1.4
Reading Age				
mean	5.7	5.3	6.3	6.1
s.d.	0.7	1.0	2.5	1.8
Years in School				
mean	12.5	12.6	16.3	11.2
s.d.	1.7	1.4	5.2	2.1
Highest Grade Completed				
mean	12.8	12.7	14.6	11.2
s.d.	2.0	1.5	4.0	2.0
Ravens progressive Matrices-Part I				
mean	10.9	10.4	11.0	9.0
s.d.	1.0	1.3	0.9	2.1
Socioeconomic Status				
mean	37.8	39.7	50.6	39.2
s.d.	10.1	14.6	21.4	15.1

Visual stimuli consisting of words and ASL signs and road signs were chosen for this study in order to include visual linguistic materials some of which would be very familiar to each of the two major groups of oral and manual subjects. It was felt that oral subjects would be more familiar with written language and that manual subjects would be more familiar with ASL signs. Road signs were included as pictoral language signs which would be equally familiar to both groups as all subjects possessed current drivers licenses. In this way within the hearing and deaf groups, equal numbers of subjects would be familiar with the different kinds of visual stimuli, and all subjects could be presented with all visual stimuli.

The literature also indicates that these stimuli result in left hemisphere advantage, and each of the visual stimuli included in this study can be justified from the literature, and is based on a review of the literature and results of the pilot study (Muendel-Atherstone & Rodda, 1982; Appendix 2). It is well established in the literature that print four letter words produce RVF responses. Results of the pilot study (Muendel-Atherstone & Rodda, 1982) indicated that Road Signs, and ASL Idioms with Arrows resulted in RVF responses. Results of visual presentation of fingerspelling have been equivocal. However, based on the argument that fingerspelling is simply a more complex kind of English orthography (Poizner, 1980), it was assumed that if the visual presentations were clear, responses should favor the RVF. Boshoven et al. (1982) found a RVF advantage for ASL signs for both hearing and deaf subjects.

The sign language materials used in the pilot for this study were ASL signs which were appropriate for use in North America. In contrast, Wilson (1977) had used BSL signs in her study. In addition, presentation of signs was changed from those used by Wilson (1977). She had used only line-drawings to represent British manual signs. As the pilot study was being conducted in Canada, signs from ASL were created using actual black and white photographs of an ASL signer, herself a deaf adult and teacher of the deaf. Photographs were taken of her signing three sets of materials. These were: fingerspelling letters, ASL signed words, and iconic signs (McNeill, 1985) or idioms (listed in Appendix 8) which involve hand movement. Facial expression was neutral, head and body posture was erect, with neither varying noticeably from sign to sign. Signs chosen were those which had a singular meaning and which were not easily confused with other signs.

In the pilot for this study subjects had been asked to respond to six different stimuli. On the basis of subjects' responses a number of modifications were made to these stimuli; one stimulus was excluded because print letters were too large and virtually all items were identified correctly. The five tasks retained from the pilot study formed the five major visual stimuli used in this study. Modifications to three of the major visual stimuli were created, adding three new visual stimuli. The eight stimuli included in the final study were the following and are presented visually in Figure 3-1.

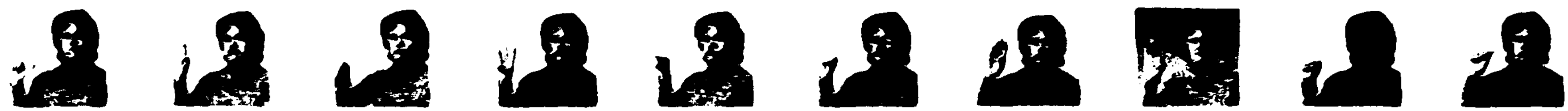
1. Lower Case Words. In order to limit imageability of nouns in the set of printed words, four-letter words consisting of a variety of parts of speech had been selected: nouns, pronouns, adjectives, prepositions, verbs and adverbs. In order to control for readability, the ten words in this set have a minimum frequency of use of 100 per million words used. The word "jump" had the highest frequency of 500 per one million words used. Frequency counts are based on data collected by Thorndike and Lorge (1968) in their study of frequency of word usage gathered to establish reading lists for school-aged children (See Appendix 8).

In the pilot for this study the lower case four letter-words produced no significant visual field differences. However, any LVF/RVF differences may have been masked in that some subjects may have matched the words by shape, producing a LVF effect, and others may have identified the words by naming, which would result in higher RVF scores. In order to determine how subjects were responding to this visual task, this task was retained for comparison and the same ten four-letter words were printed in upper case as a modification of the task.

2. Upper Case Words. This task was simply a modification of the lower case words task. For the reasons outlined above the lower case words task was replicated, using the same ten four letter words, reproduced in upper case Helvetica. Comparison of the lower and upper case materials (tasks) would determine whether subjects responded differently to the words using shape as an additional visual cue.

3. American Sign Language (ASL Words). The ASL signs used in this study were chosen which had a singular meaning and which were not easily confused with other signs. They consisted of nouns and verbs which met the criteria of frequency of use applied to all the visual stimuli (See Appendix 8). These ASL words were created by using actual black and white photographs of an ASL signer, herself a deaf adult and

Figure 3 - 1
Visual Stimuli



1. Large Fingerspelling

jump face with four blue stop mine hand have left

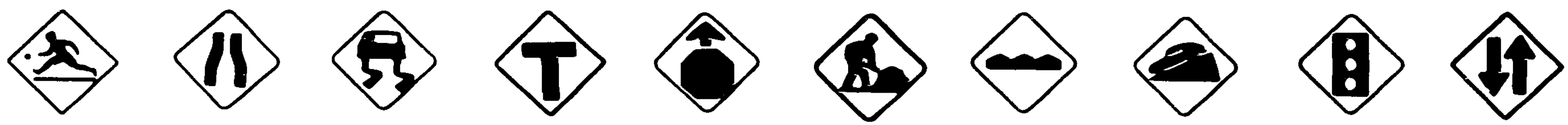
2. Lower Case Words

3. Small Fingerspelling

4. ASL Words

Visual Stimuli (continued)

5. ASL Idioms with arrows



6. Road Signs

BLUE FACE STOP WITH MINE LEFT HAVE HAND FOUR JUMP

7. Upper Case Words

8. ASL Idioms without Arrows

teacher of the deaf. Facial expression was neutral, head and body posture erect, with neither varying noticeably from sign to sign. These photographs were shown to experts on ASL to determine their clarity for this study.

4. Road Signs. Ten road signs were selected and enlarged from the Alberta driver's manual "Driver Basic License Information for all classes" published by the Alberta Solicitor General Motor Vehicle Division. Road signs were included as a visual representation of languge stimuli which would be familiar to all subjects irrespective of language experience. These ten International traffic warning signs are used throughout North America and would be just as familiar to deaf and hearing subjects as all had valid driver's licenses. These were retained from the pilot study.

5. Small Fingerspelling. In the pilot study, subjects complained that the fingerspelled letters were small and difficult to identify. Furthermore, they mentioned that they were matching not by the position of the fingers, but rather by the shading of the background of the photograph, the position of the model, the shape of the model's hair or some other cue. As these factors were kept as constant as possible, it was evident that the subjects were experiencing a great deal of frustration with this task due to the extreme difficulty of seeing the finger shapes. This task was retained for comparison in this study.

6. Large Fingerspelling. This task was simply a modification of the Small fingerspelling, with adaptations in response to subject concerns regarding size. For this reason, photographs were enlarged by fifty percent. They were changed in no other way. With cropping, the actual photograph size was identical with the other photographs with facial expression, body position, and finger configurations included in the photograph.

7. ASL Idioms with Arrows. The ASL signed materials were all photographs of a deaf professional signer, herself a teacher of the deaf. Photographs were from the waist and above. They included body posture, arm, hand finger positions, and facial expression. Although no specific questions were asked of subjects following the tests, some subjects indicated that they used the direction and position of the arrows to identify the iconic signs rather than the detail of the hand configuration of the model. Identification of the distractors by use of the directional arrows could confound the results. For this reason the same ASL idiom photographs were presented both with arrows and as explained below, without the arrows for comparison. This task was

retained for purposes of comparison. As with the other words and ASL words, the frequency of use was determined for these idioms (See Appendix 9).

8. ASL Idioms without Arrows-Modification. This task was an adaptation of the ASL Idioms with arrows. As in the previous task, subjects either could apply names to the arrows (e.g., arrow up, curved arrow, arrow right), or could match by shape and position of the arrow thus confusing whether this task was a LH or RH task. For this reason the photographs of the idioms were replicated excluding the arrows. In this way the tasks (with and without arrows) could be compared.

Color photographs were not used in this study, since the influence of color on laterality has not yet been determined. Furthermore, most of the research has been conducted with black and white photos or drawings. In all the photographs of sign language, the model was photograhed with head and shoulders and upper torso. Many of the finger configurations used for the finger spelling letters, when placed in a different position in relation to the body, convey a different meaning. An examply is the letter "Y" which becomes the word "telephone" when held near the ear. The same finger positions become the word "why" when the finger configurations begin with the dquote"A Hand" on the forehead and ends with a "Y Hand" about the level of the chin. However, when held slightly to the side of the torso, the same finger configuration is read as the letter "Y". Since finger spelling is normally seen in relation to the upper torso and head, and because of the meaning ascribed to the configuration is based on its orientation to the signer, the torso and head of the signer as well as the finger configurations were included in the photographs.

There were three kins of visual stimuli: printed words, ASL signs, and road signs. The question was whether the groups would respond to these visual stimuli similarly or differently. Three ways of representating linguistic material were chosen so as not to bias any group.

It was assumed that the printed words (2) and (7) would be language materials more familiar to the hearing and oral subjects, and that the signed materials (1), (3), (4), (5), and (8) would be language materials more familiar to subjects who had been raised with ASL as their primary mode of communication. Road signs (6) were included as a control as it was assumed that all subjects would be familiar with these signs as all subjects held valid driver's licenses.

All eight sets of visual tasks were chosen for their language content. As has been explained above, one visual task was not included in this study, so only five of the original visual stimuli from the pilot study were retained. Three stimuli which were modifications to three of the visual stimuli were added in order to validate and refine the original tasks. The ordering of the eight visual stimuli as follows was arbitrary. However, as the same order was used in the analyses and in the tables, the order of presentation and discussion of the visual stimuli will be consistent throughout this study, in the order just described.

Preparation of Visual Stimuli

All materials were dry-mounted on 23 by 31 cm. white cards covered by gloss laminating film. The 80 different stimulus cards for tachistoscopic presentation consisted of photographs (See Figure 3-1) of the eight material types (stimuli) with ten items in each group. Each stimulus card was duplicated twice, once for left visual field presentation and once for right visual field presentation with the photographs mounted four degrees to the left and right of the central fixation point respectively.

Both visual tasks, Lower Case Words and Upper Case Words were prepared in Helvetica type, in lower and upper case respectively, and were presented in a horizontal orientation. The road signs, photographs of the signed manual alphabet, and ASL words and idioms measured slightly longer than six cm (seven cm square) when the empty border around the actual meaningful part of the picture or sign was included. Size of materials was restricted by the guidelines for presentation field which have been generally established as six degrees to the left and right of fixation for unilateral presentation (Bryden, 1982).

The ASL Iconic signs included overlaid arms of the first and last positions of a sign with black arrows depicting the direction of the movements, essential to the recognition of the sign. The road signs were all enlargements of ten road signs selected from the Alberta Operators' Manual. These signs were presented as seven cm square black silhouettes in high-contrast shades of black to grey against a white background.

Presentation of Visual Stimuli

Each subject was seated in front of the tachistoscope with the multiple choice viewing board (See Appendix 10) to his right. Subjects read the instructions and were allowed five minutes to familiarize themselves with the materials. Each visual stimuli was presented for 180 msec. After the brief presentation of the stimulus, the subject looked away from the tachistoscope to the viewing board, chose one of the array of ten options and depressed a key which stopped a timer which was triggered by presentation of the visual stimulus. Both the subject's response (which was sometimes spoken, sometimes signed) and time to response were recorded.

The stimuli cards were presented by means of a Tachistoscope with two field mirrors. The illuminated preexposure field consisted of a white card with a black X in the centre, which coincided with the centre of the exposure field. The materials were presented at a distance of 22 inches (55 cm) from the subject, with a subtended angle of viewing of six degrees suggested by Bryden (1982). Before each card was presented a ready signal was given by the examiner to enable the subject to fixate on the black X. Binocular viewing was employed.

Ten practice cards were presented unilaterally (to one visual field at a time) at 180 ms. each before testing began. The precise duration of stimulus presentation was controlled by automatic electronic shutters. After each card illumination, the subject depressed the level below the picture on a viewing board that he believed corresponded to the stimulus viewed, and then to say or sign the number of the photo. Each subject sat at a two-field tachistoscopic projection booth with his forehead in a head rest 55 cm from the projection screen from which images were viewed.

Each of the 160 cards displaying one visual stimulus was presented for 180 ms. A completely randomized sequence of the 160 stimuli was presented to each subject. Each task was presented under randomly assigned conditions either left or right of fixation point. The randomized presentation of tasks was one measure taken to control for fixation so that subjects would not benefit from selective attention to one visual field. Each stimulus for each task appeared once only in each visual half field. All stimuli were presented in a different completely randomized order to each subject to minimize order effect. A random numbers generated program for 160 numbers was run on computer generating 100 different randomizations for the 160 task items. The Photographs were assigned numbers and were presented in a different random order for each of the subjects tested. The photographs were presented in a completely different randomized order for each subject so that if there were differing hemisheric effects of some of the tasks which might predispose a subsequent task to a particular hemifield, this hemispheric effect could be minimized.

Each subject was allowed five minutes to familiarize himself with the print and signed materials. The viewing board was specially designed and constructed for this study (See Appendix 10). It was constructed in such a way that a viewing window allowed viewing of only one set of visual stimuli with all ten choices to be viewed simultaneously. These photographs were reduced to fifty percent of the size of those which were presented on the screen. Immediately below each photograph or printed word was a timer switch, numbered from one to 10. When depressed, any one of the 10 timer switches would stop the timer.

The timer calibrated the time from initial presentation of stimuli to depression of one of the ten timer switches described above. Elapsed time was indicated in hundreths of seconds and in seconds. The timer was specially constructed for this study.

Following the presentation, subjects scanned the window of the viewing board for the photograph that was identical to the visual stimulus they had just seen. Subjects were shown how to depress the lever immediately below the picture they identified. They were told that this action would stop a timer. The timer was activated by the same lever that activated the light which illuminated the visual stimulus. In this way all responses were timed from onset of presentation of the visual stimulus trial to the manual response by the subject. Although the viewing board was always placed to the right of the subject, subjects varied in their use of hands to depress the lever. After a subject depressed the lever, he also gave the number of the distractor chosen. Deaf manual subjects often responded in sign as well as with voice. The examiner recorded subject responses and times to response on the answer sheet (Appendix 11). Subject response hand was not controlled.

Measures of Hemispheric Dominance

Two dependent variables served as the measures of lateral dominance: Score and Time to Response, for each of the eight stimuli Score was the number of correct responses out of a possible total of 10 correct for each task for each side (Left or Right); Time to Response was the timed response from the instant of visual presentation of the task to the instant that the subject depressed a lever indicating his selection of one of the ten photographs included in that task. Means and standard deviations of all Scores were calculated the measure of time to response was used in the calculations only when a correct response was made.

When using the dependent variables Time to Response or Response Latency (RT), Hellige and Sergent (1986) reason that if RT is used, "it is the RT of correct responses. Thus to make RT interpretable, error rates must be sufficiently low" (p. 212). If error rates are to be sufficiently low, to make response time interpretable, then clustering (benching) of scores at the ceiling is expected. Furthermore, the numerical "support" for time to response is infinite, and the scores used had this benching property. Thus the dependent variable time to response may be a more sensitive measure than the dependent variable number of correct responses.

Data Analysis Procedures

A mean Score and Time to Response for the correct responses was calculated for each of the four groups for each of the eight visual stimuli. To test the hypotheses a multivarite design was employed with the eight different visual tasks comprising the multiple variates of the study. There were three independent variables and two dependent variables which were under investigation in this study. The three factors are: (i) Hearing status (hearing/deaf); (ii) Language acquisition (oral/manual communication); (iii) Visual field: Side of stimulus presentation {Left Visual Field-Right Hemisphere (LVF-RH)/Right Visual Field-Left Hemisphere (RVF-LH)} (Table 3-3). Although these initials have been used consistently throughout the literature to differentiate hemifield from hemisphere, the inclusion of both right and left enumeration within a single descriptor appears to be confusing. Thus, for this study, and for consistency and clarity only LVF or RVF will be referred to.

A three way MANOVA with repeated measures on visual field was used for the two dependent variables, number of correct responses and time to response, for the eight visual stimuli: Large Fingerspelling; Lower Case Words; Small Fingerspelling; ASL Words; ASL Idioms with arrows; Road Signs; Upper Case Words; and ASL Idioms without Arrows (Table 3-2). Significance was determined by post-hoc Hotelling *t* test. Three separate analyses of variance with repeated measures on visual field and Task (original task compared with modified task) were used for the three pairs of tasks: a) Printed Words: Upper Case Words and Lower Case Words. b) Signed Letters: Small Fingerspelling and Large Fingerspelling. c) Signed Idioms: Signed ASL Idioms with arrows and signed ASL Idioms without arrows (Table 3-3).

Table 3-2: Design for MANOVA for all eight visual Tasks with Repeated Measures on Visual Field

Factors	Levels	Fixed/Repeated
Language Acquisition	2 (Oral/Manual)	Fixed
Hearing Status	2 (Hearing/Deaf)	Fixed
Visual Field	2 (LVF/RVF)	Repeated.

Dependent Measures: a) mean number of correct responses
b) mean time to response

for:

1. Small Fingerspelling
2. Lower Case Words
3. Large Fingerspelling
4. ASL Words
5. ASL Idioms with Arrows
6. Road Signs
7. Upper Case Words
8. ASL Idioms w/o Arrows

Table 3-3: Design for Two-Way ANOVA's with Repeated Measures on Visual Field and three Visual Tasks (original and modified)

Factors	Levels	Fixed/Repeated
Language Acquisition	2 (Oral/Manual)	Fixed
Hearing Status	2 (Hearing/Deaf)	Fixed
Visual Field	2 (LVF/RVF)	Repeated
Task	2 (Original/Modified)	Repeated

Dependent Measures: a) mean number of correct responses
b) mean time to response

for: 1) Printed words (upper/lower case)
2) Signed letters (small/large)
3) ASL Idioms (with & without Arrows)

Assumptions of Analysis of Variance

Two assumptions underlying the use of Analyses of Variance procedures are homogeneity of variance and normality of distribution. To test for homogeneity of variance, Bartlett's test was employed with the two dependent variables Score and Time to Response for the eight stimuli used in this study. Only one score for the stimulus Large Fingerspelling reached the level of significance with F=2.6 and $p<.01$. Within the group of eight visual stimuli this was the only stimulus reaching significance. Although the difference in this task was significant, it was not large and Ferguson (1981) suggests that: "moderate departures from homogeneity should not seriously affect the inferences drawn from the data" (p. 245).

However, Bartlett's test for homogeneity of variance for the dependent variable Time to Response, resulted in significance for five of the visual stimuli which were: Large Fingerspelling (F=2.26, p<.02); Small Fingerspelling (F=3.8, $p<0.01$); Road Signs (F=3.79, $p<0.01$); ASL Idioms with Arrows (F=7.13, $p=0.00$); and ASL Idioms without Arrows (F=2.38, $p=0.02$). Norusis (1985) suggests that if the data are not normally distributed then a transformation of the data might be considered. As the times to response data complied with neither of the two assumptions, homogeneity of variance or normality of distribution, log transformations of the data were conducted.

Following the log transformation, homogeneity of variance tests were carried out on the eight times to response. The only variable resulting in significant F value was (5) ALS Idioms with arrows F=(5.05: $p<.002$).

Normality of distribution was again examined by computing stem and leaf plots for each score and each transformed time to response. Scores of three of the dependent variables were clustered at the ceiling of the distribution, with subjects scoring mainly scores of 9's and 10's for the three tasks: (2) Lower Case Words, (6) Road Signs, and (7) Upper Case Words. For situations with small populations, in which a departure from normality occurs, Ferguson (1981) recommends the employment of a somewhat more rigorous level of confidence than usual. Thus for the analyses in which scores for these three tasks are included, an alpha level of .01 was used with lower levels of significance interpreted as indications of trends.

In view of previous studies (Manning et al., 1977; Poizner et al., 1979; and McKeever et al., 1976) for which it was concluded that the hearing and oral subjects score higher and more accurately in RVF than LVF presentations of linguistic materials, data in this study were subjected to an F-test to ascertain whether these findings held in the present study under these circumstances (with the separation of deaf and hearing into groups of people reared in similar language environments). Statistical results with an alpha level of less than or equal to .05 were considered significant except for interpretation of data for scores for the tasks (2), (6) and (7), for which the more conservative level of .01 was used.

Chapter 4

RESULTS

Mean LVF and RVF Scores and Times to Response were calculated for each of the four subject groups for each of the eight visual stimuli. Mean number of correct responses are presented in Table 4-1. Means for Times to Response are presented in seconds in Table 4-2. A visual inspection of Table 4-1 suggests that some of the visual stimuli failed to discriminate among groups; all four groups attained almost perfect scores for three of the visual stimuli (Lower Case Words, Road Signs, and Upper Case Words). Hearing subjects attained perfect scores and subsequently no variance for LVF presentations of Road Signs, with hearing manual subjects obtaining perfect scores for Upper Case Words.

Five of the same visual tasks used in the pilot study were included in this study for purposes of comparing responses by these subject groups. Three visual stimuli were added which were modifications of three visual stimuli used in the pilot study. One visual task was deleted based on the results of the pilot study.

Inspection of Table 4-2 indicates that mean Times to Response ranged from a low value of 2.3 for LVF presentation of Road signs to a high mean of 5.9 for LVF presentation of ASL Idioms with Arrows; both of these scores were obtained by subjects in the Hearing Oral group. As was noted in the Score means for groups, Time to Response means are closely clustered irrespective of group status for each visual stimulus. Subjects in the Deaf Manual group have consistently lower mean Times to Response for the signed materials, whether ASL or Fingerspelling visual stimuli, than the other three groups. There are no missing data.

Table 4-1: Means and Standard Deviations for Number of Correct Responses by Subject Group for Each Stimulus Presented to Left and Right Visual Hemifields

		Hearing Oral		Hearing Manual		Deaf Oral		Deaf Manual	
Visual Stimuli		LVF	RVF	LVF	RVF	LVF	RVF	LVF	RVF
Large Finger Spelling	*M*	7.0	7.2	7.1	7.7	6.0	7.7	7.6	7.7
	SD	1.9	1.9	0.6	1.0	1.8	1.6	1.9	2.3
Lower Case Words	*M*	9.5	9.8	9.9	9.9	9.8	9.7	9.5	9.8
	SD	0.7	0.4	0.3	0.3	0.6	0.7	0.5	0.4
Small Finger Spelling	*M*	6.1	6.0	7.0	7.0	5.7	6.4	5.8	6.6
	SD	1.6	0.4	0.7	1.2	0.8	1.8	1.9	1.4
ASL Words	*M*	7.7	6.4	8.0	7.3	7.7	7.1	7.7	8.1
	SD	1.3	2.0	1.4	2.1	1.6	0.7	1.5	1.7
ASL Idioms with Arrows	*M*	6.2	6.4	8.0	6.8	6.2	6.2	7.5	6.8
	SD	1.6	1.7	1.1	1.6	2.0	1.6	1.3	2.1
Road Signs	*M*	10.0	9.8	10.0	9.7	9.5	9.8	9.6	9.3
	SD	0.0	0.4	0.0	0.7	0.7	0.4	0.7	0.8
Upper Case Words	*M*	9.8	9.8	10.0	9.8	9.9	9.8	9.5	9.8
	SD	0.4	0.4	0.0	0.4	0.3	0.4	0.7	0.4
ASL Idioms w/o Arrows	*M*	6.1	6.3	7.1	7.3	6.5	6.2	7.5	6.3
	SD	1.4	1.4	1.4	1.4	1.4	1.7	1.6	2.0

Scores presented are means for all 10 subjects of each group.

Table 4-2: Times to Response* Means and Standard Deviations by Subject Groups for Each Stimulus Presented to Left and Right Visual Hemifields

		Hearing Oral		Hearing Manual		Deaf Oral		Deaf Manual	
Visual Stimuli		LVF	RVF	LVF	RVF	LVF	RVF	LVF	RVF
Large Finger Spelling	*M*	4.0	4.2	4.6	5.1	3.8	4.2	3.7	3.9
	SD	1.6	1.7	1.1	1.1	1.2	2.0	0.6	0.8
Lower Case Words	*M*	2.5	2.6	2.8	2.9	2.6	2.4	2.8	2.6
	SD	0.5	0.5	0.4	0.4	0.5	0.5	0.8	0.5
Small Finger Spelling	*M*	5.3	4.7	4.9	5.0	4.2	4.2	3.6	3.9
	SD	2.9	2.2	1.1	1.0	2.3	1.4	0.8	0.9
ASL Words	*M*	4.7	5.0	5.0	5.2	4.6	5.0	4.5	4.1
	SD	2.1	2.5	1.0	1.0	1.6	2.5	1.3	0.5
ASL Idioms with Arrows	*M*	5.9	4.8	5.1	5.0	5.4	4.7	4.4	4.4
	SD	5.0	3.6	1.0	1.2	2.2	2.5	0.9	1.1
Road Signs	*M*	2.3	2.4	2.6	2.7	2.5	2.7	2.5	2.4
	SD	0.6	0.7	0.3	0.6	0.8	1.0	0.6	0.4
Upper Case Words	*M*	2.6	2.5	2.8	2.7	2.6	2.4	2.5	2.7
	SD	0.5	0.5	0.5	0.4	0.6	0.7	0.3	0.6
ASL Idioms w/o Arrows	*M*	5.0	4.4	5.5	4.9	5.1	4.9	4.3	4.4
	SD	2.1	1.5	1.4	0.8	1.1	2.3	0.8	1.7

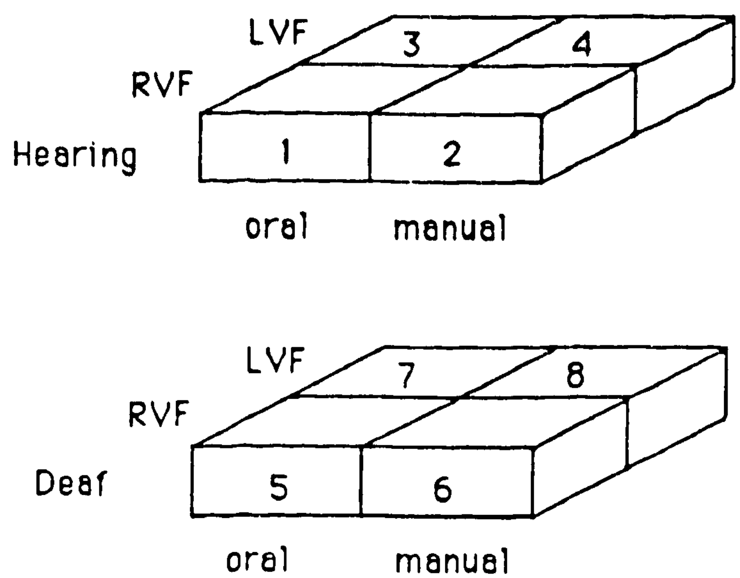
Times are presented in seconds as means for all 10 subjects.

Table 4-3: MANOVA of the Mean Number of Correct Responses to Eight Visual Stimuli by Hearing Status, Language Acquisition, with Repeated Measures on Visual Field Presentation

SOURCE	VALUE*	APPROX. *F*	*d.f.*	Sign. of *F*
Language Acquisition	.34250	1.24	8, 29	.311
Hearing Status	.33568	1.22	8, 29	.324
L.A. X H.S.	.34250	1.24	8, 29	.311
Visual Field	.57206	2.07	8, 29	.072
L.A. X V.F.	.30686	1.11	8, 29	.384
H.S. X V.F.	.37585	1.36	8, 29	.254
L.A. X H.S.X V.F.	.32268	1.17	8, 29	.350

* Hotelling's test

Figure 4-2: Contrasts for MANOVA Analyses



H1: Language Acquisition: cells (1+3+5+7) = (2+4+6+8) (oral vs. manual)
H2: Hearing Status: cells (1+2+3+4) = (5+6+7+8) (hearing vs. deaf)
H3: Visual Field: cells (1+2+5+6) = (3+4+7+8) (RVF vs. LVF)
H4: HS X LA: cells (1+3) - (5+7) = (2+4) - (6+8) (interaction)
H5: HS X VF: cells (1+2) - (5+6) = (3+4) - (7+8) (interaction)
H6: LA X VF: cells (1+5) - (2+6) = (3+7) - (4+8) (interaction)
H7: LA X HS X VF: cells (1-5) = (3-7) = (2-6) = (4-8)

Results Based on Scores

Results of the MANOVA analysis of the mean number of correct responses of the eight visual stimuli by Hearing Status by Language Acquisition, with repeated measures on Visual Field presentation are presented in Table 4-3. A three dimensional representation of the design is included in Figure 4-2. The tests conducted were as follows:

H1: Language acquisition (LA): cells (1+3+5+7) = (2+4+6+8) (Oral vs Manual)
H2: Hearing Status (HS): cells (1+2+3+4) = (5+6+7+8) (Hearing vs Deaf)
H3: Visual Field (VF): cells (1+2+5+6) = (3+4+7+8) (RVF vs LVF)
H4: HS X LA: cells (1+3)-(5+7)=(2+4)-(6+8) (interaction)
H5: HS X VF: cells (1+2)-(5+6)=(3+4)-(7+8) (interaction)
H6: LA X VF: cells (1+5)-(2+6)=(3+7)-(4+8) (interaction)
H7: LA X HS X VF: cells(1-5)=(3-7)=(2-6)=(4-8)

The interpretation of these tests is as follows:

1. There is no difference between Oral and Manual (Language Acquisition) groups.
2. There is no difference between Deaf and Hearing (Hearing Status) groups.
3. There is no difference between RVF and LVF presentations.
4. There is no Hearing Status by Language Acquisition interaction. That is there is no special combination of HS and LA which produced significant high or low scores.
5. There is no Hearing Status by Visual Field interaction. That is there is no special combination of HS and VF which produced significant high or low scores.
6. There is no Language Acquisition by Visual Field interaction. There is no special combination of LA and VF which produced signficant high or low scores.
7. There is no Language Acquisition by Hearing Status by Visual Field interaction. The distances given by these differences are all equal; that is, the plane for Hearing is parallel to the plane for Deaf.

Hearing/Deaf Differences (Objective 1, Hypothesis 1)

The first hypothesis of the study stated that Hearing (Oral and Manual) subjects would not differ significantly from the Deaf (Oral and Manual) subjects in the accuracy of correct responses to tasks presented to the right visual field.

Although the specific contrast of cells (1+2) versus (5+6) is not directly tested, the test can be inferred since no significant differences occur for any of the tests (Table 4-3);

thus cell means in the population can be considered equal. Therefore there is no Hearing Status by Visual Field interaction, and there is no special combination of Hearing Status and Visual Field which produced significant high or low scores (Table 4-3). Therefore Hypothesis 1 was accepted; Hearing (Oral and Manual) subjects did not perform differently than Deaf (Oral and Manual) subjects for either visual field presentation of materials.

Oral/Manual Differences (Objective 2, Hypotheses 2 & 3)

The second hypothesis of this study stated that Hearing (Oral) subjects would not differ significantly from the Hearing (Manual) subjects in the accuracy of correct responses to tasks presented to the right visual field.

This hypothesis is accepted since no significant differences occur for any of the tests; thus cell means in the population can be considered equal. There is no Hearing Status by Visual Field interaction, and there is no special combination of Hearing Status and Visual Field which produced significant high or low scores.

The third hypothesis of this study stated that Deaf (Oral) subjects would not differ significantly from the Deaf (Manual) subjects in the accuracy of correct responses to tasks presented to the right visual field.

This hypothesis is accepted since no significant differences occur for any of the tests; thus cell means in the population can be considered equal. Therefore there is no Hearing Status by Visual Field interaction, and there is no special combination of Hearing Status and Visual Field which produced significant high or low scores. Deaf oral subjects did not perform differently than deaf manual subjects for right visual field presentation of visual stimuli.

A trend (p=.072) toward visual field differences for the stimuli did appear, with slightly higher LVF scores overall (Table 4-3).

Results Based on Times to Response

The second three hypotheses predict that Hearing (Oral and Manual) subjects would not differ significantly from the Deaf (Oral and Manual) subjects, and that within each of the groups of Hearing and Deaf subjects, Oral subjects would not differ significantly from Manual subjects in time of response to tasks presented to the right visual field.

Results of the MANOVA tests conducted are presented in Table 4-4. A three dimensional representation of the design is included in Figure 4-2. The tests conducted were the same as those described for the results based on scores.

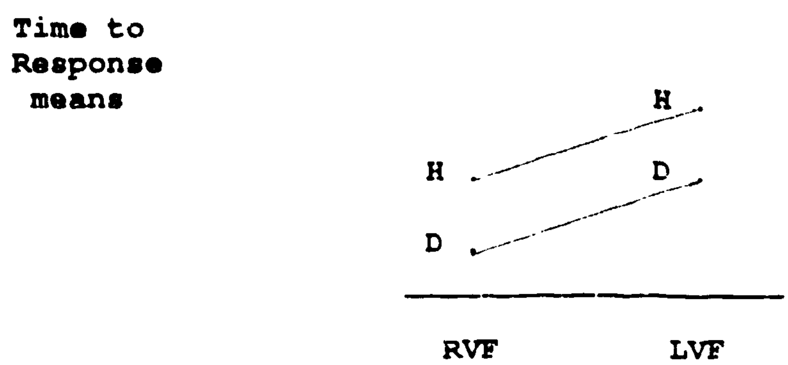
The interpretation of these tests is the same as that described in the section under results based on scores.

Table 4-4: MANOVA on Log 10 x 100 Times to Response for Eight Visual Stimuli by Hearing Status, Language Acquisition, and Visual Field Presentation

SOURCE	VALUE*	APPROX. *F*	*d.f.*	Sign. of *F*
Language Acquisition	.45098	1.63	8, 29	.158
Hearing Status	1.06574	3.86	8, 29	.003 **
L.A.X H.S.	.23447	0.85	8, 29	.568
Visual Field	.91130	3.30	8, 29	.008 **
L.A.X V.F.	.35242	1.28	8, 29	.293
H.S. X V.F.	.46435	1.68	8, 29	.145
L.A. X H.S.X V.F.	.10614	0.38	8, 29	.920

* Hotelling's test

Figure 4-3: Graphic Representation of Idealized Form of the Population based on MANOVA results of Table 4-4



H=Hearing; D=Deaf
RVF=Right Visual Field
LVF=Left Visual Field
Points indicated are the Time to Response means.

This would be the idealized form in the population based on Table 4-4.

Hearing/Deaf Differences (Objective 1, Hypothesis 4)

The fourth hypothesis of the study predicted that Hearing (Oral and Manual) subjects would not differ significantly from the Deaf (Oral and Manual) subjects, in time to response to tasks presented to the right visual field.

Table 4-4 indicates that a significant effect exists for Hearing Status (Hearing vs Deaf) and Visual Field (RVF vs LVF). Since the hypothesis of interest was that the population means for cells (1+2) = (5+6) was not tested directly, the status of this hypothesis had to be inferred from the other hypotheses tested.

In the Figure 4-3, since the interaction of HS x VF is not significant, the line between the means for RVF and LVF for the Hearing group is parallel to the line between the means for RVF and LVF for the Deaf group, indicating that the difference between the Hearing and Deaf idealized populations on the Right Visual Field is the same as the difference between the Hearing and Deaf populations for the Left Visual Field. Differences between the Hearing and Deaf groups is significant (p=.003), as are differences between Right and Left Visual Field (p=.008). If these lines were not parallel they would intersect and there would be evidence of interaction. However, none of the interactions are significant (Table 4-4). In the context of the population means the lines indicated in Figure 4-3 are parallel indicating as cited above significant differences for both Hearing Status and Visual Field. However, there are no interactions present; in particular, there is no Hearing Status by Language Acquisition (H4) interaction, neither is there a Language Acquisition by Hearing Status by Visual Field interaction (H7). Thus, it can be inferred that Hearing subjects did respond significantly differently from Deaf subjects for visual field presentation of tasks. Furthermore, visual field responses differed significantly.

However, the highly significant difference (p=.003) for Hearing Status is a reflection of the very low (fast) Time to Response means for the Deaf Manual group. The Deaf Manual group responded considerably faster with overall Times to Response (M=3.5), compared to Hearing Oral (M=3.8), Hearing Manual (M=4.2), and Deaf Oral (M=3.8). Therefore, contrary to that predicted in the fourth hypotheses, it is the deaf subjects rather than the hearing subjects, who respond faster to visual presentations of the tasks. Hearing and Deaf groups differed significantly, but the direction of the difference is the opposite of that predicted (See Table 4-4), therefore the fourth hypothesis is accepted.

Oral/Manual Differences (Objective 2, Hypothesis 5)

The fifth hypothesis stated that Hearing (Oral) subjects would not differ significantly from the Hearing (Manual) subjects in time of response to tasks presented to the right visual field.

In order to test this hypothesis and thus the contrast that the population means for cells 1 = 2 as described in Figure 4-2, a contrast was conducted, resulting in an exact F (8,29) = 1.15, p=.36 with Hearing Oral (M=3.8) and Hearing Manual (M=4.2).

Hearing Oral subjects did not respond significantly faster than or differently from Hearing Manual subjects for right visual presentation of tasks. Thus the fifth hypothesis is accepted.

Oral/Manual Differences (Objective 2, Hypothesis 6)

The final hypothesis of the study stated that Deaf (Oral) subjects would not differ significantly from the Deaf (Manual) subjects in time of response to tasks presented to the right visual field.

In order to test this hypothesis and thus the contrast that the population means for cells 5 = 6 as described in Figure 4-2, a contrast was conducted, resulting in an exact F (8,29) = 0.89, p=.53 with Deaf Oral (M=3.8) and Deaf Manual (M=3.5).

Deaf Oral subjects did not respond significantly faster than or differently from Deaf Manual subjects for right visual presentation of tasks. In fact (Table 4-2) Deaf Manual subjects responded faster to tasks presented (M=3.5) than did Deaf Oral subjects (M=3.8) which is the opposite of that which was predicted. Thus the sixth hypothesis is accepted.

Additional Analyses

Relationships between Dependent Variables

The two dependent variables Score and Time to Response have been used in this study. Bryden (1982) concludes that "rather similar effects have been reported in reaction time studies as in accuracy studies: The evidence indicates that the two procedures assess similar processes" (p. 83). In this study results for both dependent variables have been reported. However, it must be underscored that the Time to

Response notation is not a reaction time measure but is more similar to a latency measure, in that subjects' search time is also included in the Time to Response measure.

Time to response also appeared to act as a difficulty index for individual stimuli. The average time to response per stimulus (Table 4-5) ranked the eight stimuli of this study from low (fast) to high (slow) times which appeared to be along a gradient of complexity of stimulus. Low times to response were recorded for those visual stimuli which were perceptually simple and clear and were presented in black and white contrasting images: Road Signs, Large Words, and Small Words, whereas times to response of almost twice the length were recorded for those visual stimuli of more complex forms, with smaller images, and greater variations of black, white, and gray. Times to response from fastest to slowest response to visual stimuli were recorded as follows: Road signs (2.5 seconds), Upper Case Words (2.59), Lower Case Words (2.65), Large Fingerspelling (4.18), Small Fingerspelling (4.46), ASL Words (4.46), ASL Idioms Without Arrows (4.81), and ASL Idioms With Arrows (4.94).

<u>Correct and Incorrect Items</u>

Time to response was selected as a dependent variable as it was felt that subjects would respond faster to known items and slower to unknown items. In order to determine the usefulness of the inclusion of this dependent variable in this study, means Times to Response for both correct and incorrect visual stimuli were computed. A finding which emerged in the data was a difference in times to response for correct and incorrect responses with longer times to response associated with incorrect scores (Table 4-7). However, for the Deaf Manual group, the means for Times to Response scored correct and incorrect differed very little.

<u>Modifications ot Visual Stimuli</u>

Tabulation of responses to four of the more iconic signs in this group [illegible] conducted to determine whether some of the signs were so easily recognized th[illegible]imination occurred. The task item "cow" resulted in the least discriminatio[illegible] asks with subjects in three of the four groups receiving perfect scores for both left an[illegible] right visual field presentaions (Appendix 9).

Three of the visual stimuli were modified on the basis of results of the pilot study. The question raised was whether these modifications resulted in different subject responses. A full discussion of the modification of the visual stimuli and analysis is

Table 4-5: Time to Response Means for Subjects Grouped by Deaf/Hearing Status and Regrouped by Oral/Manual Status

VISUAL STIMULI		HEARING	DEAF	ORAL	MANUAL	OVERALL MEAN
6. Road	LVF	2.42	2.48	2.37	2.53	2.45
Signs	RVF	2.57	2.50	2.57	2.55	2.54
	mean	2.50	2.49	2.45	2.54	2.50
7. Upper	LVF	2.67	2.52	2.59	2.61	2.60
Case	RVF	2.59	2.56	2.45	2.71	2.58
Words	mean	2.63	2.54	2.51	2.66	2.59
2. Lower	LVF	2.67	2.70	2.57	2.80	2.69
Case	RVF	2.72	2.47	2.73	2.74	2.60
Words	mean	2.70	2.59	2.65	2.77	2.65
3. Large	LVF	4.29	3.72	3.88	4.13	4.00
Finger	RVF	4 64	4.05	4.20	4.50	4.35
Spelling	mean	4.47	3.89	4.04	4.31	4.18
1. Small	LVF	5.10	3.89	4.50	4.24	4.50
Finger	RVF	4.81	4.02	4.42	4.42	4.41
Spelling	mean	4.96	3.95	4.59	4.33	4.46
4. ASL	LVF	5.10	3.89	4.76	4.24	4.50
Words	RVF	4.81	4.20	4.40	4.42	4.42
	mean	4.96	3.96	4.59	4.33	4.46
8. ASL	LVF	5.23	4.68	5.02	4.89	4.96
Idioms	RVF	4.69	4.65	4.68	4.66	4.67
w/o	mean	4.96	4.67	4.85	4.78	4.81
arrows						
5. ASL	LVF	5.46	4.87	5.61	4.72	5.17
Idioms	RVF	4.91	4.50	4.72	4.70	4.71
With	mean	5.19	4.69	5.16	4.71	4.94
Arrows						

LVF=Left Visual Field; RVF=Right Visual Field

Table 4-6: Time to Response Means, (in Seconds), by Subject Groups for Correct and Incorrect Response to Stimuli by Visual Field Presentation

		Left Visual Field				Right Visual Field			
VISUAL Stimuli		Hearing Oral	Deaf Oral	Hearing Manual	De Manual	Hearing Oral	Deaf Oral	Hearing Manual	Deaf Manual
Large Finger Spelling	Correct	4.0	3.8	4.6	3.7	4.2	4.2	5.1	3.9
	Incorrect	5.1	5.5	5.7	3.6	5.7	5.8	6.7	4.3
Lower Case Words	Correct	2.5	2.6	2.8	2.8	2.6	2.1	2.9	2.4
	Incorrect	2.5	3.5	4.2	3.7	2.8	3.5	2.4	3.8
Small Finger Spelling	Correct	5.3	4.2	4.9	3.6	4.7	4.2	5.0	3.9
	Incorrect	5.1	5.8	6.2	4.9	4.9	6.2	6.3	4.4
ASL Words	Correct	4.7	4.7	4.9	4.5	4.9	5.0	5.1	4.2
	Incorrect	7.6	6.7	8.5	5.5	6.2	6.1	7.4	6.0
ASL Idioms w Arrows	Correct	5.8	5.4	5.1	4.4	4.8	4.6	5.0	4.4
	Incorrect	7.6	7.1	5.3	4.2	6.0	6.2	7.2	3.6
Road Signs	Correct	0.0	2.3	0.0	2.7	1.8	2.6	2.4	2.4
	Incorrect	0.0	6.1	0.0	2.6	3.3	3.3	4.7	2.1
Upper Case Words	Correct	2.5	2.2	0.0	2.4	2.5	2.2	2.5	2.8
	Incorrect	2.7	1.9	0.0	2.6	3.0	6.7	5.8	3.6
ASL Idioms w/o arrows	Correct	5.0	5.1	5.5	4.3	4.4	4.9	4.9	4.4
	Incorrect	5.8	5.8	7.3	6.0	5.7	6.3	6.2	5.6

* Incorrect Means: Based on subjects who had at least one incorrect score.

included in Appendix 12.

Four-way ANOVA analyses with repeated measures on tasks were used to compare each of the three original tasks with the modified tasks. There were no differences between subject response to the original stimulus of Lower Case Words and modified stimulus of Upper Case Words. Analyses of subject response to the two ASL Idiom tasks, one which included arrows to depict direction of motion in ASL Idioms and one without arrows also resulted in no significant differences. However, subject responses to the two fingerspelling tasks (one a photographic enlargement of the other) differed significantly on both dependent variables: Score: [$F(1,36) = 11.21$, $p<.01$ (See Appendix 12, Table 7-3)], and Time to Response: [$F(1,36) = 5.38$, $p<.05$ (See Appendix 12, Table 7-4)]. Subjects scored more correct responses with corresponding faster Time to Response for the modified stimulus, Large Fingerspelling.

Summary of Results

1. Using a MANOVA for the Scores of eight different visual stimuli with a repeated measures on visual field (left and right), no significant differences were found between the Hearing and Deaf subject groups. Results of the analysis indicate that Hearing subjects did not perform differently than deaf subjects for either visual field presentation of materials. Hearing Oral subjects did not perform better than or differently from Hearing Manual subjects for right visual field presentation of tasks. Deaf Oral subjects did not perform better than or differently from Deaf Manual subjects for right visual presentation of tasks.

No differences were found between the Oral and Manual groups. A non-significant trend ($p=.072$) toward visual field differences did appear for some of the tasks.

2. Using a MANOVA for the Times to Response of eight different visual stimuli with a repeated measure on visual field (left and right), significant differences were found for Hearing Status ($p=.003$) and Visual Field ($p=.008$). Although the results were significant for Hearing Status, the hypotheses were accepted as it was predicted that Hearing subjects would respond faster than would Deaf subjects. In fact the mean responses for Deaf subjects were faster than for Hearing subjects. Although Hearing Oral subjects responses were faster than were Hearing Manual subjects' responses, they were not significant. Deaf Manual subjects responded faster than Deaf Oral subjects, the

opposite of that hypothesized.

3. Means for Time to Response increased across the eight visual stimuli ranging from low means for perceptually simple and clear stimuli to high means for perceptually more complex stimuli.

4. As anticipated, means for Time to Response for scores incorrect were significantly higher than were means for Time to Response for correct scores. The deaf manual subjects had consistently lower (faster) mean Times to Response for the signed materials irrespective of whether their responses were correct or not.

5. In this study three of the major stimuli were modified slightly in response to the results of the pilot study to determine whether these modifications would result in differences of subject response. Four way analyses of variance (Hearing Status, Language Acquisition, Tasks, and Visual Field) of each of the three pairs of original and modified stimuli resulted in only one pair of tasks of which the modified task (enlarged version of the original task) differed significantly from the original task for scores and times to response. These tasks, Large and Small Fingerspelling tasks differed significantly in subject response to Visual Field ($p<.05$) for Scores. Significant visual field differences were found for the ASL Idioms (Time to Response) ($p>.04$; Table 7-6) and the Fingerspelling tasks (Scores) ($p>.03$; Table 7-3) indicating that these tasks are processed more effectively in the Right Visual Field (Left Hemisphere). Thus two of the visual tasks used in this study were indeed processed as predicted as linguistic or RVF tasks, one fingerspelling task and the ASL Idioms.

Chapter 5

DISCUSSION AND CONCLUSIONS

Summary of Results

1. The major hypotheses of this study that hearing subjects' responses to Right Visual Field presented stimuli would be higher than deaf subjects' responses were rejected. Hearing subjects did not perform differently than deaf subjects for visual field presentation of materials. Nor was there any evidence of a Hearing Status main effect; thus differences between the groups on the basis of Hearing Status is not evident from the analysis. No differences were found between the Deaf oral and manual groups or between the Hearing oral and manual groups.

2. MANOVA analyses of the Times to Response for the eight different visual stimuli using visual field (left and right) as the repeated measure resulted in highly significant differences for Hearing Status (p=.003) and Visual Field (p=.008). Although the results were significant for Hearing Status, the hypotheses were rejected as it was predicted that Hearing subjects would respond faster than would Deaf subjects; in fact the mean responses for Deaf subjects were faster than for Hearing subjects, in particular for subjects in the Deaf Manual group.

3. Means for Time to Response increased across the eight visual stimuli ranging from low means for perceptually simple and clear stimuli to means of twice the length for perceptually more complex stimuli.

4. As anticipated, means for Time to Response for scores incorrect were significantly higher than were means for Time to Response for correct scores.

Some inconsistencies have been noted in the correlation between the two dependent variables used in this study, in particular in relation to the deaf manual subjects who had consistently lower (faster) mean Times to Response for the signed materials irrespective of whether their responses were correct or not. In fact this group responded consistently faster on all tasks than any of the other groups. This finding raises a caution to researchers about using these two dependent variables interchangeably with certain populations.

5. In this study three of the major stimuli were modified slightly in response to the

results of a pilot study to determine whether these modifications would result in differences of subject response. Analyses of variance of each of the three pairs of original and modified stimuli resulted in only one pair which differed significantly. Large Fingerspelling and Small Fingerspelling differed significantly in subject response to Visual Field ($p>.03$).

Discussion of Non Significant Results

The results of this study for scores correct are similar to the findings of other researchers (Phippard, 1977; Poizner & Lane, 1979; Manning et al. 1977; Neville & Bellugi, 1978) who also found no significant differences between groups of deaf and hearing subjects in laterality of brain function for visual presentation of linguistic stimuli. These results suggest that auditory experience is not necessarily a prerequisite for the development of left hemisphere cerebral specialization. Where laterality differences between deaf and hearing subjects have occurred, it appears that methodological questions in regard to comparability of subject groups could be raised.

Poizner et al. (1979) found no differences in lateral asymmetry for deaf and hearing subjects' responses to projection of English words; with both groups receiving higher L. H. responses. They presented static and moving pictures of ASL signs to deaf subjects only, resulting in R.H. responses to the static signs and no asymmetry for moving signs. On the basis of these results, they concluded that ASL may be more bilaterally represented than English, even though they did not present the same ASL signs to hearing subjects whether they were naive or conversant in ASL.

In another study, Poizner and Lane (1979) devised tasks for presentation to both deaf signers and hearing non-signers, using ASL signs as well as handshapes never used in ASL. Both groups showed left visual field (hence presumably right hemisphere) advantage to the signs and non ASL signs. In this case when all stimuli are presented to all subjects (deaf and hearing) no differences between the hearing and deaf groups in hemispheric response was found.

Similarly, in the McKeever et al. (1976) study, both hearing and deaf subjects showed the expected L. H. advantage for words projected unilaterally. The hearing subjects (many of whom had as many as twenty years prior experience with ASL) showed a significant R. H. advantage for signed stimuli, whereas the hearing subjects only showed a trend in that direction. Neither the deaf nor hearing subjects were native signers. Since Silverberg et al., (1980) have documented right hemisphere advantage occurring in response to unfamiliar stimuli, and in the absence of deaf native signers in this study, it is impossible to determine whether the conclusion that ASL signs are processed as visuo-spatial tasks was warranted.

In ANOVA analyses of the two sets of ASL Idiom tasks, dicussed earlier in this study, there were no differences between Deaf and Hearing groups' responses to the tasks. However, native deaf and hearing signers were included. In this case significant visual field differences ($p>.04$) (See Table 7-6) were found for both sets of tasks (Idioms with and without arrows), for Times to Response with faster times recorded for RVF, hence Left Hemisphere responses. Thus it appears that when native signers are included in the study of ASL signed tasks, ASL signs appear to be processed as linguistic rather than as visuo-spatial tasks.

Differences in responses by college-aged deaf and hearing subjects occurred in the Scholes and Fischler (1979) study in which subjects indicated whether a letter appeared in an object's name. Deaf subjects viewing signed letters had higher correct responses to R. H. presented materials, whereas hearing subjects who viewed printed letters had higher L. H. responses. If ASL signs tend to elicit R. H. responses, but letters tend to elicit L. H. responses, then the presentation of these different tasks to these two groups has predetermined the hemifield difference of response. Since various researchers have shown that minor alterations to visual tasks can result in different visual field superiorities, without testing both deaf and hearing subjects with the same tasks, (such as hearing signing subjects with the signed letters and deaf oral subjects with the printed letters), there is no way of knowing what is the effect of the task and what is the effect of hearing loss.

Poizner (1980) had suggested that the handshapes for manual alphabet are just a more complex spatial representation of English than English orthography; thus he predicted higher RVF responses, the opposite of his findings. Virostek and Cutting (1979) compared deaf native ASL signers, hearing interpreters of ASL, and non signing hearing subjects. Although no significant differences were found between deaf and hearing subjects, the deaf signers showed a RVF advantage for the manual spelling. In this present study, the comparison of similar, although slightly modified tasks, has raised questions about which aspects of a visual task are the salient features. Certainly the highly significant differences for scores correct between the Large and Small fingerspelling tasks (p>.00) indicated that presentation size is critical to the interpretation of the task. Furthermore, in this study subjects in all four groups received significantly higher scores (p>.03,Table 7-3) for responses to RVF (Left Hemisphere) presented Large and Small fingerspelling tasks giving credence to Poizner's (1980) explanation that fingerspelling is simply a more complex spatial representation of English orthography which should therefore result in higher RVF responses.

As many methodological problems are possible in behavioural research, some of the possible sources of error in this research are discussed.

1. Ceiling effects were encountered with both Upper and Lower Case Letter tasks, making it difficult to compare LVF and RVF scores alone. However, as suggested by McKeever et al. (1986) use of the dependent variable time in conjunction with scores makes these results more interpretable. These two letter tasks meet the McKeever et al. (1986) criteria of those tasks which are perceptually simple and in which few errors occur. In fact, the higher number of correct tasks would result in the inclusion of times for more data as only times for correct scores would be included. This is, in fact, how Times to Response were calculated in this study

2. Visual tasks were presented once only to each visual field. Replication of presentation of visual tasks would allow for comparison of subject responses, as well as reducing possible influence of tasks just preceeding the one being measured. Replication of tasks would also provide greater number of scores possibly increasing the range and reducing the ceiling effect. In this study a completely different randomization of tasks was presented to each subject in order to reduce the possible influence of prior tasks on subsequent tasks. As replication would increase the length of testing time, testing could be spread over a series of sessions in order to [illegible] subject fatigue. However, in this study testing was all completed in one session in order to capitalize on subject availability.

Use of Response Time in place of Time to Response may be a preferable dependent variable as it would eliminate search time as a possible additional factor. In this study the high intercorrelations between the Times to Response indicated that the time an individual took on one task was highly correlated to his Time to Response on another task, thus indicating that each subject's search time was relatively constant.

3. One difficulty encountered in all laterality studies using tachistoscopic presentation of visual stimuli, is the variation in tasks being compared from study to study resulting from each researcher creating new stimuli. In this research actual photographs of a deaf native ASL signer were used to more closely approximate real life signs. These factors, discussed in the Literature Review, were considered when creating the photographic tasks for this study. The use of line drawings of signs with the ensuing risk of subjects relating to them as unfamiliar tasks, with subsequent bias to R. H. responses, appeared to be a less desirable alternative. The lack of task differences between the ASL idioms with and without arrows suggests that some features of a task, if perceived as irrelevant, do not interfere with hemifield response. The differemces between the Large and Small fingerspelling tasks indicate that there may be lower levels of size for which presentation of visual tasks become indiscernable, and subjects' attention is directed to other aspects of the task. In view of these findings which suggest that visual field response to tasks can be altered, further study of the specific features of fingerspelling, ASL signs, and other visual tasks would appear to be warranted.

4. Controlling spontaneous responses and hence response mode with the two deaf groups who acquired language through oral or manual means is difficult. Subjects used speech and/or signs to assist them in the identification of the stimulus on the multiple choice board. Bryden (1982) cautions that verbal mediation can destroy LVF superiority. Controlling subject spontaneous response or mental rehearsal strategy appear to be inherent problems of using both signing and oral subjects in the same study. Corina (1989) had subjects point with their nondominant hand to the visual response array, "in an attempt to discourage deaf subjects from providing a right-handed signed response which might contribute to left hemisphere activation" (p. 232). As hand responses were not controlled, response by the dominant hand could have interferred with results in this study. Alternating response hands would be one way of controlling this variable.

5. Deaf and hearing subjects raised and educated in the two predominant language acquisition modes have been compared. To further determine whether it is the task itself or experience with the task that determines laterality, hearing subjects reared in similar environments to the deaf subjects have been included. In future studies further refinements in subject selection may be possible depending on limitations of time, resources, and access to the subject populations. In this study each subject's group

assignment was made on the basis of a self-report questionnaire relying on subject memory, which is an inherent problem of retrospective studies. Other researchers may wish to consider longitudinal studies in which a full range of data could be collected specifically in regard to language acquisition and educational factors.

6. Since the subject samples were small, great care was taken in determining the comparability of the groups. With greater access to time and resources, sampling of larger segments of the populations could be undertaken.

Theoretical Implications

Coping Skills and Strategies The major contribution of this study to research on laterality is that deaf people are exposed to a wide range of visual and auditory stimuli, depending upon their education, family background, and degree of hearing and amplification. For these reasons, deaf subjects should not be treated as a homogeneous group. In the studies of laterality, the impact of deafness cannot be measured separately from the way in which language has been acquired. Thus subject selection must take into consideration language acquisition factors, educational programs, degree of hearing, and amplification.

This study proposes a possible explanation for the contradictory results found by many reearchers in this area. It is possible that the increased attention paid to visual cues in sign language fosters cognitive styles which are different from those of people who do not rely on this modality for language cues. It also appears plausible that the visual reliance on lip-reading skils for access to language may foster the development of other strategies. Some of the lip-reading strategies may overlap with those acquired by people who learn sign language; others may be similar to those of people who learn language auditorily, but the complement of strategies may differ from group to group dependent upon the degree to which individuals had to rely on the visual modality for access to language or the degree to which they had access to audition.

It is also possible that some of these cognitive styles or strategies are more predisposed to right hemisphere processing, while others are more predisposed to the left. Goldberg and Costa (1981) discuss the issue of hemispheric engagement in terms of encodability of the stimulus. They suggest that left hemisphere engagement depends on the codability of a task. Its codability depends in turn on a descriptive system which would make the task dependent upon a language-based system. Perhaps the key to which hemisphere is engaged lies in the encoding mechanism which may be determined by amount and variety of early exposure to similar stimuli.

A secondary contribution of this study is the use of actual photographs of a deaf signing model for the visual tasks. Certainly more research needs to be conducted into the actual creation of these tasks, but the use of actual photographs in place of line drawings has made the visual stimulus a more accurate representation of the visual linguisitic cue.

Lenneberg Although this study did not investigate the question of Lenneberg's (1967) "critical period" per se, some interesting points do come to light. In this study there were no significant differences between the hearing and deaf groups in terms of lateralization of language in the direction hypothesized. The deaf subjects in this study were all prelingually deaf with hearing losses in the profound range. All of the deaf subjects were attending special schools by age seven, with most of them placed in school between the ages of two and four years. Lenneberg (1967) postulated that if through lack of audition the "critical period" for language acquisition was missed, language would not develop to its potential, nor would normal lateralization occur. However, it does appear that even without audition, if the teaching of a language is introduced at an early age, irrespective of modality (oral or manual), language can be learned. Thus lateralization which is not significantly different from that in the hearing community can occur.

Lieberman All the manual subjects (both hearing and deaf) had deaf signing parents, and therefore learned a signed language system from infancy. The oral deaf subjects were also exposed to a visual language system from a very early age. Most of them were sent to special oral schools for deaf children between the ages of two and four years. The results of this study do not have limplications for Lieberman's (1975) theory that it may be the processing of complex grammatical codings (irrespective of modality of input) which may be essential to the normal development of the left hemisphere. Not enough specific data was collected in regard to the language development of the subjects as children. It is interesting that irrespective of the oral or manual language through which the deaf subjects learned language system, as adults they exemplified no significant difference from the hearing subjects in response to visual field presentation of linguistic tasks.

Arnold Results of this study would also tend to support Arnold's (1981) thesis, at least in terms of hemisphericity. Arnold (1981) suggested that the plastic brain is adaptable to using the stimulus available and can create strategies for the processing of language stimuli accordingly. Since no significant differences in lateral asymmetry were found for either groups by hearing status or language acquisition, it appears that language acquired visually can supplant an auditorily learned language. Ross (1983) concurs, postulating that "if sign languge is learned at an early age, in a naturalistic manner, it may foster the development of cerebral specialization to a greater extent than if it is learned at a later age" (p. 289).

Feedback from subjects in the pilot study (Muendel-Atherstone & Rodda, 1982) raised questions in regard to the specific features of some of the visual tasks which were then modified for use in this study. In this current study subject response to the Large and Small Fingerspelling tasks differed significantly both by scores ($p<.01$) and Time to Response ($p=.03$). It appears that the RVF advantage which would have been expected for the Small Fingerspelling was obscured by the identification difficulties presented by the small size of the stimuli. These findings correspond with those of Bentin (1980) who noted that visual field preference for stimuli will be given RH/LVF advantage if the stimuli: a) are briefly presented; b) are perceived as unrecognized script; c) are presented as hazy stimuli; or d) present other stimulus identification difficulties. Thus the degree of laterality of a stimulus can be changed by the seemingly minor modification of increased/decreased stimulus size.

These results from this study support the findings of other researchers who have documented ways in which visually presented stimuli can be altered so that shifts in visual field identification take place. Shifts from LVF to RVF have been documented to occur with practice (Hellige, 1976). Shifts in the opposite direction from RVF to LVF have been produced for unrecogniable script (Bryden & Allard, 1976), degraded stimuli (Hellige, 1976), and words presented in a second language (Neville, 1984). Although researchers have painstakingly attempted to control for these factors, the very fact that shifts in visual field are so susceptible to external factors raises the question of what is causing the shift in response from one hemisphere to the other.

Cerebral Processing Strategy

For the studies in which opposite directions of hemispheric advantage were found for deaf and hearing subjects, Ross (1983) has suggested that these might be explained in terms of differences in cerebral processing strategy rather than in terms of differences of hemisphere function. She suggests that there may simply be a greater variety of processing strategies available to those people who are raised with more than one language system. Furthermore, she contends that "it is not unlikely that deaf and hearing individuals may use different modes of processing linguistic as well as nonlinguistic material when the circumstances permit such flexibility" (p. 310).

Corina's (1989) recent study comparing deaf and hearing subjects' visual recognition of affective and linguistic expressions supports Ross' contention of flexibility of use of different modes of processing tasks. Corina (1989) found that "deaf subjects' performance was dramatically influenced by the order of the condition received. Specifically, both affective and linguistic facial expressions produced significant left visual field asymmetries when the affective facial expression condition preceded the linguistic condition"; whereas when the linguistic condition was viewed first, little visual field asymmetry was denoted for either type of facial expression (p. 235).

Pavio (1975) offers a suggestion of how the type of strategy used by subjects in response to visual stimuli is determined. He suggests that when item order is unimportant then parallel processing may be used, whereas when item order is important, serial processing may be chosen. It would appear that the type of process, imagery or verbal, that is demanded by the characteristics of the task may encourage the respective development of simultaneous and successive processing strategies.

These findings regarding different visual field response to altered and original tasks combined with the studies cited above converge to support the conclusion of Springer and Deutsch (1981) that the subject's interpretation or manner of relating to the visual presentation appeared to be a stronger determinant of which hemisphere is engaged than the artificial construction of a task to engage a particular hemisphere. Corina (1987) expanded on this concept proposing an interactive model contending that "the determinants of hemispheric specialization reside not in one single factor, but are better characterized as an interaction of stimulus content, task demands, and underlying cerebral organization" (p. 22).

The term task demands seems to imply that the features of a task will determine the way in which it will be perceived. Ross (1983) suggested that "differences between deaf and hearing individuals in hemispheric advantage may be due to differences in the mode of processing, rather than to differences in underlying brain organization" (p. 309). Different strategies may be applied to organization and interpretation of the features of a visual task than to an auditory task. These differences in organization may in turn be a function of how language has been acquired. The visual demands of a sign language, such as ASL, which demand simultaneous attention to location of the sign, hand configuration, and type of movement (Stokoe, 1966) would appear to demand very different strategies for encoding than would lipreading of a series of single word utterances. These in turn would differ from those required for encoding auditory cues. Thus conflicting results in previous studies may have arisin from confounding factors of grouping together deaf subjects, irrespective of history of language acquistion.

Practical Implications

Educational Implications The main intent of this study was to determine whether there was a visual hemifield difference between deaf and hearing adult males in the RVF processing of linguistic materials. An underlying assumption was that some of the visually presented tasks would in fact be processed as RVF tasks by the Hearing groups. Visual tasks which showed significant visual field differences favoring the RVF were the Fingerspelling tasks (for correct responses and for times to response) and the ASL Idiom tasks (Time to Response). No differences were found between the two major groups, deaf and hearing in the direction predicted.

Because few visual field differences were found for the visual tasks, the evidence is not strong enough to determine how lack of audition per se, may effect the normal development of laterality for linguistic stimuli in adult males. Whether these findings from studies using only adult males can be generalized to adult females is beyond the scope of this study. However, since studies of hemispheric processing have suggested that specialization of function in the left and right hemispheres is more strongly evident among adult males than adult females (Bryden, 1982; Goldberg and Costa, 1981; McGlone, 1978), it is possible to infer that fewer differences would be found among adult females than have been found in this study of adult males.

Levy and Reid (1978) note that atypical latralization has been associated with cognitive and perceptual deficits in hearing populations. Since deaf children have generally been found to have greater reading difficulties than their age mates, it does not necessarily follow that these are caused by a cognitive deficit. Language difficulties and hence reading and educational lags associated with early prelingual deafness may be difficult to interpret due to the variety of educational and language acquisition programs to which deaf children are commonly exposed.

Teachers do not need to be given any reason for trying every means possible to teach a deaf child the skills of language, reading, and writing. To say that the deaf child has a different pattern of lateralization than a hearing child could be interpreted as indicating that there are physiological limits to the child's ability which have been predetermined by lack of audition. Teachers might respond with unintentional lowered expectations in the teaching of a deaf child. The numbers of congenitally deaf people attending university and college, such as Gallaudet University for deaf students in Washington, D. C., are eloquent statements of the ability of deaf students.

It may be possible that some of these perceived language difficulties of deaf children may be the consequence of a mismatch between an adaptive strategy for assimilating language learned in a visuo-spatial modality and the serial order of written and spoken language. Deaf children, whether taught orally or manually, learn language, embedded within a rich visual context, through their eyes. The focus of their attention, whether a signed language or lip reading system, may influence the kinds of perceptual strategies developed. Thus, if the concept of adaptive perceptual strategies is correct, then traditional teaching methods may not facilitate learning of reading and writing for deaf children because these approaches may require strategies which may be less developed by or accessible to these children.

No differences have been found between deaf and hearing subjects in this study. Perhaps the difficulties that deaf children have in the school system may be indications of educational deficits, rather than has been suggested by some authors, as a result of functional neurological differences. If different strategies are used by deaf subjects this may indicate a development of other strategies which facilitate the learning of reading and writing. Or conversely, it may signal the need to develop curricula which are more compatable with the strategies the deaf students may be using.

Research Implications

The measurement issues concerning what constitutes evidence for cerebral dominance and laterality are still unresolved. The conclusions of this study are limited in part the inadequate criteria used for visual task and subject selection as well as inadequate control of presentation of tasks and inadeuate control of subject response to tasks. In view of these constraints, some suggestions for future research which might shed light on some of the issues are presented.

As behavioural and other measures each used in isolation are fraught with difficulties, it is recommended that in further studies with subject groups such as the four used in this study, that electrophysiological and neuroanatomical measures be used in conjunction with behavioural measures.

This study could be replicated using subject groups as described. In order to validate subjects' self-report of kinds of early schooling, school records and interviews with parents could be included. To determine whether subjects respond to the Left Visual Field as predicted, tasks usually associated with right hemisphere laterality (e.g. line orientation, facial recognition, and dot enumeration) could be included. Testing laterality of deaf people with linguistic tasks (letters and words) is problematic because it is unclear how the modality of language acquisition may influence the processing of these tasks. It is also unclear whether ASL signs are processed in the right or left hemisphere. Since the use of linguistic tasks has been compounded with the use of words or ASL signs, non-linguistic left hemisphere tasks such as calculation and rhythm (Table 2-1) could be used in their stead, thus circumventing the problem.

The possibility of strategy development which predispose individuals to hemisphere engagement for certain kinds of tasks needs to be investigated. Studies comparing hearing polyglots, who may have enhanced language processing skills, to deaf polyglots may help to determine whether L. H. processing of each is enhanced similarly.

The findings in this study that specific aspects of the visual linguistic tasks can alter hemifield response, suggest a need for more research into the lateral asymmetry of the specific features of ASL and other visual tasks. Alternately, cross-cultural studies may provide additional information about processing of visual lingusitic tasks. Nguy et al., document pictorial (Kanji) and nonpictorial (Kana) linguistic Chinese characters. Kanji characters have retained the morphological structure of Chinese characters and as such are more logographic. Comparisons of the two result in greater LVF responses for Kanji characters; whereas, Kana, is more syllabic and results in greater RVF responses (Cheng & Yang, 1989). Deaf and hearing native Chinese subjects' responses to these linguistic materials, which would appear to be predisposed to LVF and RVF processing respectively (by virtue of the more efficient lexical interpretation of character stimuli in the right hemisphere and more efficient lexical interpretation of word stimuli in the left hemisphere, Cheng & Yang, 1989), could be compared to determine which of these linguisitic tasks results in left hemisphere processing.

Discussion Summary

Results of this study indicate that deaf subjects who had early access to both oral and manual communication systems did not differ from hearing subjects in responses to RVF presented visual stimuli. If, in spite of the many limitations in this study, these results are correct, then it would be possible to assume from the literature, that their development of the left hemisphere for language is normal.

This study has questioned whether congenital profound deafness can preclude the normal development of left hemisphere involvement in the perception and mediation of linguistic materials. Correct responses by deaf subjects did not differ from those of hearing subjects reared within the same language modality whether oral or manual although deaf subjects responded significantly faster than did hearing subjects. From this evidence it would appear that, irrespective of modality, early language intervention for young congenitally deaf children is essential. It is may be that it is the early and sustained access to information through a consistent communication system which allows an individual the linguistic tools to interact with the environment

In the North American culture, which relies heavily on audition for information dissemination, whether radio, television, or classroom instruction, all of which rely heavily on talk, an implicit assumption is made that information has been received and understood simply because it has been sent. In the arrogance of sending information, we must not forget the many factors which interfere with reception and decoding information, of which deafness is only one. Other factors may be learning disabilities, emotional states, substance abuse and addiction, and illness. Certainly the development of cognitive strategies for receiving and encoding information may not only facilitate reception of sensory information but may preclude alternate reception or integration of such input. Such difficulties must not be confused with differences in underlying structures in the brain.

Further research is needed in this area to resolve the tremendous controversy in this field of study. The wide range of results confirming and denying whether deaf people differ from hearing people in hemispheric asymmetry is exemplified in the summary of laterality studies comparing deaf subjects with hearing subjects of all ages (Marcotte and La Barba, 1987). Ways in which some of the methodological problems in laterality studies could be reduced have been suggested with special emphasis placed on task and subject selection and group assignment criteria.

The use of behavioural measures in conjunction with electrophysiological and neuroanatomical measures has also been suggested. In addition, longitudinal studies of young congenitally deaf children learning language by different methods should be conducted. Additional research is needed to determine what features of visual linguistic and non-linguistic task result in hemifield differences. Comparisons of linguistic tasks which appear to be predisposed to Right or Left Visual Field differences based on their characteristics as in the case of the pictorial and non-pictorial Chinese letters might also shed light on this issue.

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Appendix 1

Glossary of Technical Terms

- American Sign Language (ASL): the system of manual sign language developed in America in the 1800's and used by a broad cross section of the adult deaf community.
- Amobarbital sodium-a seditive used for brain research with no apparent ill effects.
- Aphasia--loss or impairment of the power to use or comprehend words usually resulting from a brain lesion. Aphasic (n. or adj.)
- Auditorily--of or related to or experienced through hearing.
- Deaf group--Subjects in this study have been included if they responded "no" (self report) to the questions a through g on the Hearing Scale (Appendix 3).
- Dichaptic--relating to the two hands; sensation by the two hands.
- Dichotic--affecting or relating to the two ears differently in regard to a conscious aspect (as pitch or loudness) or a physical aspect (as frequency or energy) of sound. dichotic listening
- Dioptic--of or pertaining to sensation by the two eyes.
- Fovea--a small rodless area of the retina that affords acute vision.
- Hearing group--Subjects were included in this study if they believed that they had no hearing loss and responded "yes" (self report) to the questions a through g on the Hearing Scale (Appendix 3).
- Hemisphere: refers to the cerebral hemisphere or half of the brain: Right Hemisphere (R.H.) and Left Hemisphere (L.H.).
- Intracorotid (p.12)--injection of some fluid into the chief artery or pair of arteries that pass up the neck and supply the head.
- Hemispherectomy-surgical separation of the two cerebral hemispheres.
- Iconic: "An iconic gesture is one that in form and manner of execution exhibits a meaning relevant to the simultanesouly expressed linguistic meaning. Iconic gestures have a formal relation to the semantic context of the linguistic unit. The signifier part of the symbol is formed so as to present an image of the signified part." McNeill and Levy (1982)
- Infantile heminlegia--paralysis of one lateral half of the body or part of it resulting from injury to the motor centers of the brain in infants.
- Intracarotid-into the carotid artery which leads to the heart.
- Laterality/lateralization--localization of function or activity (as of verbal processes in the brain) on one side of the body in preference to the other
- Left Visual Field-Right Hemisphere (LVF-RH): that which is seen by the left half of each eye which is then processed by the contralateral or opposite

hemisphere, in this case the right hemisphere; thus Left Visual Field-Right Hemisphere describes this process.

- Lexical mediating strategies-strategies developed to assist in naming items.
- Manual signed system: Any system of communication which employs aspects of a signed language or gesture or finger spelling used to convey and express language.
- Manual group--Subjects were assigned to the group (Manual) .. they grew up in an environment in which American Sign Language was used as the primary language and if they were expected to communicate in ASL.
- Oral group--Subjects were assigned to the group (Oral) if they grew up in an environment in which the English language was spoken and in which they were expected to speak English.
- Polyglot--one who speaks or writes several languages.
- Propositional components of communication--an expression in language or signs of something that can be believed, doubted, or denied or is either true or false; the objective meaning of a proposition.
- Right Visual Field-Left Hemisphere (RVF-LH): describes the same scenerio on the right side of the visual field of each of the two eyes.
- Somatosensory--sensory activity originating elsewhere than in the eyes and ears and conveying information about the state of the body proper and its immediate environment.
- Temporality--of or relating to the sequence of time or to a particular time.

Appendix 2

Differences in Hemispheric Processing of Linguistic Materials in Deaf and Hearing Adults

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Paper presented at Canadian Guidance and Counselling Association,
Victoria, B.C.

June, 1982

A pilot study was conducted to serve to guide the procedures for sample selection and methodology for the major study. It replicated in part a study in which Wilson (1977) examined the relationship between hemispheric processing of sign language and print using only deaf subjects. Aspects of the McKeever et al. (1976) study were included, in particular, the comparison of hearing and deaf subjects and the testing of all subects with all tasks.

Wilson (1977) used a variety of visual tasks including both printed words and signs from British Sign Language (BSL). Her subjects were 15 male prelingually deaf adults. The four visually presented tasks were classified as print (capital letters, and four-letter words) and non print (line drawings of finger spelled letters and signed words). No visual field differences were found for any of the four tasks presented. Wilson concluded that deaf people appear to show less evidence of left hemisphere lateralization than do hearing people.

In the McKeever et al. (1976) study an attempt was made to attend to some of the subject variables by including both deaf and hearing female subjects. The hearing subjects were unique in that they all had some knowledge of ASL and could therefore be tested with the same materials as the deaf subjects. Visual stimuli included ASL line drawings of ASL signs as well as the manual alphabet, and printed words. All stimuli were presented to all subjects. RVF responses to the printed words by the hearing subjects were as predicted. Hearing subjects showed LVF superiority for signed stimuli which the authors contend indicates that these signs are processed as a visuo-spatial task. LVF scores for both printed words and signs were higher for deaf subjects than for hearing subjects, which led authors like Wilson (1977) to conclude that the deaf subjects showed a lesser degree of left hemispheric specialization for language than did the hearing subjects.

Little is known about the early language acquisition history of the deaf subjects in the McKeever et al. (1976) study other than that at the time of the study they were oral. They were compared with hearing subjects some of whom had as many as 20 years prior experience with ASL. In order to make comparisons between deaf and hearing groups, it would appear that both groups should be either native signers or have no knowledge of sign. Secondly the deaf subjects were all undergraduates which is an exceptional group within the deaf community and thus not very representative of other deaf people (Rodda, 1970). The difficulty with the McKeever et al. (1976) study as with other studies (Manning et al., 1977; Neville & Bellugi, 1978) in which deaf and hearing people are compared, is that few data are included in regard to early language background of the subjects making it difficult to ascertain whether in fact these groups are comparable. Inclusion of only females may be legitimate for comparison, but whether or not these findings hold for males appears to be questionable.

Subjects

Thus, in this study attention was given to subject selection. All subjects were right-handed adults with both male and female subjects included. Twenty subjects who were congenitally deaf were separated into two groups on the basis of modality (oral or manual) of first language learned. Ten were conversant with ASL only (deaf manual) and ten had been educated orally (deaf oral). Hearing subjects who had learned language orally (hearing oral) provided a comparison group to deaf oral subjects. They were enrolled in an introductory sign language (ASL) college course so had had some exposure to the ASL signs. Ten hearing interpreters (hearing n anual) included for their fluency in ASL, provided a counterpart to the deaf subjects who learned ASL (deaf manual) as their first language.

Pilot Visual Stimuli

The four sets of materials used by Wilson (1977) were modified and extended to six sets of materials (Figure 7-1) for this pilot study. Materials chosen were: (a) capital letters, (b) printed words of four letter length, similar to Wilson's (1977) words. In order to control for readability, the ten words in this set have a minimum frequency of use of 100 per million words used. The word "jump" had the highest frequency of 500 per one million words used. Frequency counts are based on data collected by Thorndike and Lorge (1968) in their study of frequency of word usage gathered to establish reading lists for school-aged children.

In order to limit imagability of nouns in the set of printed words, four-letter words consisting of a variety of parts of speech were selected: nouns, pronouns, adjectives, prepositions, verbs and adverbs. In addition, (c) ten road signs, actual photographs were selected from the Alberta driver's manual "Driver Basic License Information for all classes" published by the Alberta Solicitor General Motor Vehicle Division. Road signs were included as a set as it was felt that these materials would be a pictoral cue representing commonly referred to verbal commands. These ten International traffic warning signs are used throughout North America and would be just as familiar to deaf and hearing subjects [illegible] had valid driver's licenses.

The sign language materials used in the pilot study were adapted for local sign usage (ASL). In [illegible] presentation of signs was changed from those used by Wilson (1977). She had used only line-drawnings to represent British manual signs. As the pilot study was being conducted in Canada, signs from ASL were created using actual black and white photographs of an ASL signer, herself a deaf adult and teacher of the deaf. Photographs were taken of her signing the additional three sets of materials. These were: d) letters of the manual alphabet, e) signed words, and f) iconic signs (McNeill, 1985) or idioms which involve hand movement (See Figure 7-1). Facial expression was neutral, head and body posture erect, with neither varying noticeably from sign to sign. Signs chosen were those which had a singular meaning and which were not easily confused with other signs.

Procedure

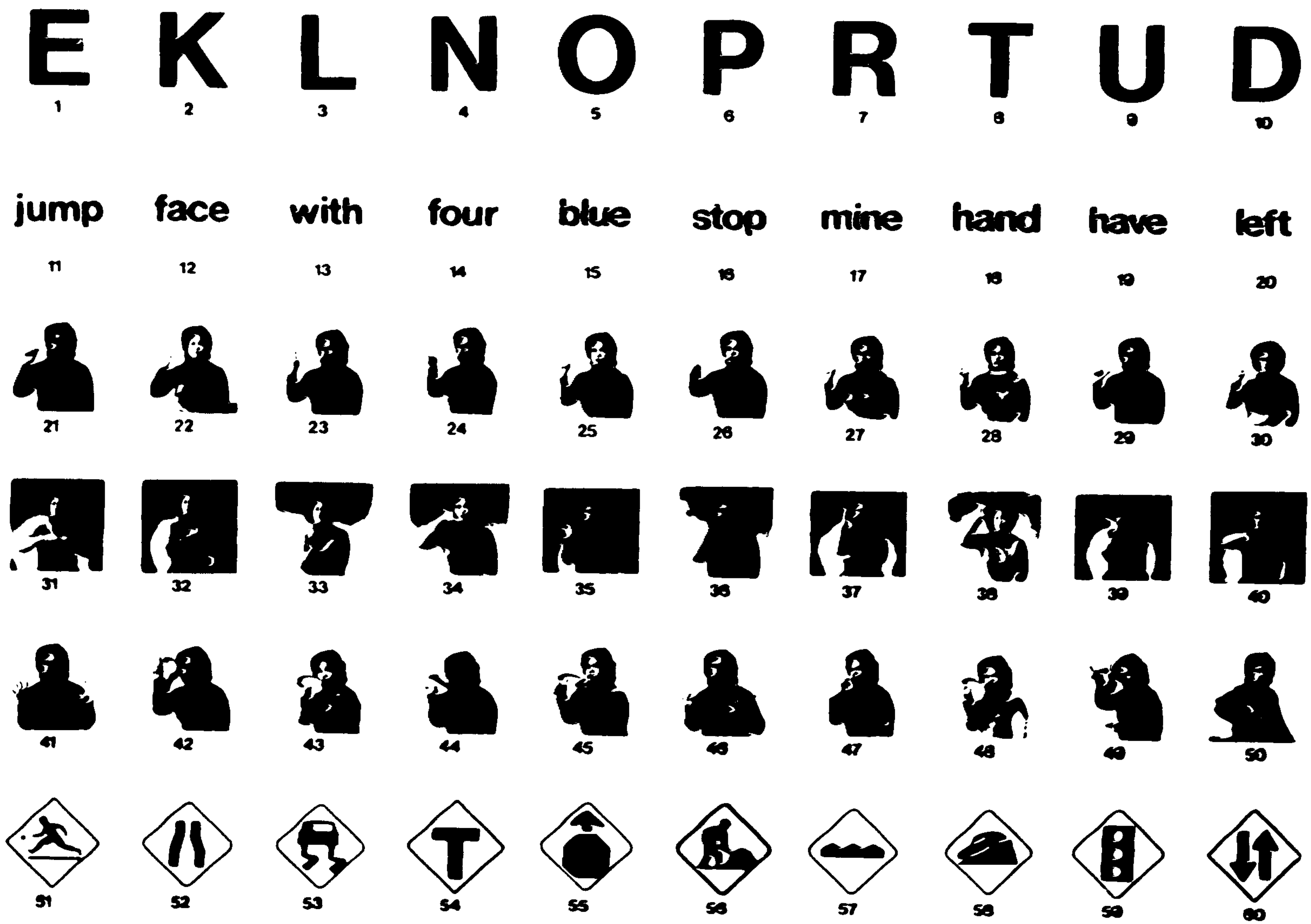
Six sets of materials of ten items each were duplicated for use in the pilot study. One set was mounted for left visual field presentation and one for right visual field presentation. The 120 pictures were completely randomized for presentation on a two-field tachistoscope to the four groups of subjects described above. Materials were presented unilaterally in a randomized sequence and each picture was presented once in each hemifield.

Results and Discussion

Results of a one-way analysis of variance with repeated measures indicated that hearing subjects scored significantly higher (p=.05) than deaf subjects on all six material types (tasks). Tasks also differed significantly with trends towards zero. In particular, subjects received higher scores for fingerspelled letters and ASL words in LVF presentation, whereas scores for the ASL idioms (with arrows) and road signs were greater in the RVF presentation. The resulting task by visual field interaction was significant (p=.04).

Differences in relation to specific tasks appeared to indicate that subjects were using different cueing systems for these tasks. The higher LVF scores for the finger-spelled letters and ASL words suggested that subjects may have been responding to these

Figure 7-1


E K L N O P R T U D
1 2 3 4 5 6 7 8 9 10
jump face with four blue stop mine hand have left
11 12 13 14 15 16 17 18 19 20
21 22 23 24 25 26 27 28 29 30
31 32 33 34 35 36 37 38 39 40
41 42 43 44 45 46 47 48 49 50
51 52 53 54 55 56 57 58 59 60

materials as a gestalt or a whole and simply performing a visual matching task. The significantly higher RVF scores for the road signs and ASL idioms could indicate that subjects were using a naming code in relation to these tasks. Thus it appeared that the visual stimuli evoked different responses from the two visual hemifield presentations. Deaf and hearing subjects responded significantly differently to the visual tasks overall, with the two hearing groups receiving higher scores.

These results raised a concern as it seemed more logical that higher scores should be received by the subjects more familiar with manual communication as a first language than the hearing group including interpreters who learned ASL as a second language. The inclusion of both female and male subjects could also account for these results. It is also possible that the groups may not have been comparable on other variables. Another interpretation is that hearing subjects may be exposed through audition to a wider range of sensory stimuli which may have resulted in the developmet of a variety of strategies which they were able to apply to these tasks.

A factor analysis of only the hearing subjects' responses resulted in four factors: signed tasks, unsigned tasks, road signs (LVF) and letters (LVF). A similar factor analysis carried out on the scores for the six sets of materials for the deaf subjects only, resulted in three factors: signed tasks, road signs, and letters. None of these resulted in visual field differences. It is of note that the first factors for both hearing and deaf groups were the ASL signs, whereas the other two factors differed considerably. In this study both hypotheses were substantiated that (a) the deaf manual subjects would show an overall reduced laterality effect, and (b) that hearing manual subjects would show bilateral effects.

Appendix 3

Hearing Scale II

Instructions: Please answer the next question the way you usually hear with both ears. If you use a hearing aid, please answer the way you hear without a hearing aid

Please circle Y for Yes, if the statement is true for you or N for No, if the statement is false for you.	CIRCLE ONE	
a. Can you usually hear and understand what a person says without seeing his face if he whispers to you from across a quiet room?	Y	N
b. Can you usually hear and understand what a person says without seeing his face if he whispers to you from across a quiet room?	Y	N
c. Can you usually hear and understand what a person says without seeing his face if he shouts to you from across a quiet room?	Y	N
d. Can you usually hear and understand a person if she speaks loudly into your better ear?	Y	N
e. Can you usually tell the sound of speech from other sounds and noises?	Y	N
f. Can you usually tell one kind of noise from another?	Y	N
g. Can you hear loud noises?	Y	N

Adapted from: Schein, J. D., & Delk, M. T. (1974). *The deaf population of the United States.* Silver Springs, MD: National Association of the Deaf.

Appendix 4

Background Questionnaire

1. Please print your name on this line____________________.

2. Address____.

3. Check one: Male__________; Female______________.

4. When were you born? Month_____Day____Year.

How old are you?__.

5. How old were you when you lost your hearing?

a)____at birth

b)____one month to 12 months

c)____13 months to 4 years

d) 5 years to 12 years

e) 13 years to 18 years

f) 19 years or older

6. What language did you first use to comunicate with your parents?

a) Ameslan/ASL

b) Finger Spelling

c) Total Communication (Signs plus oral)

d) Spoken English

e) Other________________

7. Do you still communicate in your first language? ___Yes;___NO.

8. If not, what language do you communicate in daily now?________.

9. How old were you when you first attended school? ____years old.

10.What language did you use at school? (Circle one)

a) Ameslan/ASL

b) Finger Spelling

c) Total Communication (Signs plus oral)

d) Spoken English

11.Which statement best expresses the kind of schooling you had:

CIRCLE ONE OR MORE IF APPLICABLE:

a) attended a classroom with hearing children in a public school.

b) attended a classroom with hearing children in a public school with special classes each day for the hearing impaired.

c) attended a public school in a classroom for hearing impaired.

d) attended a day program at a school for deaf children.

e) attended a residential program in a school for deaf children.

12. What grade is the highest grade that you completed?____.

13. How old were you when you learned to read?
________years old.

14. Which hand do you prefer to write with?
_____right;_____left.

15. Which hand do you prefer for sports?
________right;_____left.

16. Do you have a current drivers license?
______yes;_________no.

17. Are you supposed to wear glasses when you drive?
___yes;__no.

18. Are you presently employed?__________yes;_________no.

19. What is your present occupation?___________________.

20. If umemployed, what is your present status? (e.g. job hunting, student, homemaker)______________________________.

21. Were either of your parents deaf?_______yes;______no.

22. How did your mother communicate with you?

a) Ameslan/ASL

b) Finger Spelling

c) Total Communication (Signs plus oral)

d) Spoken English

Appendix 5

Edinburgh Handedness Inventory

Surname________________Given Names____________________

Date of Birth________________ Sex______________

Please indicate your preferences in the use of hands in the following activities by putting + in the appropriate column. Where the preference is so strong that you would never try to use the other hand unless absolutely forced to, put ++. If in any case you are really indifferent put + in both columns.

Some of the activities require both hands. In these cases the part of the task, or object, for which hand preference is wanted is indicated in brackets.

Please try to answer all the questions, and only leave a blank if you have no experience at all of the object or task.

	LEFT	RIGHT
1 WRITING		
2 DRAWING		
3 THROWING		
4. SCISSORS		
5. TOOTHBRUSH		
6. USING KNIFE WITHOUT FORK		
7. SPOON		
8. USING BROOM; POSITION OF UPPER HAND		
9. STRIKING MATCH (match)		
10. OPENING BOX; HAND ON LID		
i. Which foot do you prefer to kick with?		
ii. Which eye do you use when using only one?		

Adapted from: Oldfield, R. C. (1971). The assessment and analyses of handedness: The Edinburgh Inventory. *Neuropsychologia, 9,* 97-113.

Appendix 6

Instruction

Instructions were presented on a card to each subject.

"If you look through this machine you will see an X. soon you will see some letters, words, road signs, and some signed letters and signed words. Each word or letter comes and goes very quickly, like a flash. You will have to watch very carefully. Look at the X. After you see a letter, word, road sign or picture, please look at the display box to your right. Please press the lever below the picture that you think matches the picture you have just seen flashed on the screen. After you depress the lever, tell me or sign to me the number directly beneath the picture that you have chosen. If you are not sure which picture matches the one you have just seen, please guess. First we will practice. I will say 'ready' or tap your shoulder before I show you each picture.

First I will show you the different kinds of pictures that you will see on the screen of this viewing board. (Examiner rotates the drum, so that each of the 10 distracters in each task are visible through the rectangualar viewing window). You see, here are words, signs, and road signs. I will make sure that the picture you see is one of the pictures that is showing through the window. Do you have any questions?

We will practice now. Remember keep your head in the viewer. Look at the X. After you see a picture, find one that matches it in the window to your right. Then press the lever to stop the timer. After that tell me or sign to me the number of the picture that you have chosen. Please answer as quickly as you can. 'Ready' ".

Appendix 7

Intercorrelations of Group Characteristics, Scores and Times to Response for all eight Visual Stimuli

	Hearing Status	Learning Acquisition	IQ1	IQ2	Grade	Readage	Age	Side	YrsSchool	Score 1	Time 1
Hearing	1.0000										
Language	0.0000	1.0000									
IQ1	-0.2184	-0.4104	1.0000								
IQ2	-0.4164	-0.4487	0.7671	1.0000							
Grade	0.0166	-0.2982	0.2428	0.2049	1.0000						
Readage	0.2416	-0.0127	-0.2160	-0.2600	-0.1112	1.0000					
Age	0.3086	0.2272	-0.2349	0.0474	0.1128	-0.8601	1.0000				
Side	-0.0260	-0.0260	-0.0068	-0.0100	-0.0066	-0.0010	-0.0286	1.0000			
Yrsschool	0.1266	-0.2461	0.3214	0.2024	0.0128	-0.1270	0.1300	-0.0078	1.000		
Score 1	-0.0000	0.1611	0.0658	0.2026	-0.1620	0.1061	-0.0867	0.2161	-0.1878	1.0000	
Time 1	-0.2168	0.1028	0.0128	0.0462	0.2421	-0.1683	0.1684	0.1266	0.1464	0.0902	1.0000
Score 2	-0.0724	0.0724	0.0131	-0.0777	-0.0786	0.1419	-0.0786	0.0850	-0.1618	-0.1876	0.1804
Time 2	-0.1041	0.2380	-0.2097	-0.4492	0.0086	0.0499	-0.0777	-0.0693	-0.1197	-0.2229	0.4566
Score 3	-0.1864	0.2140	0.0412	0.1720	-0.0896	0.2404	-0.0696	0.0662	-0.0687	0.2148	-0.1861
Time 3	-0.2899	-0.0761	0.0816	0.0824	0.2080	-0.0426	0.0622	-0.0240	0.0860	-0.0922	0.7568
Score 4	0.0949	0.1739	0.1669	0.2111	0.1836	-0.0121	0.1760	-0.1661	0.2002	0.8428	0.08[illegible]
Time 4	-0.1238	-0.0823	0.0656	0.0477	0.2940	-0.0931	0.1607	0.0202	0.2880	-0.0606	0.78[illegible]
Score 5	-0.0618	0.8033	0.3194	0.0698	-0.0770	-0.0860	0.0008	-0.1610	-0.0286	0.8028	-0.0461
Time 5	-0.1006	-0.0913	0.0679	0.0404	0.1902	-0.0486	0.1060	-0.0988	0.0930	-0.1066	0.7307
Score 6	-0.2829	-0.1088	-0.0947	0.0640	0.0317	0.0866	-0.2026	-0.0983	0.0020	0.0223	0.0323
Time 6	-0.0036	0.0718	0.0242	-0.1126	0.2986	-0.0877	0.0922	0.0694	0.2920	-0.1194	0.6462
Score 7	-0.1162	-0.0681	0.1666	-0.0277	0.2099	-0.1162	-0.0718	-0.0486	0.1266	-0.0611	0.0186
Time 7	-0.0911	0.1446	-0.1718	-0.3270	0.2266	0.3023	-0.0862	0.0216	0.0409	-0.1184	0.6347
Score 8	-0.0249	0.2616	0.0894	0.1617	-0.1274	0.1446	-0.0196	-0.1168	-0.0796	0.4814	-0.1036
Time 8	-0.0968	-0.0247	0.0260	0.0976	0.3161	-0.1020	0.2848	-0.1002	0.2231	-0.0632	0.7260

	Score 2	Time 2	Score 3	Time 3	Score 4	Time 4	Score 5	Time 5	Score 6	Time 6	Score 7
Score 2	1.0000										
Time 2	0.1318	1.0000									
Score 3	0.0021	-0.2272	1.0000								
Time 3	0.3855	0.5269	-0.0658	1.0000							
Score 4	-0.0992	-0.2008	0.1128	-0.0152	1.0000						
Time 4	0.1412	0.6014	0.1810	0.7720	0.1876	1.0000					
Score 5	-0.0712	0.0022	0.1471	-0.0754	0.5160	-0.0811	1.0000				
Time 5	0.1691	0.4023	-0.1988	0.8410	0.0600	0.7762	-0.0768	1.0000			
Score 6	0.1664	0.0794	0.0126	0.2290	-0.1446	0.1157	0.0827	0.1486	1.0000		
Time 6	0.1175	0.5649	-0.2164	0.6116	0.0214	0.6264	-0.0160	0.6182	0.0641	1.0000	
Score 7	0.3692	0.0141	-0.0616	0.1784	-0.0661	0.1746	-0.0810	0.1010	0.0202	0.1066	1.0000
Time 7	0.3122	0.5618	0.0562	0.5890	-0.0658	0.4787	-0.0960	0.4628	0.0010	0.6210	0.1116
Score 8	0.0148	-0.2867	0.2802	-0.1171	0.4028	-0.1780	0.4206	-0.1710	-0.0100	-0.1766	-0.0830
Time 8	0.1080	0.4873	-0.0414	0.6060	0.0608	0.7016	-0.1262	0.6666	0.0824	0.5982	0.1206

	Time 7	Score 8	Time 8
Time 7	1.0000		
Score 8	-0.1680	1.0000	
Time 8	0.4060	-0.2181	1.0000

Code for numbers 1 to 8 for Time and Score: 1=Large Fingerspelling; 2=Lower Case Words; 3= Small Fingerspelling; 4=ASL Words; 5 ASL Idioms with Arrows; 6=Road Signs; 7=Upper Case Words; 8=ASL Idioms without Arrows. (if r >.41 then {p<.01}).

Appendix 8

List of words used and English translations of ASL words and idioms with frequency of use counts

VISUAL STIMULI	RATE	VISUAL STIMULI	RATE	VISUAL STIMULI	RATE
2/7 printed words	Freq. of use:	4 ASL words	Freq. of use:	5/8 ASL idioms	Freq. of use:
jump	AA 500	sit	AA M	finish	AA 700
face	AA M	love	AA M	what for/ why	AA
with	AA M	book	AA M	true	AA
four	AA M	telephone	A 50*	mistake	A 350
blue	AA M	three	AA 700	not/don't	AA M
step	AA M	mother	AA M	what's up	43**
mine	AA M	tree	AA M	who	AA M
hand	AA M	cow	A 700	how funny	A 288
have	AA M	sleep	AA	sick	AA 700
left	AA M	stand	AA M	late	AA M

AA=frequency of use in print in 100+/million
A=frequency of use in print of numeber indicated/million
M=500 most commonly used words in print in the English language.
* "Telephone" is included in grade 3 reading lists.
** "What's up" would be found in grade 4 reading lists,
See Figure 7-1 for photographs.
Criteria for inclusion were words used in grade 4 or below. Frequency of use counts are based on data collected by Thorndike and Lorge (1968) in their study of frequency of word usage in order to establish reading lists for school aged children.

Appendix 9

Data reported per subject for oral groups for four ASL iconic signs presented to left and right visual fields

HEARING ORAL SUBJECTS

TASK ITEM	visual field Task# *		1	2	3	4	5	6	7	8	9	10	Total
TELEPHONE	34	L	1	1	1	1	1	1	1	1	1	0	9
	114	R	0	0	1	0	1	0	1	0	1	1	5
THREE	35	L	1	1	1	0	1	1	0	1	1	0	7
	115	R	0	1	1	0	0	0	1	1	1	1	6
COW	38	L	0	1	1	1	1	1	1	1	1	1	9
	118	R	1	1	1	1	1	1	1	1	1	1	10
SLEEP	39	L	0	1	1	0	1	0	1	1	1	1	7
	119	R	1	1	1	1	1	1	1	0	1	1	9

DEAF ORAL SUBJECTS

TASK ITEM	visual field		1	2	3	4	5	6	7	8	9	10	Total
TELEPHONE	34	L	1	1	1	1	1	1	1	1	1	1	10
	114	R	1	1	1	1	1	0	1	1	1	1	9
THREE	35	L	0	1	1	1	1	0	1	0	1	1	7
	115	R	1	0	0	1	1	0	0	0	1	0	4
COW	38	L	1	1	1	1	1	1	1	1	1	1	10
	118	R	1	1	1	1	1	1	1	1	1	1	10
SLEEP	39	L	0	1	1	1	1	1	1	1	1	0	8
	119	R	0	1	0	1	1	1	1	1	1	1	8

Task Numbers were assigned to all visual materials to facilitate sorting of materials for complete randomization of presentation to each subject.

Data Reported per subject by manual groups for four
ASL iconic signs presented to Left and Right visual fields
(continued)

HEARING MANUAL SUBJECTS

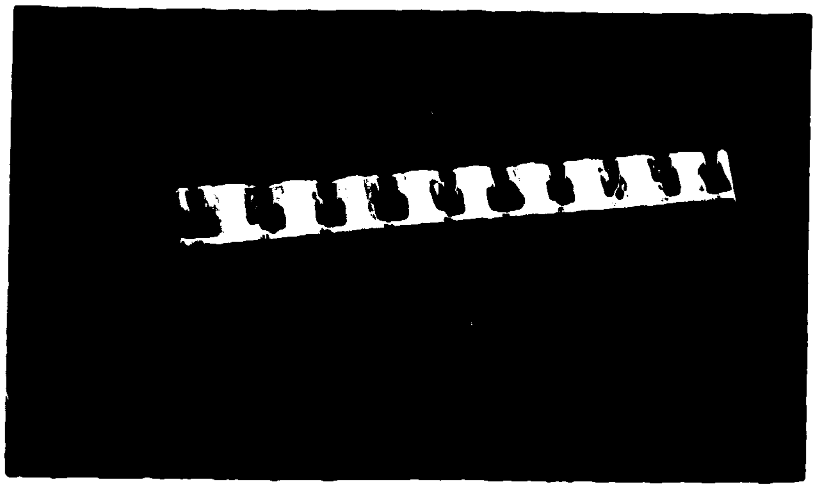
TASK ITEM	visual field	1	2	3	4	5	6	7	8	9	10	Total
TELEPHONE	34 L	1	0	1	1	0	0	1	1	1	1	7
	114 R	1	1	1	1	1	0	0	1	0	1	7
THREE	35 L	1	1	1	0	0	1	1	0	1	1	7
	115 R	0	1	1	1	0	1	0	0	1	0	5
COW	38 L	1	1	1	1	1	1	1	1	1	1	10
	118 R	1	1	1	1	1	1	1	1	1	1	10
SLEEP	39 L	1	1	1	1	1	1	1	0	1	1	9
	119 R	1	1	1	1	1	1	0	1	1	1	9

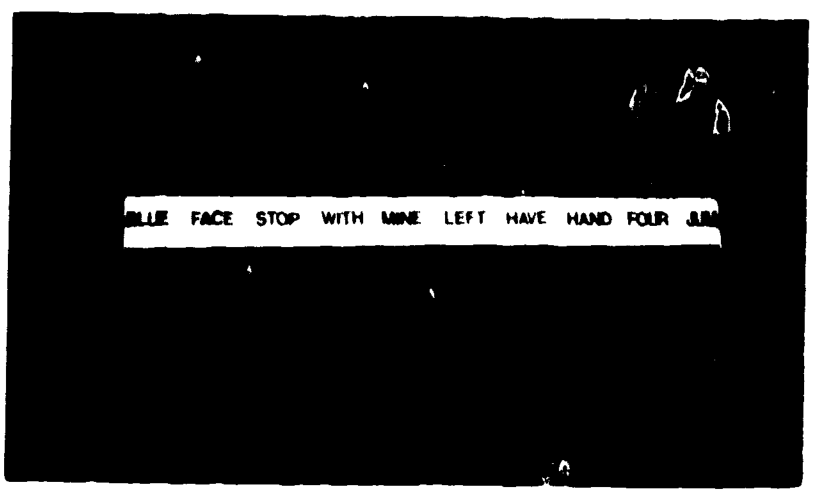
DEAF MANUAL SUBJECTS

TASK ITEM	visual field	1	2	3	4	5	6	7	8	9	10	Total
TELEPHONE	34 L	1	1	1	1	1	1	1	0	0	1	8
	114 R	1	1	1	1	0	1	1	0	1	1	8
THREE	35 L	1	1	0	1	0	1	0	0	1	1	6
	115 R	1	1	0	1	0	0	1	0	1	0	5
COW	38 L	1	1	1	1	1	1	1	1	1	1	10
	118 R	1	1	1	1	1	1	1	1	1	1	10
SLEEP	39 L	0	1	1	1	1	1	1	0	1	1	8
	119 R	1	1	1	1	1	1	1	0	1	1	9

Appendix 10

Viewing Board





Appendix 11

Answer Sheet for Subject Responses to Visual Presentations

	Number	Time		Number	Time		Number	Time		Number	Time
1.			31.			61.			91.		
2.			32.			62.			92.		
3.			33.			63.			93.		
4.			34.			64.			94.		
5.			35.			65.			95.		
6.			36.			66.			96.		
7.			37.			67.			97.		
8.			38.			68.			98.		
9.			39.			69.			99.		
10.			40.			70.			100.		
11.			41.			71.			101.		
12.			42.			72.			102.		
13.			43.			73.			103.		
14.			44.			74.			104.		
15.			45.			75.			105.		
16.			46.			76.			106.		
17.			47.			77.			107.		
18.			48.			78.			108.		
19.			49.			79.			109.		
20.			50.			80.			110.		
21.			51.			81.			111.		
22.			52.			82.			112.		

23. ______ ______	53. ______ ______	83. ______ ______	113. ____ ______
24. ______ ______	54. ______ ______	84. ______ ______	114. ____ ______
25. ______ ______	55. ______ ______	85. ______ ______	115. ____ ______
26. ______ ______	56. ______ ______	86. ______ ______	116. ____ ______
27. ______ ______	57. ______ ______	87. ______ ______	117. ____ ______
28. ______ ______	58. ______ ______	88. ______ ______	118. ____ ______
29. ______ ______	59. ______ ______	89. ______ ______	119. ____ ______
30. ______ ______	60. ______ ______	90. ______ ______	120. ____ ______

Appendix 12

Comparisons of Modified and Unmodified Tasks

Lower Case Words (2) Upper Case Words (7)

The two kinds of printed words (2) lower case words and (7) upper case words were compared for both dependent variables, score and time to response. No differences were found between upper and lower case letter type for either score or time to response (Tables 7-1 & 7-2). A hearing status by language acquisition (p=.04) was noted with scores of hearing manual and deaf oral being greater than those of the hearing oral and deaf manual groups. However all of the scores for both tasks are scewed to the upper limit with scores of 10, resulting in questions of normality of distribution, thus these results should be cautiously interpreted.

A significant visual field by language acquisition effect (p=.03) for time to response was noted with manual subjects taking longer. A visual field by task effect (p=.02) indicated that hearing subjects took longer times for RVF perception of lower case words, whereas times for processing the upper case words were greater for the LVF presentations. The reverse was noted for the deaf manual group although visual field by task by hearing acquisition interaction was not significant.

Large Fingerspelling (1) and Small (3)

The two fingerspelling tasks (1) Large fingerspelling and (3) Small fingerspelling differed significantly on both dependent measures score and time to response, with the score level of significance approaching zero (p=.00) and time to response, (p=.03). Refer to Tables 7-3 and 7-4 respectively. There were numerous interactions indicating not only that subjects responded differently to these two tasks, but also that the subjects used different response styles. There was an indication of a visual field effect (p=.08) for Score, and a significant visual field by task effect (p=.05) (See Table 7-3). Although not significant a similar trend (p>.07) is noted for time to response in the visual field by task interaction (Table 7-4). This indicated that subjects responded differentially to the two tasks depending upon side of presentation (left or right visual field). Analyses of time to response for correct score resulted in a significant task by language acquisition effect (p=.03) indicating that the tasks evoked different responses for subjects depending on whether they were oral or manual.

All subjects scored more items correct on the (1) Large fingerspelling task with

Table 7-1: Analysis of Variance Comparison of
Scores for Lower Case Words (2) and Upper Case Words (7)

	Mean scores for four groups							
	Hearing Oral		Hearing Manual		Deaf Oral		Deaf Manual	
Visual Field	Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.
LVF (2)	9.5	(0.7)	9.9	(0.3)	9.8	(0.6)	9.5	(0.5)
LVF (7)	9.8	(0.4)	10.0	(0.0)	9.9	(0.3)	9.5	(0.7)
RVF (2)	9.8	(0.4)	9.9	(0.3)	9.7	(0.7)	9.8	(0.7)
RVF (7)	9.8	(0.4)	9.8	(0.4)	9.8	(0.4)	9.8	(0.4)

Source	d.f.	Sums of Squares	F	Tail Prob.
Hearing Acq.	1	0.31	1.32	0.26
Language Sta.	1	0.01	0.03	0.87
H.A. X L.A.	1	1.05	4.57	0.04*
Visual Field	1	0.16	0.47	0.49
VF X HS	1	0.06	0.17	0.68
VF X LA	1	0.06	0.17	0.68
VF X HS X LA	1	1.06	3.19	0.08
Stimuli	1	0.16	1.14	0.29
S X HA	1	0.01	0.05	0.83
S X LA	1	0.16	1.14	0.29
S X HS X LA	1	0.01	0.05	0.83
VF X STIMULI	1	0.16	0.71	0.40
VF X S X HS	1	0.16	0.71	0.40
VF X S X LA	1	0.01	0.03	0.87
VFxSxHAxLA	1	0.01	0.03	0.87

Table 7-2: Analysis of Variance comparison of Times to Response for Lower Case Words (2) and Upper Case Words (7)

	Mean Times to Response for Four Groups							
	Hearing Oral		Hearing Manual		Deaf Oral		Deaf Manual	
Visual Field	Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.
LVF (2)	2.5	(0.5)	2.8	(0.3)	2.6	(0.5)	2.8	(0.8)
LVF (7)	2.6	(0.5)	2.8	(0.5)	2.6	(0.6)	2.5	(0.3)
RVF (2)	2.6	(0.5)	2.9	(0.4)	2.4	(0.5)	2.6	(0.5)
RVF (7)	2.5	(0.5)	2.7	(0.4)	2.4	(0.7)	2.7	(0.6)

Source	d.f.	Sums of Squares	F	Tail Prob.
Hearing Sta.	1	0.41	0.47	0.50
Language Acq.	1	1.62	1.81	0.19
HS X LA	1	0.16	0.17	0.68
Visual Field	1	0.11	2.86	0.10+
VF X HS	1	0.07	1.69	0.20
VF X LA	1	0.20	5.18	0 03*
VF X HS X LA	1	0.01	0.36	0.55
Stimuli	1	0.14	1.19	0.28
S X HA	1	0.00	0.03	0.86
S X LA	1	0.12	1.02	0.32
S X HS X LA	1	0.00	0.00	0.95
VF X Stimuli	1	0.04	0.61	0.44
VF X S X HS	1	0.42	6.07	0.02*
VF X S X LA	1	0.11	1.54	0.22
VFxSxHSxLA	1	0.10	1.47	0.23

Table 7-3: Analysis of Variance Comparison of Scores for Large Fingerspelling (1) and Small Fingerspelling (3)

Means and standard deviations for four groups

Visual Field	Hearing Oral Mean	Hearing Oral s.d.	Hearing Manual Mean	Hearing Manual s.d.	Deaf Oral Mean	Deaf Oral s.d.	Deaf Manual Mean	Deaf Manual s.d.
LVF (1)	7.0	(1.9)	7.1	(0.6)	6.0	(1.8)	7.6	(1.9)
LVF (3)	6.1	(1.6)	7.5	(2.0)	5.7	(0.8)	5.8	(1.9)
RVF (1)	7.2	(1.9)	7.7	(1.0)	7.7	(1.6)	7.7	(2.3)
RVF (3)	6.0	(1.4)	7.0	(1.1)	6.4	(1.8)	6.6	(1.3)

Source	d.f.	Sums of Squares	F	Tail Prob.
Hearing Sta.	1	2.75	0.58	0.45
Language Acq.	1	15.00	3.17	0.08
HA X LS	1	0.76	0.16	0.69
Visual Field	1	7.66	4.85	0.03 *
VF X HS	1	6.00	3.81	0.06 +
VF X LA	1	1.41	0.89	0.35
VF X HS X LA	1	1.41	0.89	0.35
Stimuli	1	29.76	11.21	0.00 **
S X HS	1	2.76	1.04	0.32
S X LA	1	0.15	0.06	0.81
S X HS X LA	1	6.01	2.26	0.14
VF X Stimuli	1	1.81	1.12	0.30
VF X S X HS	1	0.76	0.47	0.50
VF X S X LA	1	0.51	0.31	0.58
VFxSxHSxLA	1	3.91	2.41	0.13

Table 7-4: Analysis of Variance Comparison of Times to Response for Large Fingerspelling (1) and Small Fingerspelling (3)

	Means and standard deviations for four groups							
	Hearing Oral		Hearing Manual		Deaf Oral		Deaf Manual	
Visual Field	Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.
LVF (1)	4.0	(1.6)	4.6	(1.1)	3.8	(1.2)	3.6	(0.6)
LVF (3)	5.3	(2.9)	4.9	(1.1)	4.2	(2.3)	3.6	(0.8)
RVF (1)	4.2	(1.7)	5.1	(1.2)	4.2	(2.3)	3.9	(0.8)
RVF (3)	4.7	(2.1)	5.0	(1.0)	4.2	(1.3)	3.9	(0.9)

Source	d.f.	Sums of Squares	F	Tail Prob.
Hearing Sta.	1	24.88	3.11	0.09
Language Acq.	1	0.00	0.00	0.99
HS X LA	1	5.01	0.63	0.43
Visual Field	1	0.71	2.37	0.13
VF X HS	1	0.40	1.40	0.24
VF X LA	1	0.86	2.89	0.10
VF X HS X LA	1	0.33	1.11	0.30
Stimuli	1	3.21	5.38	0.03 *
S X HS	1	1.75	2.94	0.10
S X LA	1	2.88	4.83	0.03 *
S X HS X LA	1	0.76	1.27	0.27
VF X Stimuli	1	1.79	3.37	0.07 +
VF X S X HS	1	0.51	0.96	0.33
VF X S X LA	1	0.54	1.02	0.32
VFxSxHSxLA	1	0.00	0.01	0.92

+=a non-significant trend.

mean scores for RVF of 7.6, and LVF of 6.9, whereas subjects scored a full point lower for the RVF scores of the (3) Small Fingerspelling task with mean scores of 6.5 for RVF and 6.2 for LVF respectively.

Not only were scores higher on the (1) Large fingerspelling task, but subjects scored higher for RVF which suggested that subjects were responding differently to the two tasks. The results of these analyses in conjunction with the mean scores for tasks indicates that these two tasks are perceived quite differently by the subjects and as such cannot be grouped together as one task.

ASL Idioms With (5) and Without (8) Arrows

Overall there was no significant difference between subjects' scores for the two tasks, Idioms With (5) or Without (8) Arrows as is evident from the lack of significance for "Task" on both analyses of variance Tables 7-5 and 7-6 for scores and times to response respectively. This indicates that there is no difference between materials containing arrows and those which did not contain arrows.

Manual subjects scored significantly higher (p=.02) than oral subjects for both tasks which was expected due to their fluency with Sign Language. It is, however, more interesting that both manual groups, hearing and deaf scored not only higher, but higher in the LVF presentations (Table 7-5). A difference between Right and Left Visual Field presentations was also evident for the second dependent variable, time to response. All subjects responded significantly faster (p>.04) to RVF-viewed tasks (Table 7-6).

Within the manual group, the deaf and hearing subjects responded not only differently, but just the opposite to one another in response to the two tasks in the RVF presentations. The score of hearing manual subjects increased from a mean of 6.8 for Idioms With Arrows to a mean of 7.3 for Idioms Without Arrows, whereas the Score of the deaf manual group actually decreased from a mean of 6.8 for Idioms With Arrows to a mean of 6.3 Without Arrows.

Summary of Task Modifications

In the previous section, three pairs of tasks in which one task was a modification of the other were compared. The major conclusion was that only one set of comparison tasks, Large Fingerspelling (1) and Small Fingerspelling (3), differed significantly from each other, and each was, therefore considered a separate and discrete task.

Table 7-5: Analysis of Variance Comparison of Scores for ASL Idioms With Arrows (5) and Without Arrows (8)

	Means and standard deviations for four groups							
	Hearing Oral		Hearing Manual		Deaf Oral		Deaf Manual	
Visual Field	Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.
LVF (5)	6.2	(1.6)	8.0	(1.2)	6.2	(2.0)	7.5	(1.3)
LVF (8)	6.1	(1.4)	7.1	(1.4)	6.5	(1.4)	7.5	(1.6)
RVF (5)	6.4	(1.7)	6.8	(1.6)	6.2	(1.6)	6.8	(2.1)
RVF (8)	6.3	(1.4)	7.3	(1.4)	6.2	(1.7)	6.3	(1.9)

Source	d.f.	Sums of Squares	F	Tail Prob.
Hearing Sta.	1	0.6	0.12	0.73
Language Acq.	1	32.4	6.31	0.02*
HS X LA	1	0.9	0.18	0.68
Visual Field	1	4.9	2.68	0.11
VF X HS	1	1.6	0.87	0.36
VF X LA	1	5.6	3.08	0.09
VF X HS X LA	1	0.0	0.01	0.91
Stimuli	1	4.00	0.28	0.59
S X HS	1	1.00	0.07	0.79
S X LA	1	0.63	0.44	0.51
S X HS X LA	1	0.23	0.16	0.69
VF X Stimuli	1	0.23	0.13	0.73
VF X S X HS	1	3.03	1.69	0.20
VF X S X LA	1	0.90	0.50	0.48
VFxSxHSxLA	1	1.60	0.90	0.35

Table 7-6: Analysis of Variance Comparison
of Times to Response for ASL Idioms With Arrows (5)
and Without Arrows (8)

	Mean scores for four groups							
	Hearing Oral		Hearing Manual		Deaf Oral		Deaf Manual	
Visual Field	Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.
LVF (5)	5.9	(5.0)	5.1	(1.0)	5.4	(2.2)	4.4	(0.9)
LVF (8)	5.0	(2.1)	5.5	(1.4)	5.1	(1.1)	4.3	(0.8)
RVF (5)	4.8	(3.6)	5.0	(1.2)	4.7	(2.5)	4.4	(1.1)
RVF (8)	4.4	(1.5)	4.9	(0.8)	4.9	(2.3)	4.4	(1.7)

Source	d.f.	Sums of Squares	F	Tail Prob.
Hearing Sta.	1	6.26	0.47	0.50
Language Acq.	1	2.80	0.21	0.65
HS X LA	1	5.92	0.45	0.51
Visual Field	1	5.54	4.38	0.04 *
VF X HS	1	1.22	0.97	0.33
VF X LA	1	2.44	1.93	0.17
VF X HS X LA	1	0.00	0.00	0.96
Stimuli	1	0.60	0.23	0.63
S X HS	1	0.44	0.17	0.68
S X LA	1	1.44	0.56	0.46
S X HS X LA	1	1.56	0.61	0.44
VF X Stimuli	1	0.31	0.33	0.57
VF X S X HS	1	0.25	0.27	0.61
VF X S X LA	1	1.44	1.54	0.22
VFxSxHSxLA	1	0.19	0.21	0.65

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