HEMISPHERIC SPECIALIZATION IN HEARING IMPAIRED CHILDREN WHO USE CUED SPEECH

by

Susan L. Kennedy

Thesis submitted to the Faculty of the

Virginia Polytechnic Institute and State University

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

in

Family and Child Development

APPROVED:

____

Dr. Shirley Farrier, Chairman

______________________ ______________________

Dr. Cherry Houck Dr. Cosby Rogers

May, 1983

Blacksburg, Virginia

ACKNOWLEDGEMENTS

I have profited from the advice and support of many people in my efforts to complete this research. I wish to thank:

The members of my committee - Drs. Shirley Farrier, Cherry Houck and Cosby Rogers - who managed to be available whenever I was in town.

My mother and father, for their expertise in computer jargon, exceptional children, and transportation of the tachistoscope.

Christopher Vaden, for those comforting words, "Don't worry, everything will work out".

The following people for consultations in their field or loan of equipment: Dr. Catherine Riggs, O.D.; Dr. Albert Prestrude, Dr. Joseph Franchina and Mr. Hugo Neuberg, all of the Psychology Department; Dr. Marvin Lentner, Dr. Thomas Seaver and Ms. Marilyn Drucker, all of the Statistics Department; Dr. Suzanne Hasenstab, of the University of Virginia Deaf Education program; Dr. Richard Stratton, of the Health, Physical Education and Recreation Department; and Dr. Gary Fenstermacher, for the use of his office. A special thank you to the parents of the children used as subjects in this research.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

Introduction

Hemispheric asymmetry for processing language information in the brain is demonstrated as early as infancy (Molfese, 1977; Segalowitz & Chapman, 1980; Witelson & Pallie, 1973), and continues to be demonstrated in childhood (Eling, Marshall, & van Galen, 1981; Starck, Genesee, Lambert, & Seitz, 1977) and in adulthood (Kimura, 1975; Miller & Turner, 1973; Segalowitz & Stewart, 1979). This is true whether the language stimuli are presented through auditory (Shankweiler, 1974) or through visual channels (Umilta, Sava & Salmaso, 1980). The language stimuli commonly used in research are spoken language (Studdert-Kennedy & Shankweiler, 1974), written language (Leehey & Cahn, 1979), or sign language (Poizner, Battison, & Lane, 1979). The majority of normal hearing right-handed subjects exhibit left hemispheric specialization for spoken language (Umilta, et al., 1980; Studdert-Kennedy & Shankweiler, 1974), whereas hearing impaired subjects who use speech or a combination of speech and sign language do not uniformly develop left hemispheric dominance for language. They demonstrate right hemispheric dominance (Phippard, 1977), left hemispheric dominance (Manning, Goble, Markham, & LaBreche, 1977), or no predictable dominance for processing language information (Phippard, 1977; Ross, Pergament, &

Anisfeld, 1979). Visuospatial relationship processing and limited language processing have been demonstrated as right hemisphere capabilities in most right-handed hearing subjects (Searleman, 1977).

Statement of the Problem

The purpose of this study was to determine whether there is hemispheric specialization in children who use cued speech to communicate. Cued speech was developed by Dr. Orin Cornett of Gallaudet College as a means of conveying complete spoken language information to a deaf individual. In this system, phonetic information is represented by handshape cues, placement of hand cues, and cues from lip formation during speech (See Appendix A). Through translating spoken language into visually presented phonetic cues the child is able to see the sounds of spoken language. This thesis questions which information in the cued speech code is processed by the brain more efficiently. Does the visual mode for transmitting the speech code encourage a right hemispheric dominance for language ability? Or does the type of information in the cued speech code enable the left hemisphere to specialize in language processing?

The null hypothesis to be tested is that there is no difference in language processing abilities between the right and left hemispheres for a same or different response to paired letter stimuli from hearing impaired children who use cued speech.

Justification

The importance of learning language for the successful development of the deaf child cannot be over-emphasized. Indeed, the problem has nurtured a continuing controversy between educators over the methods of stimulating language development within the hearing impaired child. The research on language dominance in deaf children has been confined to subjects communicating with speech or with speech and sign language. This study examined another means of communication open to a deaf child - cued speech. Through cued speech the deaf child can learn spoken language. Perhaps cued speech is also instrumental in establishing hemispheric specialization for language in the child who uses cued speech.

CHAPTER II

Review of Literature

Language development can be described in acquisitional stages of semantic and syntactic structures. Several factors affect the acquisition of language skills, such as parental role models, education, intelligence and intact hearing. Children with a hearing impairment often do not achieve the complexity of spoken language as their hearing peers. Research with subjects who use cued speech has shown enhanced language skills in the cued speech subjects (Nicholls, 1979) compared to most hearing impaired children.

The left hemisphere specializes in language processing in most right-handed, normal hearing subjects (Kimura, 1975). The subjects used in hemispheric specialization research include subjects with brain damage, subjects without brain damage, infant, child and adult subjects, normal hearing subjects, and hearing impaired subjects. Hearing impaired subjects do not demonstrate a predictable hemispheric specialization for language processing (Phippard, 1977; Ross, et al., 1979).

Language Acquistion

The development of language in children is documented as a series of stages. There is a preverbal or babbling stage, a one-word stage, a two-word stage, and a three-or-more-word stage which is refined into adult language.

In the preverbal stage the infant's language consists of gestures and vocal play. Bates (1976) presented an outline of the gestural systems and preverbalizations of infants. The infant uses gestures which may be classified as declarative or imperative. The declarative gesture directs an adult's attention and the imperative gesture is used as a means to obtain a goal. Gestures occur alone or with vocalizations accompanying the motor activity of the gesture. Through the gestural/ performative framework, the infant is able to acquire the rudiments of spoken language propositions (Bates, 1976).

During the preverbal stage the infant practices vowel and consonant sounds repeated in consonant-vowel strings or consonant-vowel-consonant strings (Kretschmer & Kretschmer, 1978). Initially, vowel production progresses from the front of the mouth to the back of the mouth, with /i/ being produced before /a/. Consonant production progresses from the back of the mouth to the front of the mouth, with /k/ being produced before /p/ (Glucksberg & Danks, 1975). In the preverbal stage, the infant also acquires a rudimentary mastery of intonational patterns which help to identify new information and to understand linguistic units in speech such as sentence or clause boundaries (Kretschmer & Kretschmer, 1978). When the infant progresses from the preverbal stage to the one-word stage, consonant and vowel production is reversed from the initial developmental sequence. Back vowels are produced before front vowels, and front consonants are produced before back consonants. Hence we observe the first words to be "mama" and "papa" (Glucksberg & Danks, 1975).

Bloom and Lahey (1978) described a child's first words as substantive words and relational words. Substantive words refer to object concepts such as "blanket" or "mommy". Relational words express the concepts of existence, nonexistence, recurrance, and disappearance. The first words deal with causality-locative relationships involved directly with the infant. Then the infant progresses to relationships more remote to the infant, such as experiencer, possessor, and stative-locations (Kretschmer & Kretschmer, 1978).

In a transitional period between the one-word and two-word stages, the child will string together single words in successive utterances. The words do not have a syntactic organization but rather a semantic organization (Bloom & Lahey, 1978). Then the child acquires syntactical organization in two-word utterances expressed as functional relationships and grammatical relationships (Bloom & Lahey, 1978). In a functional relationship

> ...relational words that have a particular meaning are combined with other, substantive words, and the meaning relation between the words in combination is the same as the meaning of the relational word. Such combinations are described as having linear

syntactic relationship. Other combinations of words result in a meaning relation that is not the same as the meaning of the individual words. These combinations involve categories of nouns, or pronouns, in relation to verbs. Such categories are described in terms of sentence subject and sentence predicate, with hierarchical syntactic [grammatical] relationship (Bloom & Lahey, 1978, p.163).

Brown (1973) also presented a theory of the semantic relations expressed in the child's language development. The eight semantic relations are : agent action, agent object, X + location (where X denotes a word), negation + X, modifier + X, possessor, and introducer + X. The grammatical and functional relationships of the two-word stage are refined and developed into complex sentences in the three-or-more-word stage. Two operations are necessary to create complex sentences from the grammatical and functional relationships. One operation is the embedding of a functional relationship into a grammatical relationship. A second operation is the combining of two grammatical relationships with a common element to make a sentence in which the second, redundant, common element is deleted.

As the child's language skills increase, he learns the grammar of adult language. Skinner (1957) attributes language learning to the conditioning of the infant's verbal behavior by his parents and other language models in the infant's environment. However, the infant learns new structures at a quicker rate and without the stimuli repetition necessary for Skinner's theory to account for the natural rate of acquisition. Chomsky (1969) points out that the child contnues to learn new syntactic structures until approximately age ten. Language structure can be described in many ways. One method of description is phrase structure grammar.

> Phrase-structure grammars are among the simplest of the formal grammars. The central feature of these grammars is that they describe a structural analysis of a sentence in the order that the words actually occur.... Words are grouped together in successively larger segments according to grammatical function (Glucksberg & Danks, 1978, p.79).

Phrase structure grammar only describes individual sentences without relating sentences together semantically (Glucksberg & Danks, 1978). A second method of describing adult language which accounts for semantic relationships between sentences was formulated by Chomsky (1968).

Chomsky (1968) explained his generative-transformational grammar of adult language as having two components: the deep structure or semantic intent of language and the surface structure conveyed by the syntax and morphology of language. Through a surface structure analysis, transformations are identified which relate surface structures to one another and their corresponding deep structures. A third descriptive method for adult language, case grammar, was developed by Fillmore (1968). Case grammar is a semantic analysis in which the verb is the central organizing unit of the sentence. The other elements in the sentence are described as cases, such as agentive, instrumental, objective, and locative, and are analyzed in relation to the verb. Fillmore (1968) described cases as

> ...universal concepts which identify certain types of judgements human beings are capable of making about the events that are going on around them, judgements about such matters as who did it, who it happened to, and what got changed (p.24).

Language acquisition is a series of stages through which the child develops the syntactic and semantic functions of adult language. The stages are: the preverbal stage, the one-word stage, the two-word stage, and the three-or-more-word stage which is refined into adult language. There are several ways of describing adult language, including the syntactic analysis of phrase structure grammar (Glucksberg & Danks, 1978), the surface structure and deep structure analysis of Chomsky (1968), and the semantic analysis of case grammar (Fillmore, 1968).

Language Acquisition for the Hearing Impaired

Deaf children possess the inherent ability of the human species to acquire language. They follow the normal stages of language development, though as a group do not achieve the complexity of adult language found in the normal hearing population.

Deaf children and their hearing peers both employ gestures in their early communication attempts (Bates,1976; Kretschmer & Kretschmer, 1978). In Goldin-Meadow's research (cited in Kretschmer & Kretschmer, 1978) the multi-gesture phrases of young deaf children were classified as an action proposition or an attribute proposition.

> As would be expected, action propositions or phrases were produced with greater frequency and at earlier ages than attribute propositions or phrases. This behavior has a parallel in spoken language, in which action two-word verbalizations are produced with greater frequency and at earlier ages in the developmental process than two-word adjectival (attribute) utterances (Kretschmer & Kretschmer, 1978, p.90).

The deaf child develops a more highly organized gestural system than his hearing peer, while the hearing child quickly makes the transition to spoken language (Kretschmer & Kretschmer, 1978). In a study of early spoken language in deaf subjects, Skarakis and Prutting (1977) found that oral deaf children aged two to four years demonstrated semantic development comparable to hearing children aged nine to eighteen months. Semantic functions such as agent, object, action, and location were conveyed by the child through motor activity, gesture or gesture combined with vocalization. Hess (cited in Kretschmer & Kretschmer, 1978) matched a hearing impaired child to a hearing child of the same linguistic level and compared the linguistic output of the two subjects. Both children demonstrated similar syntactic development with the exceptions that the hearing impaired child had less differentiation of the subject form class and had greater development of structures leading to a negative sentence frame.

Though the pre-school deaf child is able to acquire semantic skills (though not necessarily speech skills) similarly to normally hearing children, the language development of deaf children does not match their hearing peers' rate of acquisition. Research with older deaf children consistently shows the deaf child with more agrammatical mistakes in written or oral sentence repetition (Sarachan-Deily & Love, 1974; Kretschmer & Kretschmer, 1978). In a sentence repetition task, the deaf subjects produced agrammatical word orders, word substitutions which changed the meaning of the sentence, or incorrect word endings (Sarachan-Deily & Love, 1974).

Spoken language skill in a deaf child is closely related to the degree of hearing loss, and many deaf children do not develop full competency of transformational grammar in spoken language. The lack of syntactic complexity in the deaf child's language skills is also evident in written language samples. Kretschmer and Kretschmer (1978) reported on their study of 3000 compositions from hearing impaired and normally hearing children and young adults. Compositions by the hearing-impaired subjects were considered

> ...uniformly rigid and simple with myriads of problems ranging from formation of simple sentence frames to incomplete mastery of the lexical items inserted into these sentence frames.... [The] deaf children demonstrate difficulty with base structure particularly with use of articles, verbs and prepositions (Kretschmer & Kretschmer, 1978, p.121).

In summary, deaf children follow the same stages of language development but do not achieve the complexity of spoken language of their hearing peers. Gestural systems tend to be highly developed and delays in syntactic and semantic development are evident for most hearing impaired children.

Cued Speech

Dr. Orin Cornett devised cued speech during 1965-66 as a method of conveying complete spoken language information to the deaf.

> The method utilizes 12 cues, which are so designated because they do not actually identify individual phonemes. Instead, they furnish only enough information in each case to permit precise identification of the phoneme from what is visible on the lips. Used without the lips, they are unintelligible.... Four of the cues used in Cued Speech are hand-positions which identify groups of visually-contrastive vowels so as to permit positive identification of each vowel from the lips. Eight are configuration cues which similarly group the consonants (Cornett, 1967, p.6).

Moores (1969) pointed out several issues of cued speech use which are answered by Dr. Cornett (1969). The phonetic base of cued speech provides deaf children with visible evidence of the phonetic base of spoken language. Cued speech clarifies the speech of the hearing speaker and provides a means for clarifying imitation of speech production by the deaf child. A hearing person fluent in cued speech will be presenting fluent spoken language to the deaf child. Though there are inconsistencies among persons in pronunciation of individual words, the deaf child is able to learn such discrepancies through the course of normal conversation as do his hearing peers.

Clarke and Ling (1976) reported on eight deaf subjects with one year's experience with cued speech in the classroom. Sentences were presented to the subjects with and without cues, with and without the subjects wearing their hearing aids, and at a slow and normal rate of talking. Sentences presented with cues were more accurately written by the subjects than sentences without cues, irrespective of the rate of presentation or use of hearing aids by the subjects. Another report of twelve profoundly deaf children using cued speech for only one year in the classroom also showed that sentences presented with cued speech were more accurately recorded by the children than sentences presented without cued speech (Ling & Clarke, 1975).

One research study found that children who use cued speech do develop language skills similar to their hearing peers (Nicholls, 1979). Eighteen profoundly deaf children who know cued speech were presented syllables and sentences with key words under several conditions. The conditions were: audition alone, lipreading alone, cued speech alone, audition and lipreading, cued speech and audition, cued speech and lipreading, and cued speech, lipreading and audition. The sentences were of two types: high predictability for the key word, and low predictability for the key word. The deaf children's scores for two conditions-cued speech, lipreading and audition, and cued speech and lipreading- were excellent; for all other conditions the scores were poor. The children were able to understand language information under conditions typical of cued speech usage (Nicholls, 1979).

Research on cued speech use is sparse; however, the cued speech subjects studied have demonstrated enhanced language skills if compared to the normal level of language skills found in most hearing impaired children.

Hemispheric Specialization

Lenneberg formulated his theory of plasticity of the brain to explain language development in a two sided brain. Both hemispheres would start with equal potential for language development lasting through the first two years, but then dominance would be progressively established in one hemisphere. The dominant hemisphere becomes dominant not through an increased involvement of that hemisphere but through a decreased involvement by the non-dominant hemisphere (Lenneberg, 1967). Moscovitch (1977) adds:

> The plasticity interpretation suggests further that the right hemisphere's linguistic capacities will remain relatively impoverished unless early damage to the left hemisphere enables the right to develop and extend its linguistic skills (p. 197).

Research subjects in studies of hemispheric specialization for language are chosen with respect to several variables: left-handed and right-handed; brain damaged and without brain damage, infant, child, and adult; male and female; normal hearing and hearing-impaired. This review will present research illustrating combinations of these subject variables.

Subjects with brain damage. Much about language specialization is learned through patients with brain lesions. Lenneberg (1969) reports on several cases of unilateral lesions to the hemisphere assumed to be dominant for language (right-handed subjects with left side lesions). Damage to the dominant hemisphere before the age of three and one-half years resulted in complete language recovery following the normal stages of language development. Damage between the ages of three and one-half years and ten years resulted in recovery of language capabilities from the point of interruption in the normal developmental stages. Damage after age ten resulted in recovery of language capabilities but with residual aphasic effects.

In another study, Branch, Milner and Rasmussen (1964) reported on patients screened for brain surgery with sodium amytal injections. The sodium amytal temporarily disrupts speech functions when injected into the carotid artery on the side of hemispheric specialization for speech and language. An injection is made into each side one day apart. The procedure is too risky to be used except as a final screening procedure when it is necessary to determine the exact hemisphere of speech representation. Of the 48 right-handed patients, 90% demonstrated speech representation on the left side and 10% demonstrated speech representation on the right side. The 71 left-handed patients demonstrated speech functions as: 48% on the left side, 19% bilateral, and 38% on the right side. In an effort to understand factors influencing the development of hemispheric specialization, patients with brain damage from infancy are compared to patients with brain damage occurring in childhood or later. By categorizing left-handed patients into groups for an "early age" and a "late or unknown age" of occurrence, Branch, Milner and Rasmussen (1964) found that for the 27 early damage patients, 22% had speech represented on the left side, 11% had speech represented bilaterally, and 67% had speech represented on the right side. For the 44 late damage patients, 64% had speech represented on the left side, 16% had speech represented bilaterally, and 20% had speech represented on the right side. Those left-handed patients with brain damage occurring after infancy were able to develop language specialization in percentages comparable to the normal left-handed population. Even with nerological injury they were still able to develop language skills. For the subjects reported by Lenneberg and by Branch, Milner, and Rasmussen, language development was possible even after damage to the assumed dominant hemisphere for language processing.

More recent research with brain-damaged subjects has also illustrated hemispheric asymmetry for language processing. Woods (1980) tested 50 subjects with an average age of fifteen years who had unilateral lesions occurring before the first year or after the first year. Subjects below the age of fifteen were given the Wechsler Intelligence Scale for Children (Wechsler, 1949) and subjects fifteen or older were given the Wechsler-Bellevue II (Wechsler, 1946). The subjects with early damage had below average Performance and Verbal scores but no significant difference between the two scores (Woods, 1980). The subjects with brain lesions occurring after the first year were further divided into two groups- those with left side or right side lesions. Subjects with damage on the left had below average Verbal and Performance scores but no significant difference between scores. Those subjects with later damage on the right side showed normal Verbal scores but significantly lower Performance scores (Woods, 1980). Comparing ten subjects with hemidecortication on either side (where a portion of the brain cortex has been surgically removed) because of brain damage during the first year, Dennis (1980) found that cognitive skills were not significantly different between the right and left hemidecordicates. Subjects were tested with sentence repetition and sentence recall tasks, a syntactic token test, a sentence-to-picture matching task, and a semantic understanding of surface structure task. The subjects with left side damage were inferior in syntactic discrimination tasks (Dennis, 1980). Working with 50 subjects, Gainotti, Caltagrone, Miceli and Masullo (1981) found that subjects with right hemispheric damage had problems with lexical discriminations in auditory language comprehension and reading comprehension tests but not phonemic discrimination tests. The left hemisphere would be more involved in processing phonemic and complex syntactical information and the right hemisphere would have limited capabilities for processing language information.

Research design, subjects without brain damage. Studies researching specialization for language processing using normal hearing subjects without brain damage use two modes, auditory and visual, to present stimuli to the subjects. Using the first method of stimulus presentation, the auditory mode, the examiner designs a dichotic listening task which presents two competing stimuli through headphones to the subject. When comparing one ear to the other in monotic listening tasks, presenting stimuli to one ear at a time, there is no ear preference. Both ears process stimuli efficiently (Ling, 1974; Berlin, Lowe-Bell, Cullen, Thompson, & Loovis, 1974; Berlin, Willet, Thompson, Cullen, & Lowe, 1970). Yet with more stress on the system, as is the case with a dichotic listening task, it becomes evident that speech is processed better in a hemisphere dominant for language.

The second mode of stimulus presentation is the visual mode, where the examiner uses a tachistoscope or a tachistoscopic projector to present the stimuli to the right visual field (RVF) or the left visual field (LVF) or both hemifields. Both the auditory and visual neural pathways are organized contralaterally. Therefore, if stimuli are processed faster through the right ear or RVF rather than the left it is assumed to indicate a left hemispheric superiority for that task. Conversely, a left ear advantage or an LVF superiority is assumed to indicate a superiority in right hemispheric processing.

Several factors need to be considered when designing a tachistoscopic study of hemispheric specialization for language processing (White, 1972). The stimuli must be specific enough to elicit the desired response. Stimuli used for differentiating visuospatial processing from language processing are often of two different types, one visuospatial stimulus to elicit visuospatial processing and one language stimulus to elicit language processing. Yet, by using two different stimuli it is difficult to be sure that comparisons between the resulting responses can be accurately made. Using matched letter pairs allows one kind of stimuli to elicit different kinds of processing responses (Segalowitz & Stewart, 1979). The paired letter stimuli can be matched by physical identity cues or name identity cues, such as "AA" or "Aa", respectively. Research supports the finding of left hemispheric superiority in identifying name matches (Geffen, Bradshaw, & Wallace, 1971; Cohen, 1972; Davis & Schmit, 1973). The capital and lower cases of a matched pair cannot have similar physical characteristics in order to ensure that the name matches are not processed by physical cues (Cohen, 1972). "Cc" would not be an appropriate stimuli pair, whereas "Nn" would be appropriate. One kind of stimulus (a letter pair) can elicit visuospatial processing (a physical match) or language processing (a name match). This produces a more accurate comparison of hemispheric abilities.

There are three conditions to account for when presenting the stimuli binocularly. First, the letter pair should be vertically aligned to discourage horizontal reading habits in the subject's eye movement. Second, the letter pair should be presented at an angle off the central fixation point in order to stimulate only retinal fibers of the eye transmitting to the opposite hemisphere. Third, the duration of the stimuli presentation time should be short enough to ensure that saccadic eye movement does not fixate the eyes on the letter pair, thus delivering stimulation to both hemispheres (White, 1972).

The response of the subject should not be a response which can be initiated by only one hemisphere. Such is the case when a verbal response is required (Geffen, Bradshaw, & Nettleton, 1972). The left hemisphere is able to initiate a verbal response relating to processing in either hemisphere. The right hemisphere is not capable of initiating a verbal response in persons with a left hemispheric specialization for language. Utilizing verbal responses could slant results towards the left hemisphere or disguise results from the right hemisphere. A manual response can be initiated by either hemisphere when the whole hand is required in the response (Filbey & Gazzaniga, 1969). Using a manual response would allow each hemisphere to initiate the response triggered by the incoming stimuli.

In an effort to establish the course of development of hemispheric specialization there is research on several stages of human growth: asymmetry in the physiological development in the brain evident at birth, and asymmetry demonstrated in infancy, childhood, and adulthood.

Infant subjects. There is evidence that at birth one hemisphere is physiologically equipped to be superior for language processing. Witelson and Pallie (1973) examined in neonatal and adult brains the planum temporale, which is associated with speech or language capabilities. The study found a similar asymmetry in neonates and adults, with a greater development of planum temporale exhibited on the left side.

Studies with infants have used speech and musical stimuli in dichotic listening procedures. Entus (1977), using a non-nutritive sucking reduction response, found a left hemispheric advantage for processing the speech stimuli. Vargha-Khadem and Corballis (1979) attempted to replicate Entus' results without success. They employed the same procedure as Entus with three modifications. In Entus' study, the experimenter held the rubber nipple in the infant's mouth and was acquainted with the order of stimulus presentation. Vargha-Khadem and Corballis used a mechanical arm to hold the rubber nipple in the infant's mouth, with a screen separating the experimenter from the infant. A double-blind format was used to prevent the experimenter from knowing the order of stimulus presentation. Perhaps the depersonalization of the modifications by Vargha-Khadem and Corballis influenced the infants' responses. Or perhaps the results in Entus' study were biased by the experimenter's influence on the infants. Another possible explanation of the difference in results between the two studies is that the experimental design was not sufficiently sensitive to measure hemispheric asymmetry in infants (Vargha-Khadem & Corballis, 1980).

Another response used in testing hemispheric specialization is an Auditory Evoked Potential (AEP), which is "the electrical response generated by the brain and recorded at the scalp in response to specific stimulus events" (Molfese and Molfese, 1980, p.575). Measuring AEP's for ten infants' response to musical and speech stimuli, Molfese (1977) found a greater change in response within the left hemisphere for speech stimuli and within the right hemisphere for musical stimuli. Segalowitz and Chapman (1980) used a limb tremor reduction response with 153 premature infants and also found a left hemispheric specialization for response to speech stimuli.

Children as subjects. Eling, Marshall and van Galen (1981) designed a dichotic listening study using as subjects ten boys and ten girls at four age levels (8, 10, 12, and 16 years). The subjects used a manual response to match words to a target rhyme word (phonetic category) or to a target word of a semantic category. Both sexes demonstrated a right ear advantage for discriminating both categories of words. With a procedure of enumerating two, three, four, five or six dots presented tachistoscopically, Young and Bion (1979) used as subjects ten boys and ten girls in three groups, ages 5, 7 and 11 years. The boys had greater left visual field superiority than girls for processing the visuospatial stimuli.

There is evidence that specialization can be strengthened through enriched language stimulation (Starck, Genesee, Lambert, & Seitz, 1977). Native English-speaking children were divided according to schooling experience into a monolingual group and a trilingual group. The children were in Kindergarten, grade one or grade two at either a school taught in English or a Hebrew school with an immersion program for French language learning. Eight children were in each group for grade level and schooling experience. Both groups exhibited a right ear advantage for repeating dichotically presented words and digits, with the trilingual group demonstrating a greater advantage in accuracy of recall than the monolingual group.

Adult subjects. Segalowitz and Stewart (1979), using 30 adult males and 30 adult females as subjects, found that both sexes demonstrated a right visual field superiority for processing matched letter pair stimuli. However, females were found to be less specialized for visuospatial processing than were males. Bryden (1980) found no difference between the sexes for a focused attention dichotic listening task when adult subjects were instructed to listen to both ears for speech stimuli. When the subjects were allowed free choice and told not to concentrate on both ears, the males exhibited a greater right ear advantage than did the female subjects.

Stimuli used in tachistoscopic presentations include: words, single letters, pictures, and lines of various spatial orientation. The left hemisphere is found to be superior in processing verbal over nonverbal stimuli when the verbal stimuli are letters (Kimura, 1966; Cohen, 1972; Bryden & Rainey, 1963; Leehey & Cahn, 1979; Segalowitz & Stewart, 1979) or words (Miller & Turner, 1973). White (1971) found an RVF superiority for identifying both capital letters and certain orientations of lines in space. The ability of the left hemisphere to process the spatially oriented lines is possibly related to the kind of analysis used. Umilta, Rizzolati, Marzi, Zamboni, Franzani, Carmarda, and Berlucchi (1973) proposed that the left hemisphere can analyze certain line orientations by naming the category to which the line belongs (e.g., horizontal), whereas the right hemisphere analyzes line orientation by a slower visuospatial coding.

In a dichotic word task the stimuli are easier to detect if meaning can be derived from the task by completing sentences from the stimulus words. When subjects were asked to list the stimulus words according to side of presentation, a right ear advantage was found for recall of stimulus words (Emmerich, Goldenbaum, Hayden, Hoffman, & Treffts, 1974). Left hemispheric superiority for processing speech has been demonstrated using a series of digits for the subject to repeat (Kimura, 1974). Shankweiler (1974) found a left ear advantage for processing familiar tunes and a right ear advantage for repeating digits.

Using speech sounds divided into consonant and vowel stimuli, Studdert-Kennedy and Shankweiler (1974) demonstrated with a dichotic listening task that consonants are processed better in the left hemisphere and vowels are processed better in the right hemisphere. Research is continuing in an effort to determine the exact phonetic information which can be processed in each hemisphere. This limited ability for the right hemisphere to process language information (vowels) illustrates a distinction to be made in terminology. Dominance in language processing should not be viewed as a complete control of language processing by one hemisphere, but rather as a specialization or superiority for processing language information in that hemisphere.

The overriding conclusion from the research dealing with normal hearing subjects is that there exists a tendency for the left hemisphere to specialize in processing information which can be phonetically encoded (Barry,1981; Gainotti, et al., 1981; Liberman, 1974). This does not rule out language processing in the minor hemisphere. There is ample evidence for language processing in the right hemisphere (Searleman, 1977). Yet, a right hemispheric specialization for language is not frequently found in normal populations.

Research with Hearing Impaired Subjects

Hearing impaired subjects who use speech or speech and sign language to communicate do not uniformly demonstrate left hemispheric dominance for language. They demonstrate right hemispheric dominance (Phippard, 1977), left hemispheric dominance (Manning, et al., 1977) or no predictable dominance for processing language information (Phippard, 1977; Ross, et al., 1979). Perhaps it is the dependence on a visual means for gathering information which influences stronger right hemispheric specialization (Kelly, 1978).

Many studies with hearing impaired subjects used written word and American Sign Language (ASL) stimuli. The deaf subjects demonstrated a left visual field advantage for the ASL stimuli or a tendency towards a left visual field superiority. Hearing subjects who are proficient with sign language also demonstrated a significant LVF superiority for ASL stimuli (Manning, et al., 1977; McKeever, Hoemann, Florian, & VanDeventer, 1976; Poizner & Lane, 1979). The fact that hearing subjects demonstrate a right hemispheric superiority for processing sign language stimuli supports the theory that the sign language is processed as visuospatial information. Poizner, Battison, and Lane (1979) found an LVF superiority for static pictorial sign stimuli but no visual field preference for moving sign language stimuli. In contrast to these results is the RVF superiority for sign language alphabet stimuli demonstrated by deaf and hearing subjects fluent with sign language (Virostek & Cutting, 1979). Perhaps the manual alphabet letters are processed through the left hemisphere by naming the letters rather than by the right hemisphere processing the visuospatial configuration of the manual alphabet stimulus.

Kelly and Tomlinson-Keasey (1977) used as subjects profoundly deaf children in grades three, four and five, with thirteen children at each grade level.

> The experimental task involved the processing of word and picture stimuli presented singly to the left and right visual hemifields. Reaction times were measured for the subjects' decision as to whether or not the stimulus-pairs matched (p.525).

The study resulted in no overall significant difference in hemispheric processing for either the verbal or pictorial stimuli, though there was a significant superiority for right hemisphere processing of high image words. McKeever, et al. (1976) also found an RVF superiority in a unilateral word recognition task. This would indicate a left hemisphere advantage for the grammatically (phonetically) coded information in the written word stimuli.

In a study comparing orally-trained students and total communication (speech and sign language) students, Phippard's (1977) subjects were an oral group (n = 10; CA = 12 to 16 years) and a 'total communication' group (n = 28; CA = 11 to 19 years). The verbal and nonverbal stimuli in the study consisted of: lower case letters, graphic representations of the manual alphabet, short lines with various spatial orientations, and unfamiliar male faces.

> The orally-trained children show a clear left visual field superiority in the perception of both verbal and nonverbal material, whereas for the 'total communication' group, no appreciable differences in left-right accuracy emerged from either type of material (Phippard, 1977, p.556).

Ross, Pergament and Anisfeld (1979) used upper and lower case letter stimuli with sixteen adult hearing subjects and sixteen adult deaf subjects fluent in sign language and found that the deaf subjects did not demonstrate a visual field preference while the hearing subjects exhibited an RVF superiority.

In conclusion, language is acquired through several stages in both hearing and hearing impaired children. The hearing impaired children as a group do not acquire the same level of language complexity as do their hearing peers. Cued speech subjects show enhanced language skills compared to the normal skills of hearing impaired subjects. Hearing subjects demonstrate left hemispheric specialization for language processing (Studdert-Kennedy & Shankweiler, 1974) and right hemispheric specialization for visuospatial (including sign language) processing (Poizner, et al, 1979; Searleman, 1977). The left hemispheric specialization is evident in subjects with and without brain damage, and subjects with ages ranging from birth to adulthood. Hearing impaired subjects demonstrate no clear-cut hemispheric specialization for language as a group. Sign language stimuli are processed more efficiently in the right hemisphere (Manning, et al., 1977). Manual alphabet letters are found to be processed by the left hemisphere (Virostek & Cutting, 1979) or both hemispheres (Phippard, 1977). Written words are also found to be processed by the left hemisphere (Kelly & Tomlinson-Keasey, 1977) or both hemispheres (Phippard, 1977).

CHAPTER III

Procedure and Methodology

Letters can be matched by name identity (Aa) or by physical identity (AA) (Posner & Mitchell, 1967). In normal hearing subjects a left hemisphere advantage is found for matching letters based on name identity (Cohen, 1972; Segalowitz & Stewart, 1979). The procedure for this study was a tachistoscopic letter matching task administered binocularly to right-handed hearing impaired children who use cued speech to communicate.

Subjects

The subjects were four male and four female prelingually deaf children from the metropolitan Washington, D.C. area who were fluent with cued speech. The average hearing loss for speech frequencies (500Hertz, 1000Hertz, 2000Hertz) was greater than 85 decibels in the better ear. All subjects were right-handed and seven years old or older. The subjects were not experienced in sign language and had no uncorrected visually handicapping condition (See Appendix B for a sample information sheet and permission slip).

Instrument

The stimuli were letter pairs in a vertical alignment on cards. The letters were A, B, H, and R. They were divided into 32 same pairs (AA, aa) and 32 different pairs (Ab, bR, BH, ra). Upper and lower case letters appeared equally in each half of a letter pair. Each matched letter pair appeared in each visual half-field (See Appendix B for the stimuli letter pairs). The order of the response condition (same/different) and the visual half-field (left/right) was random with the constraint that neither reponse nor visual field occurred more than three consecutive times.

Procedure and Scoring

The Peabody Individual Achievement Test (PIAT) (Dunn & Markwardt, 1970) Reading Comprehension subtest and Reading Recognition subtest were administered to estimate the subjects' reading abilities. The raw scores were converted to age equivalents. The number of years experience with cued speech was recorded for each subject. This information is presented in Table 1. Handedness was assessed through informal testing. The subject demonstrated how to: use a fork, use a pencil, kick a ball, look through a tube, and throw a ball. Each subject was assessed as being right-handed.

TABLE 1

Reading Scores and Years of Cued Speech

Subject (Sex)	Chronological Age	Reading Comprehension Age equiv.	Reading Recognition Age equiv.	Years Cued Speech
1 (F)	8-4	*	6-4	4
2 (M)	9-11	8-9	10-1	8
3 (M)	7-5	8-6	8-8	3
4 (F)	11-4	11-9	12-10	5
5 (M)	12-6	16-4	15-1	11
6 (F)	7-3	7-7	8-5	6
7 (M)	8-7	8-9	9-6	3 1/2
8 (F)	10-7	13-7	14-7	2 1/2

* Subject's performance insufficient to assign an age equivalent.

The stimuli were presented binocularly using two channels of a tachistoscope, with a card with a central fixation point appearing first, followed by the stimuli letters card. The stimuli letter pairs were positioned on the card three degrees to the right or the left off the center of the card in order to ensure a unilateral viewing. The duration of the fixation point card was one second. The duration of each stimulus card presentation was 175 to 185 milliseconds in order to ensure a unilateral viewing (Moses, 1970). A millisecond clock was activated with the onset of the fixation point card presentation. The response for the subject was to press a "same" or "different" button with either hand to stop the timer. Name matched cards responded to incorrectly were repeated later in the testing in order to gather the same number of "same" responses from each subject. Subjects had a trial run of sixteen cards to establish a ninety percent accuracy rate. All subjects reached the criterion of ninety percent accuracy (See Appendix C for a sample score sheet).

The mean response times for name identity and physical identity matches within each hemisphere were compared by way of a paired t-test. Language processing differences between hemispheres were analyzed through a Wilcoxon Signed Rank test.

CHAPTER IV

Results

The purpose of this study was to determine whether there is a significant difference in ability between the right and left hemispheres for processing name and physical matches of paired letter stimuli in deaf subjects. This chapter presents the analyses of the data collected from eight hearing impaired children who use cued speech.

The mean reponse time for name and physical matches in the right and left hemispheres for each subject are reported in Table 2 (See Appendix E for raw data). The difference in response times within each hemisphere for name match minus physical match were computed. A comparison between hemispheres was achieved by subtracting the name-physical difference for the left hemisphere from the name-physical difference for the right hemisphere. These differences are recorded in Table 2.

Box plots were constructed for the name - physical match response time differences within each hemisphere in order to test the normalcy of the distribution of the differences. The differences were judged as within normal limits. Paired t-tests were used to analyze the response times within each hemisphere. Each t was highly significant, with the probability of a larger t less than .0005 for both hemispheres (See Table 3). Physical matches were processed in less time than name matches in both the right and left hemispheres.

A box plot was constructed for the comparison of differences between hemispheres. The box plot revealed an outlier which indicates an abnormal distribution. The outlier would increase the variance and standard error, thus decreasing the value of a t and lessening the probability of significance when using a t-test. A Wilcoxon Signed Rank test was used to determine if the median difference between the hemispheres was significant from zero. The test t was significant at the .10 level of significance but not at the .05 level of significance. The positive mean difference between the hemispheres (.27) indicates a slight overall left hemispheric superiority for processing name-matched letter pairs.

TABLE 2

Mean Response Times and Differences
(in milliseconds)

	Right Hemisphere				Left Hemisphere	
	Name Match	Phys. Match	Diff. w/in Right	Diff. betw. R / L	Diff. w/in Left	Name Match	Phys. Match
Subj.							
1	3076	2830	246	- 26*	272	2892	2620
2	2643	2208	435	3	432	2788	2356
3	2988	2434	554	265	289	2670	2381
4	2467	2204	263	179	84	2248	2164
5	2847	2377	470	232	238	2750	2512
6	3070	2707	363	154	209	3077	2868
7	3068	3021	47	-397	444	3234	2790
8	2678	2422	256	-189	445	2827	2382

* negative difference indicates right hemisphere superiority.

TABLE 3

Statistical Analyses

Paired T-test:

$s^2 = 1/n-1(\Sigma d^2 - ((\Sigma d)^2/n))$

$t = \bar{d}/(s/\sqrt{n})$

Comparison of name match and physical match response times within right hemisphere.
degrees of freedom = 7
one-tailed test
t = 5.772
level of significance .0005

Comparison of name match and physical match response times within left hemisphere.
degrees of freedom = 7
one-tailed test
t = 6.5652
level of sifnificance .0005

Wilcoxon Signed Rank Test:

Comparison between hemispheres:
Difference in response times =
(Left:Name minus physical) minus (Right:name minus physical)
Ranking of differences:
(time in milliseconds)

	-397,	-189,	-26,	3,	154,	179,	232,	265
Ranks:	1,	2,	3,	4,	5,	6,	7,	8
Signed ranks:	-1,	-2,	-3,	+4,	+5,	+6,	+7,	+8

$\Sigma R+ = 30$
$\Sigma R- = 6$
T = 6
Two-tailed test
T significant at .10 level
T not significant at .05 level

CHAPTER V

Summary, Conclusions, and Recommendations

The purpose of this study was to determine the difference between the hemispheres for language processing abilities for name and physical matches of paired letter stimuli, using as subjects hearing impaired children who communicate with cued speech. Statistical analyses were used to evaluate the difference within each hemisphere and between the hemispheres for the response times to the stimuli. Since the sample size was small, no further statistical analysis was attempted. Other factors considered as possibly associating with hemispheric specialization for language were reading abilities and number of years experience with cued speech.

Summary

Results indicate a highly significant difference within each hemisphere for processing name and physical matches. In comparing the right and left hemisphere a difference in processing abilities was found to be significant at the .10 level of significance but not at a .05 level of significance.

A case-by-case overview revealed: two subjects with no apparent hemispheric superiority for language processing, four subjects with a left hemispheric specialization for language processing, and two subjects with a right hemispheric superiority for processing language information. The two subjects without hemispheric specialization for language processing also demonstrated reading abilities slightly below a chronological age equivalent. The remaining subjects all demonstrated reading abilities above age level. A cursory observation of the number of years experience with cued speech does not show an apparent relationship with the establishment of hemispheric specialization for language processing. The sex of the subject would not apparently be related to hemispheric specialization in the present study as each sex was equally represented in each of the three categories of hemispheric specialization (right, left, and no specialization).

Conclusions

The lack of one hemisphere emerging as clearly superior for language processing in deaf children who know cued speech is consistent with other language processing research with hearing impaired subjects. Deaf subjects exhibit either: a left hemispheric superiority for language processing (Manning, et al., 1977); a right hemisphere specialization for processing language information (Phippard, 1977); or no significant difference between the hemispheres (Ross, et al., 1979; Phippard, 1977). The present study revealed the same results when reviewed case-by-case. Four subjects demonstrated left hemispheric specialization for language processing, two subjects demonstrated a right hemispheric superiority for language processing, and two subjects did not demonstrate a superiority in either hemisphere for processing language information. Because of these mixed results, a conclusion cannot be drawn about the question of how the brain processes the cued speech code -- as a visual code or a phonetic code.

The two subjects demonstrating a right hemispheric specialization for processing language information could be developing hemispheric specialization similarly to normal hearing individuals. There is a small percentage of normal hearing right-handed persons who are superior in the right hemisphere in language processing. On the other hand, these two subjects could be following other research with hearing impaired subjects fluent in sign language who demonstrate a right hemisphere superiority for sign language stimuli (Manning, et al., 1977; Poizner & Lane, 1979). The explanation for the right hemisphere developing facility for language processing is that the sign language is transmitted through a visual code which can be processed more efficiently through the right hemisphere. Perhaps the two cued speech subjects with a right hemisphere superiority for language processing are processing the cued speech as a visual code through the right hemisphere.

The two subjects with no apparent hemispheric specialization for language processing may also be developing hemispheric specialization similarly to normal hearing populations. This is indicated by the slightly lower reading scores for these two subjects. For normal hearing subjects, research continues in an effort to establish a definite correlation (Kershner, 1977) or lack of correlation (McKeever & Huling, 1970) between reading ability and hemispheric specialization for language.

It is unclear what factors contribute to a lack of specialization. Obviously, a hearing impairment disrupts normal language learning and therefore would influence the brain's ability to develop through response to language stimulation. If the development of hemispheric specialization can be strengthened through enriched language stimulation (Starck, et al., 1977), perhaps the development is slowed down or halted when language stimulation is decreased by a hearing impairment. This conclusion is supported by previous research with adult hearing impaired subjects , who demonstrated little or no apparent specialization for language (Ross, et al., 1979; Kelly & Tomlinson-Keasey, 1977). Yet in this research with cued speech subjects, only two of the eight failed to demonstrate hemispheric superiority for language.

Researchers continue to study the factors influencing the development of hemispheric specialization. One possible conclusion from the evidence that the brain has the capability for specialization at birth is that the brain does not begin with equal potential for either hemisphere to become superior in language processing. Specialization would develop through activation by language stimulation of the capabilities available in one hemisphere at birth (Kinsbourne & Hiscock, 1977). The deprivation of language stimulation caused by a hearing impairment could cause less development of hemispheric specialization for language in the brain. Again, the results with cued speech subjects showed a lack of specialization in only two subjects. If a hearing impairment was sufficient to lessen hemispheric specialization, then six of eight subjects should not have demonstrated a hemispheric superiority for language.

A second conclusion from the evidence of hemispheric specialization at birth would be that without traumatic injury to the superior hemisphere, the minor hemisphere would not develop specialization for language processing. A hearing impairment may or may not be traumatic enough to influence a change in hemispheric capabilities at birth. The two cued speech subjects demonstrating a right hemispheric superiority for language processing might have possessed such a capability from birth. Or, perhaps the hearing impairment caused a disruption in left hemispheric capabilities at birth, so that a right hemispheric specialization developed. This second explanation would not seem consistent with the fact that four cued speech subjects demonstrated left hemispheric specialization for language processing. If the hearing impairment could disrupt the hemispheric capabilities at birth, then four subjects in this study would have to have had a right hemispheric capability for language at birth. Such a high percentage of right hemispheric specialization is totally inconsistent with the percentage found in normal hearing populations.

The four cued speech subjects with left hemispheric superiority for language processing could be developing hemispheric specialization similarly to the normal hearing population. These subjects' reading scores indicate a potential for surpassing the average deaf individual, who reads at a fifth grade level. Much of the lack of reading achievement in the deaf population is attributed to the hearing impairment causing the deaf person to lose the continuity of the grammatical information in spoken language, thus preventing the deaf person from becoming fluent in spoken language. These four subjects demonstrate a reading ability which indicates an understanding of the grammatical coding of language. They demonstrate a left hemispheric superiority for processing language information, which is similar to research results with normal hearing subjects.

Limitations and Recommendations for Future Research

Through the course of this research, limitations of this study and suggestions for further study became apparent. Future researchers should:

1. Increase the sample size to obtain a more representative sample of children who use cued

speech.

2. Increase the number of trials of the sixty-four card set for each subject in order to enhance test-retest reliability. The children were able to complete one trial of the sixty-four card set in one sitting. Separate testing dates would be required to obtain additional data from each subject in order to avoid fatigue in the subjects.
3. Further the research with cued speech subjects in order to determine the effects of age, sex, I.Q., and years experience with cued speech on the development of hemispheric specialization for language processing.
4. Further the evaluation of the evidence for right hemispheric specialization for language demonstrated by two subjects in order to discover if the percentage of cued speech subjects with right hemispheric specialization is similar to normal hearing populations.
5. Further the research to discover the contributing factors which might reduce efficiency in language processing in either hemisphere and possibly cause a lack of specialization, as demonstrated by two subjects in this study.
6. Using the procedure in this study, continue the research on normal hearing subjects comparing

language processing abilities and reading abilities in order to establish if a correlation between the two actually exists.

Through the research suggested in the present study, and through other related research, perhaps some of the secrets of hemispheric specialization in the brain can be deciphered.

REFERENCES

Barry, C. Hemispheric asymmetry in lexical access and phonological encoding. Neuropsychologia, 1981, 19, 473-478.

Bates, E. Language and context. The acquisition of pragmatics. New York: Academic Press. 1976.

Berlin, C.I., Lowe-Bell, S.C., Cullen, J.K., Thompson, C.I., & Loovis, C.F. Dichotic speech perception: An interpretation of right ear perception and temporal offset effects. In N.J. Lass, (Ed.), Experimental phonetics, New York: M.S.S. Information Corp., 1974.

Berlin, C.I, Willet, M.E., Thompson, C., Cullen, J.K., & Lowe, S.S. Voiceless versus voiced CV perception in dichotic and monotic listening. Journal of the Acoustical Society of America, 1970, 47, 75-76.

Bloom, L., & Lahey, M. Language development and language disorders. New York: John Wiley and Sons, 1978.

Branch, C., Milner, B., & Rasmussen, T. Intercarotid sodium amytal for the lateralization of cerebral speech dominance. Journal of Neurosurgery, 1964, 21, 399-405.

Brown, R. A first language, Cambridge, Mass.: Harvard University Press, 1973.

Bryden, M. Sex differences in brain organization: Different brains or different strategies? The Behavioral and Brain Sciences, 1980, 3, 230-231.

Bryden, M.P., & Rainey, C.A. Left-right differences in tachistoscopic recognition. Journal of Experimental Psychology, 1963, 66, 568-571.

Chomsky, C. The acquisition of syntax in children from 5 to 10. Cambridge, Mass.: M.I.T. Press, 1969.

Chomsky, N. Language and mind. New York: Harcourt, Brace, Javanovich, Inc., 1968.

Clarke, B., & Ling, D. The effects of using cued speech: A follow up study. Volta Review, 1976, 78, 23-34.

Cohen, G. Hemispheric differences in a letter classification task. Perception and Psychophysics, 1972, 11, 139-142.

Cornett, O. In answer to Dr. Moores. American Annals of the Deaf, 1969, 114, 27-29.

Cornett, O. Cued speech. American Annals of the Deaf, 1967, 112, 3-13.

Davis, R., & Schmit, V. Visual and verbal coding in the interhemispheric transfer of information. Acta Psychologica, 1973, 37, 229-240.

Dennis, M. Capacity and strategy for syntactic comprehension after left or right hemidecortication. Brain and Language, 1980, 10, 287-317.

Dunn, L., & Markwardt, F. Peabody Individual Achievement Test. American Guidance Service, Inc.,1970.

Eling, P., Marshall, J., & van Galen, G. The development of language lateralization as measured by dichotic listening. Neuropsychologia, 1981, 19, 767-773.

Emmerich, D.S., Goldenbaum, D.M., Hayden, L.L., Hoffman, L.S., & Treffts, J.L. Meaningfulness as a variable in dichotic hearing. In N.J. Lass, (Ed.), Experimental phonetics, New York: M.S.S. Information Corp., 1974.

Entus, A.K. Hemisheric asymmetry in processing of dichotically presented speech and nonspeech stimuli by infants. In S.J. Segalowitz & F.A. Gruber,(Eds.), Language development and neurological theory. New York: Academic Press, 1977.

Filbey, R.A., & Gazzaniga, M.S. Splitting the normal brain with reaction time. Psychonomic Science, 1969, 17, 335-336.

Fillmore, C. The case for case. In E. Bach & R. Harms, (Eds.), Universals in linguistic theory. New York: Holt, Rinehart, and Winston Inc., 1968.

Gainotti, G., Caltagirone, C., Miceli, G., & Masullo, C. Selective semantic-lexical impairment of language comprehension in right-brain-damaged patients. Brain and Language, 1981, 13, 201-211.

Geffen, G., Bradshaw, J., & Nettleton, N. Hemispheric asymmetry: Verbal and spatial encoding of visual stimuli. Journal of Experimental Psychology, 1972, 95, 25-31.

Geffen, G., Bradshaw, J.L., & Wallace, G. Interhemispheric effects on reaction time to verbal and nonverbal visual stimuli. Journal of Experimental Psychology, 1971, 87, 415-422.

Glucksberg, S., & Danks, J. Experimental psycholinguistics. An introduction. Hillsdale, N.J.: Lawrence Erlbaum Associates, 1975.

Henegar, M., & Cornett, O. Cued speech handbook for parents. Washington,D.C.: United States Department of Health, Education, and Welfare, 1971.

Kelly, R. Hemispheric specialization of deaf children: Are there any implications for instruction? American Annals of the Deaf, 1978, 123, 637-645.

Kelly, R.R. & Tomlinson-Keasey, C. Hemispheric laterality of deaf children for processing words and pictures visually presented to the hemifields. American Annals of the Deaf, 1977, 122, 525-533.

Kershner, J.R. Cerebral dominance in disabled readers, good readers, and gifted children: Search for a valid model. Child Development, 1977, 48, 61-67.

Kimura, D. Dual functional asymmetry of the brain in visual perception. Neuropsychologia, 1966, 4, 275-285.

Kimura, D. Cerebral dominance and perception of verbal stimuli. In N.J. Lass, (Ed.), Experimental phonetics, New York: M.S.S. Information Corp., 1974.

Kinsbourne, M., & Hiscock, M. Does cerebral dominance develop? In S.J. Segalowitz & F.A. Gruber, (Eds.), Language development and neurological theory. New York: Academic Press, 1977.

Kretschmer, R., & Kretschmer, L. Language development and intervention with the hearing impaired. Balitmore: University Park Press, 1978.

Leehey, S.C., & Cahn, A. Lateral asymmetries in the recognition of words, familiar faces, and unfamiliar faces. Neuropsychologia, 1979, 17, 619-635.

Lenneberg, E. Biological foundations of language. New York: John Wiley and Sons, 1967.

Liberman, A. The specialization of the language hemisphere. In F.O. Schmitt & F.C. Worden, (Eds.), The neurosciences: Third study program. Cambridge, Mass.: M.I.T. Press, 1977.

Ling, A. Dichotic listening in hearing impaired children. In N.J. Lass, (Ed.), Experimental phonetics, New York: M.S.S. Information Corp., 1974.

Ling, D., & Clarke, B. Cued speech: An evaluative study. American Annals of the Deaf, 1975, 120, 480-488.

Manning, A.A., Goble, W., Markham, R. & LaBreche, T. Lateral cerebral differences in the deaf in response to linguistic and nonlinguistic stimuli. Brain and Language, 1977, 4, 309-321.

McKeever, W.F., & Huling, M.D. Lateral dominance in tachistoscopic word recognitions of children at two levels of ability. Quarterly Journal of Experimental Psychology, 1970, 22, 600-604.

McKeever, W.F., Hoemann, H.W., Florian, V. & VanDeventer, A. Evidence of minimal cerebral asymmetries for the processing of English words and American Sign Language in the congenitally deaf. Neuropsychologia, 1976, 14, 413-423.

Miller, L.K., & Turner, S. Development of hemifield differences in word recognition. Journal of Experimental Psychology, 1973, 65, 172-176.

Molfese, D.L. Infant cerebral asymmetry. In S.J. Segalowitz & F.A. Gruber, (Eds.), Language development and neurological theory. New York: Academic Press, 1977.

Molfese, D., & Molfese, V. Cortical responses of preterm infants to phonetic and nonphonetic speech stimuli. Developmental Psychology, 1980, 16, 574-581.

Moores, D. Cued speech: Some practical and theoretical considerations. American Annals of the deaf, 1969, 114, pp. 23-27; 29-32.

Moscovitch, M. The development of lateralization of language functions and its relation to cognitive and linguistic development: A review and some theoretical speculations. In S. Segalowitz & F. Gruber, (Eds.), Language development and neurological theory. New York: Academic Press, 1977.

Moses, R.A. Adler's physiology of the eye. St. Louis: The C.V. Mosby Company, 1970.

Nicholls, G. Cued speech and the reception of spoken language. Unpublished master's thesis, McGill University, 1979.

Phippard, D. Hemifield differences in visual perception in deaf and hearing subjects. Neuropsychologia, 1977, 15, 555-561.

Poizner, H., Battison, R., & Lane, H. Cerebral asymmetry for American Sign Language: The effects of moving stimuli. Brain and Language, 1979, 7, 351-362.

Poizner, H., & Lane, H. Cerebral asymmetry in the perception of American Sign Language. Brain and Language, 1979, 7, 210-226.

Posner, M., & Mitchell, C.R.F. Chronometric analysis of classification. Psychological Review, 1967, 74, 392-409.

Ross, P., Pergament, L., and Anisfeld, M. Cerebral lateralization of deaf and hearing individuals for linguistic comparison judgements. Brain and Language, 1979, 8, 69-80.

Sarachan-Deily, A., & Love. R. Underlying rule structure in the deaf. Journal of Speech and Hearing Research, 1974, 17, 689-698.

Searleman, A. A Review of right hemisphere linguistic capabilities. Psychological Bulletin, 1977, 84, 503-528.

Segalowitz, S.J., & Chapman, J.S. Cerebral asymmetry for speech in neonates: A behavioral measure. Brain and Language, 1980, 9, 281-288.

Segalowitz, S.J., & Stewart, C. Left and right lateralization for letter matching: Strategy and sex differences. Neuropsychologia, 1979, 17, 521-525.

Shankweiler, D. Effects of temporal lobe damage on perception of dichotically presented melodies. In N.J. Lass, (Ed.), Experimental phonetics, New York: M.S.S. Information Corp., 1974.

Skarakis, E., & Prutting, C. Early communication: Semantic functions and communicative intentions in the communication of the preschool child with impaired hearing. American Annals of the Deaf, 1977, 122, 382-391.

Skinner, B.F. Verbal behavior. New York: Appleton-Century-Crofts, 1957.

Starck, R, Genesee, F., Lambert, W., & Seitz, M. Multiple language experience and the development of cerebral dominance. In S.J. Segalowitz & F.A. Gruber, (Eds.), Language development and neurological theory. New York: Academic Press, 1977.

Studdert-Kennedy, M., & Shankweiler, D. Hemispheric specialization for speech perception. In N.J. Lass, (Ed.), Experimental phonetics, New York: M.S.S. Information Corp., 1974.

Umilta, C., Rizzolati, G., Marzi, C., Zamboni, G., Franzani, C., Camarda, R., & Berlucchi, G. Hemispheric differences in normal human subjects: Further evidence from the study of reaction time to lateralized stimuli. Brain Research, 1973, 49, 499-500.

Umilta, C., Sava, D., & Salmaso, D. Hemispheric asymmetries in a letter classification task. Brain and Language, 1980, 9, 171-181.

Vargha-Khadem, F., & Corballis, M.C. Cerebral asymmetries in infants. Brain and Language, 1979, 8, 1-9.

Virostek, S., & Cutting, J.E. Asymmetries for Ameslan hand-shapes and other forms in signers and nonsigners. Perception and Psychophysics, 1979, 26, 505-508.

Wechsler, D. Wechsler Bellevue Intelligence Scale, Form II. New York: The Psychological Corp., 1946.

Wechsler, D. Wechsler Intelligence Scale for Children, New York: The Psychological Corp., 1949.

White, M.J. Visual hemifield differences in the perception of letters and contour orientation. Canadian Journal of Psychology, 1971, 25, 207-212.

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

Witelson, S., & Pallie, W. Left hemispheric specialization for language in the newborn. Brain, 1973, 96, 641-646.

Woods, B. The restricted effects of right hemisphere lesions after age one. Neuropsychologia, 1980, 18, 65-70.

Young, A., & Bion, P. Hemispheric laterality effects in the enumeration of visually presented collections of dots by children. Neuropsychologia, 1979, 17, 99-102.

APPENDIX A

Cued Speech

CUED SPEECH

English

CHART I
Cues for Vowel Sounds

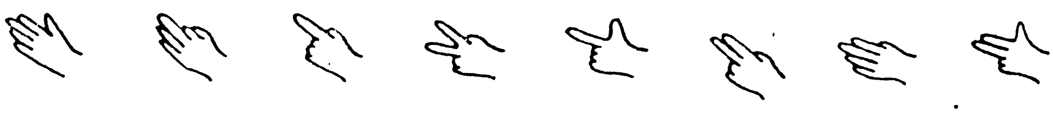
	Side	Throat	Chin	Mouth
open	ah (father) o (got)	a (that)	aw (dog)	ee (see)
flattened-relaxed	u (but)	i (is)	e (get)	ur (her)
rounded	oe (home)	oo (book)	ue (blue)	

CHART II
Diphthongs

ie (my) ou (cow) ae (pay) oi (boy)

CHART III
Cues for Consonant Sounds

t m f	h s r	d p zh	ng y ch	l sh w	k v tH z	b n wh	g j th



(reproduced from Henegar & Cornett, 1971, p.154)

APPENDIX B

Sample Information Sheet and Permission Slip

NAME OF CHILD:___________________________________

DATE OF BIRTH:___________________

HEARING LOSS (measured within last year):

LEFT: 500Hz_____ 1000Hz_____ 2000Hz_____

RIGHT: 500Hz_____ 1000Hz_____ 2000Hz_____

AGE LOSS DETECTED:_____________________

AGE HEARING AIDS FIT:___________________

OF YEARS AIDS WORN:____________________

DESCRIPTION OF LOSS: Sensorineural, Conductive, both.

YEARS EXPERIENCE WITH CUED SPEECH:________________

OF PERSONS CUEING WITH CHILD:__________

DOES YOUR CHILD KNOW SIGN LANGUAGE? (if yes, please explain)_____

HAS YOUR CHILD EVER ATTENDED CLASS WHERE SIGN LANGUAGE WAS USED ?

READING ACHIEVEMENT SCORE (if known, within 6 months):

TEST:_______________________________________

SCORE or LEVEL:_____________________________

DOES YOUR CHILD HAVE A VISUAL IMPAIRMENT?______

DOES YOUR CHILD WEAR GLASSES?_______

I give my permission for ______________________________ to participate in research on hemispheric dominance conducted by Susan Kennedy for the completion of her Masters of Science at Virginia Polytechnic Institute and State University. The specific tests will be a tachistoscopic letter matching task and the reading subtests of the Peabody Individual Achievement Test. I understand that the identity of my child will be confidential and that the results of the testing will be available to me.

Signed _________________________

Date ________________

APPENDIX C

Stimuli Letter Pairs

STIMULI LETTER PAIRS

Left		Right	Left		Right
1	AH		33	bR	
2	BA		34		rA
3		aA	35	aA	
4	Ah		36	hh	
5		HA	37		Ar
6		bH	38		Hh
7		bB	39	HR	
8	rh		40	rR	
9		RH	41	aa	
10	Rb		42		RB
11		Rr	43		Bb
12		hH	44	rr	
13		Bh	45		aa
14	hb		46		hr
15	RR		47	hA	
16		BB	48		rr
17		hh	49	Aa	
18		hb	50	rB	
19	bb		51	bB	
20	ba		52		bb
21		bh	53		RR
22		ab	54	Ha	
23		AA	55		aR
24	BB		56		BR
25	aH		57	hH	
26		AB	58		hB
27		HH	59	AA	
28	Br		60		ra
29		rR	61		Ra
30		Aa	62	HH	
31	Hh		63	Rr	
32	ar		64	Bb	

APPENDIX D

Sample Score Sheet

Name: ______________________________

	Different	Left	Right		Different	Left	Right
1	______			33	______		
2	______			34	______		
3	______			35	______		
4	______			36		* ______	
5	______			37	______		
6	______			38			______
7			______	39	______		
8	______			40		______	
9	______			41		* ______	
10	______			42	______		
11			______	43			______
12			______	44		* ______	
13	______			45			* ______
14	______			46	______		
15		* ______		47	______		
16			* ______	48			* ______
17			* ______	49		______	
18	______			50	______		
19		______		51		______	
20	______			52			* ______
21	______			53			* ______
22	______			54	______		
23			* ______	55	______		
24		* ______		56	______		
25	______			57		______	
26	______			58	______		
27			* ______	59		* ______	
28	______			60	______		
29			______	61	______		
30			______	62			* ______
31		______		63			______
32	______			64			______

APPENDIX E

Subject Response Times

Subject 1

Time in milliseconds

Physical Match Left	Name Match Left	Physical Match Right	Name Match Right
2779	3017	2591	2329
2528	2998	3465	3819
2471	3074	2517	2841
2512	3055	2714	3115
2573	2706	2740	3330
2909	2977	2615	3031
2602	2683	2906	2977
2587	2623	3096	3165

Subject 2

Time in milliseconds

Physical Match Left	Name Match Left	Physical Match Right	Name Match Right
2299	2305	2247	2635
2663	2664	2197	3022
2058	2971	2164	2703
2212	3066	2394	2180
2489	2907	2406	3050
2132	2253	2105	2679
2443	2843	2136	2173
2557	3297	2019	2702

Subject 3

Time in milliseconds

Physical Match Left	Name Match Left	Physical Match Right	Name Match Right
2834	3134	2272	3008
2453	1849	2856	3063
2325	3125	2267	3417
2777	2626	2959	2737
2221	3253	2284	3411
1998	2009	2351	3038
1910	2985	2298	2482
2531	2378	2189	2751

Subject 4

Time in milliseconds

Physical Match Left	Name Match Left	Physical Match Right	Name Match Right
2309	2097	2419	2739
2114	1807	2201	2679
2200	2692	2062	2569
2210	2130	2127	2702
1949	2492	2151	2622
2290	2138	2223	2146
2239	2254	2177	2131
2003	2375	2274	2148

Subject 5

Time in milliseconds

Physical Match Left	Name Match Left	Physical Match Right	Name Match Right
3032	2725	2690	3194
2739	2648	2767	3230
2436	2665	2167	3089
2318	2527	2275	2918
2394	2768	2322	2864
2505	2875	2373	2307
2153	2403	2306	2596
2519	3386	2195	2580

Subject 6

Time in milliseconds

Physical Match left	Name Match Left	Physical Match Right	Name Match Right
2498	3098	3050	3038
2917	2882	2793	3278
2823	3662	2698	2992
2722	3203	2581	2959
3584	3300	2521	2628
2825	3012	2666	2951
2698	2766	2650	3327
2873	2690	2699	3456

Subject 7

Time in milliseconds

Physical Match Left	Name Match Left	Physical Match Right	Name Match Right
2740	2677	3400	3024
2694	2709	2762	3080
2387	2995	2698	3364
2832	2805	2937	2727
3015	3790	3990	2867
3210	3008	2792	2611
2582	4972	2706	3106
2859	2839	2884	3767

Subject 8

Time in milliseconds

Physical Match Left	Name Match Left	Physical Match Right	Name Match Right
2204	2750	2484	2345
2184	2601	2278	2388
2334	3410	2686	2402
2426	2447	2755	2347
2377	3165	2300	3170
2934	2584	2226	2632
2380	2941	2165	3100
2215	2721	2486	3044

APPENDIX F

Analyses

Paired t-test:

$s^2 = 1/n-1(\Sigma d^2 - ((\Sigma d)^2/n))$

$t = \bar{d}/(s/\sqrt{n})$

Right hemisphere:

Comparison of the difference,

Name match minus Physical match

$\Sigma d^2 = 1.046$

$(\Sigma d)^2 = 6.9379$

$\bar{d} = .329$

$\sqrt{n} = 2.827$

$s^2 = 1/7(1.046 - (6.9379/8))$

$s^2 = .026$

$s = .162$

$t = .329/(.162/2.827)$

$t = 5.772$

t highly significant

Left hemisphere:

Comparison of the difference,

Name match minus Physical match

$\Sigma d^2 = .848$

$(\Sigma d)^2 = 5.822$

$\bar{d} = .302$

$\sqrt{n} = 2.827$

$s^2 = 1/7(.848 - (5.822/8))$

$s^2 = .017$

$s = .13$

$t = .302/(.13/2.827)$

$t = 6.5652$

t highly significant

Comparison of the difference between hemispheres:

(Left:name minus physical) minus (Right:name minus physical)

Wilcoxon Signed Rank test

Differences:	-397,	-189,	-26,	3,	154,	179,	232,	265.
Ranks:	1,	2,	3,	4,	5,	6,	7,	8.
Signed ranks:	-1,	-2,	-3,	4,	5,	6,	7,	8.

$\Sigma R- = 6$ $\Sigma R+ = 30$

$T = 6$

T significant (two-tailed) at .10 level of significance.

T not significant at .05 level of significance.

The vita has been removed from the scanned document

HEMISPHERIC SPECIALIZATION IN HEARING IMPAIRED CHILDREN WHO KNOW CUED SPEECH

by

Susan Kennedy

(ABSTRACT)

Hemispheric specialization for language processing is demonstrated as a left hemispheric function for most normal hearing right-handed subjects. Hearing impaired subjects, however, do not demonstrate a predictable hemispheric specialization for language processing. This research used a matched letter pair stimulus presented tachistoscopically to four male and four female right-handed, profoundly deaf children who use cued speech to communicate. Analysis of the test data shows a small significant trend towards left hemispheric specialization for language processing. A case-by-case review reveals that four subjects demonstrated left hemispheric specialization for language processing, two subjects demonstrated right hemispheric superiority for language processing, and two subjects did not demonstrate superiority for language processing in either hemisphere. A larger sample size would be required to determine if the cued speech subjects develop hemispheric specialization the way normal hearing subjects do or whether they develop the inconsistent pattern of specialization of other deaf subjects.