UNIVERSITY OF ALBERTA

Laterality of Deafness and the Acquisition of Language

BY

Robin Hill ©

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for a degree of Master of Education.

in

SPECIAL EDUCATION

DEPARTMENT OF EDUCATIONAL PSYCHOLOGY

EDMONTON, ALBERTA

FALL, 1992

ISBN 0-315-77208-5

UNIVERSITY OF ALBERTA

RELEASE FORM

NAME OF AUTHOR: Robin Clifford Cowan Hill

TITLE OF THESIS: Laterality of Deafness and the Acquisition of Language

DEGREE: Master of Education

YEAR THIS DEGREE WAS GRANTED: 1992

RCHill Aug 7, 1992

student's signature

11724 - 42 Avenue, Edmonton,
Alberta, T6J 0W7
438-6106

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled Laterality of Deafness and the Acquisition of Language submitted by Robin Clifford Cowan Hill in partial fulfillment of the requirements for the degree of Master of Education.

M. Rodda

supervisor, M. Rodda

H. Ilott

D. Baine

Abstract

In this thesis, the idea that the specific laterality of a hearing impairment (whether a person is more impaired on the right side or the left side) may have an influence on the acquisition of language is discussed. Factors affecting language development in deaf people, and the way in which hearing loss is measured are also discussed. Studies of brain lateralization are reviewed and the effect of hearing impairment on the development of cerebral organization is considered. It is concluded that previous studies support the hypothesis that the laterality of a hearing impairment may have an impact on language development.

Subjects were selected by reviewing the school records of hearing impaired students at the Alberta School for the Deaf, and the Edmonton Public School Board. Dependent measures were three of the Canadian Achievement Tests (Total Reading, Spelling, and Total Language). Using t-tests and Mann-Whitney tests, no significant difference was found between the independent measures - female and male, less impaired and more impaired, and between right ear advantaged and left ear advantaged subjects ($p = 0.10$, one tailed). A multiple regression analysis to determine the predictive value of the three independent variables in estimating the dependent variables did not yield significant results ($p = 0.10$).

Acknowledgements

The author would like to thank the committee, especially Michael Rodda and David Baine for their patient guidance during difficult times. Further thanks must go to the Alberta School for the Deaf and the Edmonton Public School Board for the use of student records.

Table of Contents

List of Tables

Chapter 1
INTRODUCTICN

The Problem

In general, hearing impaired people experience greater difficulty in acquiring expressive and receptive English skills than do hearing individuals. The purpose of this thesis was to investigate the possibility that one factor influencing the difficulty with which a hearing impaired person acquires language is the specific laterality of the hearing loss. The study is based on the fact that the left hemisphere of the brain (in most people, at least) regulates verbosequential tasks, while the right hemisphere controls visuospatial tasks (Springer & Deutsch, 1981). It was proposed, therefore, that stimuli arriving at the left hemisphere are more important for language acquisition than are those that arrive at the right hemisphere. For a person with a hearing loss differing in degree laterally, less effective residual hearing stimulating the left hemisphere may provide a greater detriment to language acquisition than a hearing impairment that is greater on the right side.

A variety of factors influence a deaf person's ability to acquire language. The age at onset of deafness and degree of hearing loss (or level of residual hearing) have been shown to affect language development (Bamford & Saunders,1985). Allen (1986) found that girls managed better than did boys and those in an integrated setting did better than did those in a segregated setting. Level of intelligence was found by Conrad (1979) to have a significant effect, and Levine (1981) described a variety of family influences that could shape language development. A study by Yoshino (1983) suggested that being aided in the right ear is more important for auditory motor training than is being aided in the left ear, allowing for the possibility of a laterality difference in language development.

Purpose of the Study

General objectives.

This study used information from school records. High school aged students with a prelingual severe or profound hearing loss were grouped according to three factors. They were separated into groups by sex, degree of hearing impairment and laterality of hearing loss. Results on the language component of a set of standardized tests (Canadian Achievement Tests) were used as a measure of language skill. One purpose of the study was to determine whether such a retrospective analysis could be used to identify the same language skill differences according to sex and degree of hearing impairment that others have found. Furthermore, an effect due to laterality of hearing loss was sought by correlating standardized test score information with audiometric information obtained from school records.

Hypotheses.

Three specific research hypotheses were formulated:

1. Females with a hearing impairment will perform better on a language task than will males with a hearing impairment.

2. Individuals with a lesser degree of hearing impairment will perform better on a langauge task than will individuals with a greater degree of hearing impairment.

3. Individuals with more residual hearing in their right ear than in their left ear (right ear advantage) will perform better on a language task than will individuals with more residual hearing in their left ear than in their right ear (left ear advantage).

Implications and Limitations

Implications.

Since it appears that the hemispheres of the cerebrum are specialized for general functions at a young age (Kinsbourne & Hiscock, 1977, Witelson, 1977, Young, 1977), this study may give clues to the brain's plasticity. If individuals deafened more in the right ear have greater trouble with language, it may be that the brain cannot adequately adapt its neural pathways so that the left auditory cortex gets the stimulation it needs, or that the functions the left hemisphere does not perform as a result of sensory deprivation are not adequately assumed by the right hemisphere.

Currently, level of hearing impairment is used as a very rough predictor of the difficulty with which an individual will find language learning. It was thought this study might help to refine that prediction somewhat by demonstrating that the specific hearing impairment of the right ear is a better predictor of language difficulties for persons having severe or profound hearing impairment than is the degree of deafness in general.

Similarly, during the 1980s, cochlear implants have been surgically placed in many hearing impaired individuals. They are placed unilaterally and results of these implants have been mixed. In some cases, the implant results in major improvements, and in others the results are disappointing. This study explored whether or not one predictor of the success of a cochlear implant might be based on the ear which receives it. On the other hand, if the study had found no differences in language skills between those with right and left lateralized hearing impairments, it may be that the brain is capable of dealing with a sensory deprivation by the functional adaptation of its pathways to other purposes.

Limitations.

This study is by nature exploratory. Data collected retrospectively from school records present some limitations. It would be impossible to establish with certainty cause and effect relationships, since other potential causes cannot be conclusively ruled out. Too many extraneous variables cannot be controlled. All standardized tests were administered in a school setting by teachers. However, the tests were administered at different times by different people in different places. Employing different testers and different settings are potential sources of test unreliability. While the same test was administered to all subjects, different levels of the test were used. Therefore, different items were used in assessing the subjects. All subjects being measured by the same level of the test would have been preferable.

The standardized tests used (Canadian Achievement Tests) were designed for English speaking Canadian students. The tests were not designed for hearing impaired students, they have not been normed for hearing impaired students, and as far as the author is aware, no validation studies of their appropriateness for the deaf population have been carried out. Therefore, it is not possible to know with precision what the tests are measuring when they are used with the deaf population.

The students' audiometric tests were also administered at various times by different people. Ideally one person, using the same standardized setting and equipment should have done all the audiometric testing. Furthermore, it is not known exactly what differences in impairment between ears are enough to produce a measurable effect on language development. It may be that a laterality effect can only be found if all subjects had a larger difference in residual hearing between ears.

It cannot be known from school records whether all subjects have language skills localized in the left hemisphere. Although 96% of right handers have language localized in the left hemisphere, only 70% of left handers have language localized in the left hemisphere (Springer & Deutsch, 1981). It is not possible to know from school records whether subjects are right or left-handed. So, while the assumption was made that the subjects process language in their left hemispheres, that assumption is probably incorrect for a small percentage of the subjects.

Deaf students present a very diverse population, and there are clearly a large number of influences on the language development of a deaf person. Therefore, in this study there was a large degree of within groups variance. This problem was particularly acute since the group sizes were small.

According to Smith and Glass (1987, p. 77), "The greater the variance within the groups, the smaller the t. With larger samples, the chances of reaching significance are greater, other things being equal." If it had been possible to have had access to a larger sample of subjects, it may have been easier to isolate a laterality effect from the myriad of cognitive and environmental factors that influence language development in hearing impaired people. However, the present sample represents the largest number of subjects practically accessable.

These limitations were considerable. Nonetheless, the question was important enough, and the potential for exciting results great enough, to have made this study well worth carrying out. A lack of a significant difference between those with a right ear advantage and those with a left ear advantage does not necessarily show that a laterality effect does not exist. If nothing else, this study could provide a foundation for other studies to be built upon.

Chapter 2
REVIEW OF THE LITERATURE

Lateralization and Language

Numerous studies have shown that in most people the left cerebral hemisphere is primarily responsible for speech. (see Springer & Deutsch, 1981). Rasmussen and Milner (1977) have shown that 96% of right-handers, and 70% of left-handers have speech lateralized in the left hemisphere. The remainder of the population exhibit speech lateralized in the right, or show no speech lateralization. Bryden (1988, p. 509) summarized, "The left hemisphere has been described as verbal, analytic, linear, and a serial processor of information, whereas the right hemisphere is considered to be a spatial, nonverbal, holistic, a parallel processor and creative." While left hemisphere damage often results in difficulty with language, right hemisphere damage is likely to result in perceptual or attentional problems, or problems with spatial orientation and memory for spatial relationships (Springer & Deutsch, 1981). For example, a person with right hemishere damage may have difficulty in learning their way around a new building or even be disoriented in a familiar setting.

It is difficult to trace an exact neuroanatomical pathway from the ear to the brain. The auditory nerve makes its way to the neurons of the cochlear nuclei in the hindbrain. From there the signal travels to the pons where the fibres decussate. Eventually, the signal arrives at the thalamus. The thalamus acts as a relay centre for most signals entering the cerebral cortex. Since the fibres decussate, and the signals from the cochlea are distributed by the thalamus, it would appear that there is not a strong laterality of stimulation. However, studies (for example, Heffner & Heffner, 1989, Scherg & von Cramm, 1986) showed that for practical purposes, auditory signals cross, stimulating predominantly the contralateral hemisphere. These studies and their findings will be discussed in more detail later.

Hemispheres and Language

Springer and Deutsch (1981) described a study by the Hoskins Laboratories in which it was found that the left hemisphere is better at decoding extremely rapid transitions in frequency that are part of speech sounds. In dichotic listening tasks, right-handed subjects showed a right ear (therefore left hemisphere) advantage for consonant - vowel syllables such as "ba," "da," and "ga." These sounds differ only in terms of the rapid frequency changes that take place in the first 50 milliseconds or so of the syllable, so the left hemisphere appears to have an advantage over the right hemisphere in processing this quickly changing information.

So, in general, the left hemisphere deals with language and sequential skills, and stimuli that contain rapid transitions in frequency. The right hemisphere tends towards spatial, nonverbal processing.

An analysis of rapid frequency changes shows that sounds we hear as "b" are different in "ba" from those we hear as "b" in "be" or "bo". Yet, even though the physical properties of the sound are different, in each case we perceive an identical "b" sound. It is speculated that the reason the sounds are perceived in the same way is that to produce the sounds, we would have to undergo the same muscle actions.

The motor theory of speech (Rodda and Grove, 1987) states that speech is perceived in reference to its articulation. A specific movement of the lips makes a "b" sound, a movement of the tip of the tongue makes a "d" sound, and a movement of the back of the tongue makes a "g" sound. Therefore, in analysing speech, the brain is analysing what it would do in order to make that sound. This can explain why people with different sounding voices or even accents can be understood readily, even though the physical sounds produced vary from person to person. Furthermore, this theory implies that fine motor sequences are an inseparable part of our language communication system.

Nature/Nurture and Language Development

If the specific laterality of a hearing impairment influences the nature of language development, it is only one of many factors to do so. In some cases, there may be an interaction effect between other factors and the laterality of the hearing impairment. Other factors, such as environmental influences, probably affect language quite independent of the effects of laterality. It is necessary to outline various factors affecting language development among the deaf in order that laterality and language development can be viewed in the proper perspective.

Nature

One school of thought that says humans all have an innate linguistic potential. The best known advocate of this position is Noam Chomsky (see Levine, 1981 for a more detailed description). Chomsky feels humans have an innately determined language responsible cognitive structure (LRCS) localized neuroanatomically. If all people are born with such a neural structure, it would explain why children from many different cultures acquire language easily, rapidly, and in a more or less fixed developmental schedule. It would also explain why all languages have some common systematic features. Chomsky also postulates a transformational-generative grammar - an innate understanding of the rules of grammar. Linguistic competence is the theoretical ability to use this grammar competently. In reality, all of us possess only some degree of linguistic performance - the actual productions of the language user.

The presence of a genetically determined language centre seems to be consistent with the observations that cerebral organization appears to be rather consistent among people. If there is such an innate language centre, an important question is: To what extent, if any, does deafness disrupt the normal imprinting of language onto the genetic program? To what extent can lipreading or sign language build from the same program that determines oral/aural language competence?

Nurture

Not everyone accepts Chomsky's view of the importance of an innate cognitive structure. Campbell and Wales (1970) believed that Chomsky's view greatly underestimated the effects of the environment on language development, in particular, the importance of parent-child dialogue. Streng, Kretschmer, and Kretschmer (1978, p 45) stated, "Evidence is accumulating that caretakers, usually although not always mothers, all over the world talk in special ways to very young children and that these strategies of communication seem best adapted to what children need to hear at any given point in order that communication may be fostered." This pattern of social interaction would be disrupted by deafness. Streng et al. went on to point out that upon learning that their child is deaf, parents go through a psychological shock process that seriously inhibits their ability to function as parents and to establish meaningful communication. In a similar way, Bamford & Saunders (1985) felt that the contextual aspects of language acquisition must not be underestimated. They suggested that researchers must look at how deafness alters normal adult-child interactions. If children are born with some form of a LRCS and stimuli from the environment are intended to be imprinted on it, a hearing impairment would affect the nature of those stimuli. Moreover, deafness alters the nature of the social interactions that would stimulate a child's nervous system.

In comparing language acquisition in hearing and deaf children, Levine (1981, p. 54) stated, "As hearing babies become increasingly aware of the sounds in their environment the visual and touch hunger that guided their earlier explorations are gradually matched if not exceeded by auditory hunger." She lists a series of stages through which this auditory hunger takes the baby. First, babies begin to attend. Second, they perceive differences in sound. Third, they discover they produce sounds. Fourth, their own sounds stimulate increasing vocalization. Fifth, differences take on meaning, specific sounds take on meaning, and words are associated with concepts. Sixth, it becomes a game to listen, imitate, practice and experiment. Seventh, language begins to fill an expressive and receptive need and aids thinking. In contrast, vocalizations of a deaf baby diminish and cease, and there is no beginning speech. Hearing babies listen, but deaf babies watch. Deaf babies try to glean meaning from facial expression and body movements, but they are largely an onlooker in comparison to their hearing peers.

To what extent does the nature of the communication deaf children are exposed to affect their language development? Some deaf children learn their language through lipreading, but Conrad (1979) claimed that, on average, hearing children are better lipreaders than are deaf children. Rodda and Grove (1987) described lip readers as gamblers. Presumably some children are better gamblers than others. Language development for an oral, deaf child may be affected by whether the deaf child's family happens to be easy to lipread. On the other hand, using sign language may interfere with the acquisition of English. Spoken language is temporal, but Cumming and Rodda (1985) asked to what extent lipreading is spatial or temporal, and to what extent sign language is spatial or temporal. Is communication of the deaf right brain or left brain? Even if deaf and hearing communcation are both processed by the left brain, are they processed in the same way? These questions are important to understand how the specific laterality of a hearing impairment could influence language acquisition.

Levine (1981) also said, "A hearing child acquires language through audition, but a deaf child must memorize it piece by piece" (p. 71). Although Levine uses the word "language," it is clear that she is referring to English. Levine continued, stating that increasingly hearing children create their own language through vocalizations. Deaf children, on the other hand, have language imposed from outside. For deaf persons, Levine concluded, language means learning to memorize, while for hearing children, it means learning to think, learning to communicate, and learning to learn. Language would appear to take on increasingly different functions as deaf and hearing children grow.

Another factor important to the acquisition of language is the age of the child at the onset to the deafness. Is there a critical period for language learning, and how long does it last? Conrad (1979) considered any onset of deafness before the third birthday to be prelingual. In contrast, Bamford and Saunders (1985) felt that a child who becomes deaf at any time during the first year has a significant advantage over a child who is born deaf. The authors also felt that the time between between onset and diagnosis was critical, as well as the time amplification and rehabilitation were provided. For a child born deaf, Bamford and Saunders stated that being fitted with hearing aids at 9 months is too late, but, on the other hand, the authors wondered what effect identifying a child as deaf this early does to the parent-child relationship.

The etiology of the hearing impairment or other handicaps could have an effect on the acquisition of language skills. Rodda and Grove (1987) discussed various hearing impairments that occur at or around the time of birth. They found that some causes are associated with possible or probable additional impairments to deafness. These are: rubella, Rh incompatability, meningitis, the drug teratogen, trauma in utero or at birth, low birth weight and anoxia. On the other hand, other causes of hearing impairment are likely to exist without other handicaps. These are: genetics, mumps, otitis media and the drug ototoxin. It is likely that most studies of the deaf have included some subjects with accompanying impairments and some subjects without.

Factors Correlated With Language Development

Intelligence has an important role to play in the acquisition of language by deaf people. Conrad (1979) described intelligence, as measured by the Raven's Progressive Matrices, as having a highly significant effect on language development. There are different views on the interaction of language and intelligence. Vygotsky (1962) saw the two as tightly intertwined, with the presence of language and the nature of language determining intellectual development. On the other hand, Furth (1966) felt that while language is a useful tool, thinking can develop without language. Nonetheless, it is safe to say that the level of intelligence will affect a deaf child's ability to acquire language and language acquisition in turn will affect a child's intellectual growth.

Some interesting studies have compared other factors that influence language development among the deaf. As well as Conrad's description of a significant correlation of language skill with intelligence, Allen (1986) found some factors that are related to the development of reading comprehension skills among deaf children. Being female, and attending a local school showed a moderately positive correlation with the development of good reading comprehension skills. Evidence will be presented later that suggests that females may have a biological difference that affects language development, although social differences may interact with, or perhaps even cause this biological difference. Being tested in 1983 as opposed to 1974 showed a strong positive correlation with the development of good reading comprehension skills. Perhaps diagnosis, and intervention procedures have improved (or perhaps causes of deafness have changed). On the other hand, having a profound as opposed to less than profound hearing impairment showed a weak negative correlation with the development of good reading comprehension skills. This finding is in agreement with evidence showing that residual hearing is important (Bamford & Saunders,1985). Having the onset of the hearing impairment before the age of three and having one or more physical handicaps showed a weak negative correlation with the development of good reading comprehension skills, and having one or more cognitive handicaps in addition to a hearing impairment showed a strong negative correlation with reading comprehension skills. These many influences on the language development of hearing impaired people emphasize the importance of the etiology of a hearing impairment in relation to language development. Many studies group subjects that are hearing impaired and have other impairments with subjects that have deafness as their only impairment. Such a grouping of subjects should be a concern since the two samples can be expected to vary in language skill.

Wolk and Schildroth (1986) looked for factors related to a hearing impaired child's ability to speak. The authors found that for children with a less than severe hearing impairment, 86% had intelligible speech, for those with a severe or profound hearing impairment, only 24.7% had intelligible speech. For children who spoke only, 90.4% had intelligible speech; for those that spoke and signed, 40.2% had intelligible speech, and for those that signed, only 6.9% had intelligible speech. Of those with no academic integration, 31.1% had intelligible speech, and for those with some academic integration, 64.6% had intelligible speech. For those with no other handicapping conditions, 47.3% had intelligible speech and for those with some other handicapping conditions, 39.1% had intelligible speech. While these studies do not show a cause-effect relationship, they illustrate that groups of deaf children in a variety of settings and from a variety of backgrounds have very diverse communication skills. Something, or more likely, many things, innate and environmental influence this diversity. It is likely that many factors interact in subtle ways, making it difficult to isolate one specific cause influencing language development.

Degree of Hearing Loss

Hearing loss is usually measured in terms of the ability to perceive a pure tone at 500, 1000, 2000 and sometimes 4000 Hz. (Rodda & Grove, 1987). The sound stimulus can be transmitted through air (auditory canal) or bone (skull). Regardless of how hearing is measured, it is possible to define categories of hearing impairment. For example, Rodda and Grove (1987) described, a mild hearing loss as a loss of not more than 40 dB, a moderate loss as a 41 - 55 dB loss, a moderately severe loss as a 71 - 90 dB loss and a profound loss as a greater than 90 dB loss. Unfortunately, not everyone uses the same cut-off points. For example, Bamford and Saunders (1985) used 40 or less as mild, 41 - 70 as moderate, 71 - 95 as severe, and greater than 95 as profound. Does a profound loss start at 90 or 95 dB? Unless specific data is provided, a reader cannot be confident that different studies have used the same measurement criteria in defining their populations.

Bamford and Saunders (1985) described work by Conrad that demonstrated that the degree of hearing loss was a significant predictor of reading skill. A reading age was established using the Brimer Wide-Span Reading Test for 359 prelingually hearing impaired youths attending British special schools. Results were as shown in Table 2.1.

Bamford and Saunders reported an important transition at 85 dB. Only 25% of subjects with a hearing impairment of greater than 85 dB had a reading age of less than 7:0, while 50% of subjects with a hearing impairment of greater than 85 dB had a reading age less than 7:0. As well, 8% of those with a hearing impairment of less than 85 dB had a reading age equal to their chronological age, while only 2% of those with a hearing impairment of greater than 85 dB had a reading

Table 2.1

Relationship Between Hearing Loss and Reading Age

Hearing Loss (dB)	Mean Reading Age (years:months)
< 66	10:4
67-85	10:1
86-95	9:1
96-105	8:11
> 105	8:3

age equal to their chronological age. This cut-off at 85 dB is significant since most studies consider such deafness to be a severe or profound hearing impairment (e.g. Marcotte, 1985). Such a categorization would lump together subjects on both sides of the 85 dB cut off. In fact, Bamford and Saunders' report showed that a group including individuals with a severe or profound hearing impairment would be a group that is far from uniform in terms of reading age.

This study shows that there is a continuum of impact with increasing hearing loss. Every increased level of hearing loss correlates with a reduction in reading age. One might think that the residual hearing of persons with a 95 - 105 dB loss would have no value for the development of language, but such a loss apparently leaves them better off than those with a greater than 105 dB loss. It would seem to be best to conclude that any residual hearing can have value, and the more residual hearing one has, the better off one is for the acquisition of language.

Measurements from the pure-tone test are graphed. Often, the result is plotted as a sloping or, less frequently, a U shaped audiogram, thus making it difficult to attribute a specific number to the impairment. For this reason, Bamford and Saunders (1985) pointed out that a pure-tone audiogram cannot be considered an exact predictor of speech and language competence. As well, they pointed out that consonants are spoken more quietly than are vowels; consonants have the highest frequency of spoken sounds, and consonants are the major source of speech intelligibility. It makes sense, therefore, that a hearing loss that slopes towards profound at higher frequencies would have a greater impact than would one that does not.

Borchgrevink (1982) described the brain as a central pattern analyser that "appears to work with the harmonic frequency pattern as a kind of template for sound analysis." He felt that speech perception is a function of a listener's ability to synthesize relevant sentence completions. Pure-tone audiometry involves no test of synthesis skills, so pure-tone audiometry is an insufficient measurement tool for the prediction of speech perception abilities. Bamford and Saunders (1985) suggested that any of the audiometric speech tests are of more practical value than is a pure-tone audiometric test. The authors described an audiometric speech test as one that measures the ability to perceive phonemes (words) and grammar (sentences). A unit of measurement can be the speech reception threshold (SRT) at which an individual can identify 50% of what is presented to them, or the speech awareness threshold (SAT) at which the individual is aware of the presence of speech 50% of the time. While such a test may lack the simplicity and precision of a pure-tone test, it is a more valid indicator of the individual's ability to perceive speech sounds.

Effects of Laterality

It is clear that the left hemisphere is the language hemisphere for most people. Springer and Deutsch (1981) reported that the left hemisphere also processes nonsense syllables and even speech played backwards. This finding suggests that the stimuli don't have to be language, as long as they are verbal in some way. The authors also pointed out that for people with speech lateralized in the left hemisphere, there is more right hand movement during talking than there is left hand movement. This observation implies that expressive hand movements associated with speech are lateralized and influenced by the speech centre.

Bryden described findings related to laterality as being conflicting, but suggested that it appears that "poor readers are born with a damaged or poorly developed left hemisphere, so that language is less clearly lateralized in these people" (1988, p. 515). Many studies have shown male/female differences in laterality. McGlone (1978) found a greater verbal IQ deficit in males than in females following similar left hemisphere lesions. Kimura and Harshman (1984) reviewed a large number of studies of recovery of function following left hemisphere strokes. They found that recovery of speech was better in women than it was in men. They concluded that expressive language is more symmetrical in females than it is in males. Kimura and Durnford (1974) found that females have less robust lateralization than do males. Goldberg and Costa (1981) concluded that the left hemisphere development is completed later than is right hemisphere development, and development of laterality is completed earlier in females than in males. So, lateralization is somewhat different in females than in males. It is interesting to recall that Allen found that deaf girls were significantly better at language than were deaf boys. The data seem to suggest that whether the disruption to neural organization is due to a lesion or deafness, females are either less affected, or better able to adapt than are males.

Netley and Rovet (1988) looked for laterality differences in individuals with chromosomal abnormalities. They found that Turner Syndrome women (one X chromosome only) developed their laterality early and showed strong verbal skills and weak spatial skills. On the other hand, individuals with too many sex chromosomes (XXX, or XXY) developed their laterality more slowly and had strong nonverbal abilities and weak verbal abilities. This observation suggests that the physical structure resulting from human genetic endowment influences cerebral organization and the pattern of its development, and that this organization and development is not entirely environmentally determined.

Hearing and Laterality

There is evidence that neural pathways are predominantly cross lateral between ears and the cerebral cortexes. Heffner and Heffner (1989) showed that monkeys with damaged auditory cortexes experienced a hearing loss in the opposite ear. This condition appears to be the case for humans as well. Scherg and von Cramon (1986) found that for humans, a lesion of the auditory cortex resulted in difficulty with auditory discrimination on the contralateral ear. There is also evidence that the brain is lateralized aurally for verbosequential stimuli. At the Montreal Neurological Institute, Kimura (1973) exposed patients with temporal lobe damage to pairs of digits (e.g. 1,9). Subjects had to report three pairs after they were presented in rapid succession. Patients with left temporal lobe damage reported the digits more poorly than did patients with right temporal lobe damage. As well, patients were able to report digits presented to the right ear more accurately than they were able to report digits presented to the left ear. Such a right ear advantage was also found for persons without brain damage. These results show that the left hemisphere is, for practical purposes, connected to the right ear.

This evidence is rather surprising, since both hemispheres have access to signals from both ears. That is because the ears are connected to both the contralateral and ipsilateral hemispheres, and the hemispheres are connected by the corpus callosum and other commisures. It is interesting, therefore, that Kimura found that contralateral signals are more effective than are ipsilateral signals when the left and right ears are required to process different signals simultaneously. She suggested that when there are two simultaneous signals, the ipsilateral signal is suppressed. Of course, a signal can proceed from the left ear to the right hemisphere and then across to the left hemisphere via the corpus callosum. However, Bryden (1982) found that such stimulation lacks efficiency. He concluded that a signal from the left ear arriving at the left hemisphere via the corpus callosum is less effective because such crosslateral transmission takes time, and images or messages received in this way are somehow less clear than are direct messages transmitted through the contralateral path.

Deafness and Laterality

Despite differences in experience between deaf and hearing people, is brain organization the same in the two groups? Rodda & Grove (1987) reported that there is conflicting evidence on the exact nature of, or even the existence of differences in lateralization between deaf and hearing people. They noted methodological concerns, including the concern that different methods of measuring laterality may not be measuring the same thing. With that caution in mind it is appropriate to look at some studies of laterality and deafness.

Sarno, Swisher and Sarno (1969) reported that deaf people who have strokes seem to be affected in the same way that hearing stroke sufferers are affected. Kimura, Battison and Lubert (1976) found that left hemisphere damage is associated with manual communication disorders. Ross (1983), and Panou and Sewell (1984) concluded that sign language is processed in the left hemisphere, just as is oral/aural language. Poizner (1984) found that for deaf signers, non-language, visual spatial processing is similar to that of a hearing person. This finding was taken to imply that the processing of sign language and non-language visual spatial stimuli are separate functions, even though sign language is a visual and spatial medium. Such evidence has led some (Bellugi, 1989; Marshall, 1986) to suggest that the left hemisphere has an innate predisposition for language, regardless of the language's modality.

In general, these findings would seem to be in agreement with the motor theory of speech. It could be that a left hemisphere disorder that results in a language disruption is really a problem of motor sequencing. Any conclusion that sign language and speech must be processed in the same way, since they are both disrupted by a left hemisphere lesion, could be a gross oversimplification. The motor theory of speech would state that speech and sign language are both disrupted by left hemisphere damage because they both rely on complex motor behavior. The specifics of the processing disruptions could be quite different, yet some form of language disability is an inevitable result.

Even though such differences in processing are difficult to isolate, some researchers feel they exist. Arnold (1983) concluded that the left hemisphere plays a much smaller part in hearing impaired people and the right hemisphere a much greater part compared with hearing people. Bellugi, Poizner, and Klima (1983) studied deaf adults who used American Sign Language (ASL) and found that specific damage within the left hemisphere led to selective impairment of certain components of sign language. Scholes and Fischler (1979) felt that although hemispheric asymmetry doesn't develop normally in the deaf, deaf individuals do develop the analytic skills needed to deal with the structure of language.

Development of Lateralization and the Effect of Early Deafness

To what extent does a template upon which language is to be imprinted exist at birth, and to what extent does any such template result from interaction with the environment? Studies of brain lateralization in infants can give us a clue. There is ample evidence that brain lateralization exists soon after birth. Kinsbourne and Hiscock (1977), Witelson (1977), and Young (1977) suggested that hemispheric lateralization is present at birth. Entus (1977) showed that in dichotic listening studies of infants a few weeks of age there is a right ear advantage for processing verbal material and a left ear advantage for processing nonverbal material.

Marshall (1980) made the case that language or speech related asymmetries can be detected in infants. He noted that even in infants, the left temporal lobe is larger than is the right temporal lobe and wondered if behavioral asymmetries are related to morphological asymmetries. As a point of comparison, he observed that the sensory and motor cortex for the hands is much larger than is the region of the cortex responsible for the entire trunk of the body, suggesting that size is related to functional importance. Marshall also discussed the electrical output of the brain of infants. He found that evoked potentials to simple visual and auditory stimuli showed hemispheric asymmetries. As well, the average evoked potential is larger over the left hemisphere for words and syllables and larger over the right hemisphere for noises.

Best (1988) found that an infant's left hemisphere may be particularly responsive to rapidly changing acoustic information, whereas the right hemisphere is more responsive to steady state spectral information. She felt that hemispheric processing in a 3 1/2 month old is the same as in an adult. Turkewitz (1988) found that at birth, human newborns are more responsive to speech presented in the right ear than to the left ear; the reverse is true for nonspeech sounds. In an interesting way, Turkewitz proposed that these differences observed in very young infants don't necessarily mean that these differences are a result strictly of genetics. He postulated that they may result from a child's exposure to its intrauterine environment. It was suggested that earlier in a pregnancy when the uteral lining is loose, digestive noises would dominate the child's experience. Towards the end of the pregnancy, the lining of the uterus is taut and speech sounds would be transmitted much more clearly, and therefore make up a more important component of a fetus' experience. Different parts of the brain could be developmentally responsive to stimuli at different times in the pregnancy. A deaf fetus of course would not have the same intrauterine exposure, leaving the possibility that a deaf child could be born with differences in hemispheric lateralization, differences that were environmentally caused.

<u>Development of Lateralization Throughout Life</u>

Other researchers see lateralization as a continuous developmental process. So, while Bryden (1982) claimed that there is little sign of any change in laterality with increasing age, at least from age three to adulthood, Dorman and Geffen (1974), and Geffen (1976) described hemispheric specialization as a normal component of brain maturation that is completed between age 5 and puberty. Brown and Jaffe

(1975) on the other hand, believed that cerebral dominance was something that evolves continually throughout life.

Marcotte and LaBarba (1985) found that for congenitally severely or profoundly deaf children, speech lateralization has been set by the age of three. These researchers took this finding to be evidence that cerebral organization is largely invariant. Strauss (1983) took the question one step further, and used an interesting method to judge at what point lateralization exists. Children who had received left hemisphere damage were compared. Of those who had received damage to the left cortex following the first year of life, 82% regulated speech exclusively with the left hemisphere. This percentage is of course less than one would find in the general population, and suggests, therefore, that some children, following brain damage, transferred exclusive control out of the left hemisphere as an adaptation. However, for children that received damage to the left hemisphere prior to being one year old, only 33% had speech controlled exclusively by the left hemisphere, suggesting a far greater amount of transference. Apparently, the brain was much more able to adapt at a younger age. These findings would appear to be in conflict with Marcotte and LaBarba's conclusion of developmental invariance. The possibility of an adaptation of cerebral organization in response to brain injury is an interesting one. Springer and Deutsch (1981) agreed with Strauss' findings that right hemisphere control of language is much more common in people that have had minor brain damage, and point out that right hemisphere control of language is more common in stutterers and people with a learning disability.

There is, therefore, evidence of similarities in lateralization between deaf people and those with normal hearing, but what about differences? With Rodda and Grove's caution about methodology in mind, some studies that have found specific differences between the exact nature of lateralization in deaf and hearing subjects can be noted. It is interesting that more left-handed people have language controlled in the right hemisphere, and Weston (1983) found that more deaf people are left-handed. Since handedness is related to laterality, this might indicate that there are differences in laterality between the deaf population and the general population. Corina (1989) found a difference in visual organization between deaf individuals and those with normal hearing. Gibson and Bryden (1984) using a dicchaptic test suggested the possiblility of right hemisphere involvement in reading among deaf subjects.

Sanders, Wright and Ellis (1989) concluded that the nature of a child's first language influences cortical organization. Neville, Kutas and Schmidt (1984) stated that the language acquisition process is an important variable in the development of cerebral organization. Levine (1981) concluded that regardless of anything else, an early severe hearing impairment affects brain lateralization.

When drawing conclusions about the nature of cerebral organization of deaf people in comparison with that of hearing people, one must be very careful. Neural organization is complex and a researcher's ability to analyse it is superficial. Samar (1983) stated that for congenitally deaf people, cerebral specialization is complicated, and may relate to the general cognitive performance of each individual person. Thompson (1984) agreed, saying that dichotomous models shed little light on such complex structures and may serve only to add confusion to the complexity. So, it may be possible to say with confidence only that brain organization among deaf people is in many ways the same as it is for hearing people, but apparently there are some differences.

Laterality of Deafness and the Acquisition of Language Skills

How good is the case that the specific laterality of a hearing impairment has an effect on the acquisition of language skills? The evidence is quite strong that laterality could have an effect. It would appear that there is some form of a neural structure that is innate and localized under normal conditions to regulate language development. In a person deaf from birth, the lateralized cerebral organization one normally finds is somewhat altered. Abnormal lateralization is more likely to have occurred in poor readers, in stutterers and in learning disabled individuals. This seems to suggest that there is a relationship between the development of a normal lateralized structure and the development of at least some aspects of language.

The development of lateralization is also different between deaf and normally hearing individuals. It is changed because the nature of an individual's language seems to influence cerebral organization. Whether a deaf child communicates through signing, or speech/lip reading, the brain will be stimulated differently from that of a hearing child's. The motor theory of speech draws attention to the brain's analysis of fine motor sequences that accompany language. It is reasonable to assume that such analysis would not be carried out in a deaf signer in the same way that they would in a hearing child. Deafness affects cerebral organization of girls less, or at least differently than it does the cerebral organization of boys. Deafness having an onset at different ages seems to have a varied effect. But the conclusion that deafness influences brain development is hard to escape.

Most deaf individuals (certainly anyone fitted bilaterally with hearing aids) are receiving some form of auditory stimulation from both ears. Whatever the stimulation is, it probably has some value for language development, since the level of residual hearing correlates positively with language skills. The question for a deaf person is not how loud is the stimulation, for hearing aids can provide quite a considerable amount of amplification, but what is the nature of the stimulation? More specifically, it is reasonable to say that what is important is the clarity of stimulation arriving at the left hemisphere. Kimura (1973) showed that stimulation from the left ear to the left hemisphere is overridden by stimulation from the right ear. Therefore, it may be that the less impaired the right ear is, the more residual hearing can allow the process of lateralized brain development to proceed normally. On the other hand, if the signal from the right ear is poorer, this less clear signal will suppress the better left ear signal, preventing it from reaching the left hemisphere. Such a process might prevent normal cerebral organization from unfolding effectively.

There is some indirect evidence supporting the view that a right ear loss is more significant for language acquisition than is a left ear loss. Yoshino (1983) studied deaf children who were aided on only one side. He found that those who improved in auditory-motor function, auditory function and speech production showed a strong right ear advantage. Surr, Montgomery, and Mueller (1986) also studied deaf children fitted on one side with hearing aids and although there was a lot of variability, a right ear advantage was found in this study as well.

Of course, identifying the effect of one factor from the myriad of others that affect language development in the hearing impaired is difficult. Exactly what is the nature of a hearing difference between ears that will have a significant effect on language development? Can such a difference be measured? Is the critical difference the same for all people, or does a laterality effect interact with intelligence, ecological factors, the syntax and semantics of language, or the quality of technical aids? It seems that laterality of deafness may affect the sexes differently, but does it influence children of various ages differently?

These factors all make it difficult to say with confidence that a laterality effect could be isolated through research. However, the question is worth pursuing because of its importance to the understanding of the development of cerebral organization and how that organization influences linguistic performance.

Chapter 3
METHOD

Sample Selection

The initial goal of the study was to select a sample of individuals that had a greater hearing impairment in one ear than the other. These individuals were to be divided into two groups - those that had better hearing in their right ear (right ear advantage) and those with better hearing in their left ear (left ear advantage). These groups were to be compared on a language task. The sample selection was completed by searching school records at the Alberta School for the Deaf (ASD) and the Edmonton Public School Board (EPSB). The search was confined to individuals who ceased being students at the ASD or the EPSB between 1985 and 1990. The search was carried out during the spring of 1991.

The study hypothesized that individuals with a greater impairment in the right ear would have more difficulty acquiring language skills than would those individuals with a greater impairment in the left ear. However, the study was exploratory, and it was not known precisely what level of difference between ears would be enough to produce an observable effect. Nonetheless, in terms of bilateral hearing loss, it had been shown that there was a gradual sloping impact on language development. That is, the greater the hearing loss, the more difficult was speech development (Wolk & Schildroth, 1986), and the more difficult was reading development (Bamford & Saunders, 1985). Perhaps, therefore, even a small difference laterally would be significant. Thus, it was decided that any individual who had a Speech Awareness Threshold (SAT) difference between ears of at least 5 dB on the most recent audiological examination would be considered to have an impairment that differed laterally. The reports of these audiological examinations, contained within student files, were carried out by an ASD or EPSB audiologist.

After identifying individuals with a lateralized hearing impairment, the records were checked to ensure that their impairments were acquired before the age of three. Any person whose onset of impairment was later than three years of age was considered to be postlingually impaired and was excluded from the sample. Next, any individual who had been diagnosed as having any other handicapping condition that may have influenced language development was excluded. These conditions included a mental handicap, a visual impairment, cerebral palsy, autism, a learning disability, or an emotional or behavioral disorder. While the school records specifically listed other handicapping conditions, it was possible that some of the more subtle conditions, like learning or emotional disorders could have existed but had been undiagnosed. The possible confounding influence of such other conditions has been a possible limiting factor in much work with the hearing impaired population.

Another question of importance that could not be answered from the school records was whether the subjects were right- or left-handed. This information would have been useful since although right-handed individuals usually have language processing localized in the left hemisphere (96%), left-handed individuals less often have language localized in the left hemisphere (70%) (Springer & Deutsch, 1981). Since it was important, for this study, to make the assumption that the subjects processed language in the left hemisphere, the sample could have been more precisely defined if left-handed individuals could have been excluded. Such precise definition was unfortunately not possible, since the ASD and EPSB school records did not indicate whether the students were left- or right-handed.

The Independent Measures

The laterality of the hearing loss served as one independent measure. There were two other independent measures. One was the sex of the individual, easily obtained from the school records. Allen (1986) found that being female was a positive factor relating to language skill among deaf people. It was hypothesized in this study that a similar relationship, between sex and language skill, could be demonstrated using school records. The third independent measure was the level of impairment. Bamford & Saunders (1985) found a gradual sloping effect, with the greater the hearing loss, the more difficult the acquisition of reading skill, but also found a significant cut-off point at 85 dB. The subjects were therefore divided into two groups based on level of hearing loss. Those with a loss in their better ear of 85 dB or more according to SAT scores were considered to be more impaired. The remainder were considered to be less impaired. The final sample consisted of 28 individuals.

Speech awareness threshold (SAT) scores were the logical choice for independent variables related to the ability to process language. In fact, Frisina (1962) stated that "the information offered by the SAT is centered around the critical frequencies necessary for understanding speech" (p. 479). Unfortunately, many researchers discuss degrees of hearing impairment without mentioning whether the numbers reported were pure-tone thresholds, speech awareness thresholds, or possibly speech reception thresholds. It is likely that much of the literature uses pure-tone thresholds, so an important question is: How do the SATs of this study compare with pure-tone thresholds reported in the literature? Frisina claims that there is a close relationship, with SAT scores generally falling within plus or minus 5 dB of the 500 Hz pure-tone threshold. Such a close relationship allows SAT and pure-tone measurements to be interchanged with a minimal loss of precision.

The Dependent Measures

For each subject of the sample, scores from the most recently written Canadian Achievement Tests (CAT), Form A were recorded. These tests results were contained in the students' files. The CAT were written by students at the ASD yearly and by some students within the EPSB at the end of grade nine. The CAT are composed of four separate tests. Scores recorded for each subject were the grade equivalents of the total reading score, the spelling score and the total language score. These scores served as the study's dependent measures. Results of the fourth set of tests of the CAT, those making up the mathematics test, were not used in this study.

Nature of the Canadian Achievement Tests and Validity

The CAT, Form A are a set of tests that are both norm-referenced and criterion-referenced (Whyte, 1985). These tests were intended by the authors to be usable in all Canadian schools in which the language of instruction is English. Objectives of the CAT were based on provincial and school district curriculum guides and major textbooks. The CAT were based initially on a pool of items from the California Achievement Tests. It was felt by the authors that the validity of the CAT does not depend on a correlation with any other test as this validity was established during the test's development.

Test development was described by the authors to have taken place in the following manner (Canadian Achievement Tests, Technical Bulletin, 1983).

First, the California items were evaluated for their relevance to the Canadian school curricula. Next, one thousand new items were written by Canadian teachers. The items were then field tested to select a pool of items that provided an adequate representation of the levels of achievement among Canadian children. The field testing involved 76,000 Canadian students that varied in geographical location and level of urbanization. The field testing was intended to ensure that performance on each item fulfilled six criteria.

1. Each item had to be easiest for the highest grade and hardest for the lowest grade for which it was intended.

2. The mean of the correct response was greater than for any distractor.

3. The item produced a biserial correlation coefficient greater than +.30.

4. When the examinees were divided into fifths according to their performance on other items, the number choosing the correct response diminished from the highest to the lowest fifth.

5. Difficulty for each test item was harder than .30 for the highest grade for which it was designed.

6. The reliability of the test was higher with each item than without it. Therefore, each item makes a contribution to the reliability of the test.

There are eight levels of the CAT. Each level of the test is intended to be used with a specific grade of student. The various test levels and the corresponding grades are listed in Table 3.1.

The authors developed a single, equal interval scale of standard scores on which to plot the range of performance from grades 1.7 through 12.7. "It was constructed to extend across all eight levels of the test batteries so that scores on the different levels of the tests would be related to a single scale rather than to a scale which is specific to a particular grade or to a particular level of the series. This scale provided the basis for producing all other derived scores" (p. 47, Canadian Achievement Tests, Technical Bulletin, 1983).

Table 3.1

Levels of the Canadian Achievement Tests and grades for which they are intended.

Test Level	Target grade
12	1.6 - 2.9
13	2.6 - 3.9
14	3.6 - 4.9
15	4.6 - 5.9
16	5.6 - 6.9
17	6.6 - 7.9
18	7.6 - 9.9
19	9.6 - 12.9

As previously noted, the dependent measures were made up of grade equivalent scores on the total reading, spelling and total language tests of the CAT. The total reading test score is derived from the scores on the reading vocabulary and reading comprehension subtests. The total language test score is derived from the language mechanics and language expression subtests. There were no subtests that had to be integrated to derive the spelling grade equivalent.

Reliability of the CAT

The Kuder-Richardson formula 20 (KR 20) was used to produce an internal consistency coefficient based on a single administration of the test. KR 20 coefficients for the components of the CAT employed in this study are included in the raw score summary statistics found in Appendix II.

The standard error of measurement is an estimate of the amount of error to be expected in a given score. It indicates a standard deviation of a theoretical distribution of scores of a test if the test were administered repeatedly to the same individual. Standard errors of measurement for the components of the CAT employed in this study are included in the raw score summary statistics found in Appendix II.

Appropriateness of the Canadian Achievement Tests

Given that the Canadian Achievement Tests are an established and respected set of tests designed for Canadian, English speaking students (Whyte, 1985) it is possible that they provided suitable dependent variables. Under the circumstances, they were the only source of objective language data about a sample of deaf students. However, a note of caution must be added. The CAT were not designed for deaf individuals, and have not been normed for deaf students. While the CAT do a good job of evaluating the general Canadian population, it was unknown if the tests do an equally good job of evaluating language skills of deaf students.

Levine (1974), among others, found that, in general, the use of standardized tests with the deaf were of restricted value. Levine conducted a survey of psychologists from across the United States who did testing with deaf clients. She found that while the Weschler tests of intelligence were used extensively with the deaf, the psychologists that used them felt that the tests had limited predictive value for academic learning. She summarized the respondents' attitudes towards achievement tests by stating that there was "a general feeling that achievement tests do little more than measure a deaf child's ability or inability to handle the language of his culture" (p. 315). While this study is now dated, there is no reason to assume that deaf people have changed so much that standardized tests have a significantly greater validity for the deaf population now than they did in 1974. Therefore, the CAT scores of deaf individuals used as data in this study must be considered to be of questionable validity. It is important to note however, that Levine described achievement tests as primarily tests of language when used with the deaf. This is significant since for this study, the results of the CAT are being used solely as a test of language.

A further note of caution must be added. In this study, different levels of the CAT were used to evaluate the subjects' language skills. That is, not all subjects took the same tests with the same questions. The tests' authors have developed a single scale that allows raw scores to be transformed into grade equivalents. Whether this is an appropriate procedure for scaling the scores of deaf individuals is open to question.

The CAT are apparently a useful set of tests designed for the regular Canadian school population, but were not designed specifically with deaf children in mind. Questions about the validity of the CAT for the present study have had to remain unanswered.

The Final Sample and Data Analysis Procedures

One goal of the study was to determine whether school records could be used as an effective measure of language achievement. It was, therefore, decided to try to replicate two effects generally accepted in the field and noted in the literature review of this study: a) that deaf girls perform better than do deaf boys and, b) that those less deaf perform better than those with a greater impairment on language tasks. Of the 28 individuals that made up the sample, 12 were females, and 16 were males. More impaired were those individuals who had a level of impairment of at least 85 dB as measured by the SAT score in their better ear. There were 10 subjects in the more impaired group and 18 subjects in the less impaired group. The two independent variables, more impaired vs less impaired and male vs female were compared with the three dependent variables, total reading score, spelling score and total language score on the CAT using t-tests and Mann-Whitney U tests each with a significance level of 0.10 (one tailed).

A second goal of the study was to determine whether school records could be used to detect a relationship between the laterality of an impairment and language ability. It had been hypothesized that those with more residual hearing in the right ear would manage to acquire language better than would persons having more residual hearing in the left ear. Of the sample of 28 subjects, 19 had a right ear advantage and 9 had a left ear advantage. The independent variable, laterality of impairment, was compared with the three dependent measures - total reading score, spelling score and total language score on the CAT using t-tests and Mann-Whitney U tests with an alpha level of 0.10 (one tailed).

Rationale for Using t-Test and Mann-Whitney Test

Coldeway (1989) lists some assumptions that accuracy of a t-test depends upon.

1. Observations were randomly selected from the population of interest. This assumption is violated in this

study, since all but one of the subjects were students at the ASD. Members of the deaf community are not selected at random to attend the ASD, so it cannot be claimed that subjects of this study were randomly selected from the general deaf population.

2. The estimate of the standard error is based on the unbiased estimate of the population variance. The estimate of the standard error approaches the true value as the sample size increases.

3. The populations from which the two samples were collected have equal variability, so that it can be assumed that differences in means are not simply differences in variances.

Assumptions 2 and 3 can only be satisfied if assumption 1 is satisfied, which of course it is not, and if the sample size is large. In this study there are group samples as small as nine (left ear advantage). Alder & Roessler (1968) pointed out that the ability of a t-test to detect a false hypothesis (its power) is increased with increasing sample size. This study is limited by small samples not randomly selected from the deaf population. Therefore, it cannot be said with confidence that t-tests would be able to identify meaningful mean differences in the population.

Nonetheless, t-tests were used for this study since the t-test is a simple, commonly used test that compares two independent means when the standard deviation of the populations from which the samples were drawn is unknown. Despite its shortcomings for this particular application, the t-test serves as a convenient first look at the data.

Concerns about the validity of using the t-test for this study are serious enough to necessitate a second look at the data using a nonparametric test. The Mann-Whitney is a distribution free test. It does not depend upon estimating the parameters of the population. Alder and Roessler (1968) described the Mann-Whitney test as having almost as much power as a t-test when using larger samples, and more power than the t-test when employing smaller samples. They described the Mann-Whitney as being particularly more efficient than the t-test for samples whose distributions deviate considerably from a normal distribution. It is therefore reasonable to use the Mann-Whitney to analyse the data in this study.

Multiple Regression Analyses

Finally, multiple regression analyses were carried out to determine whether the three predictor variables, sex, degree of impairment and laterality of impairment could be combined to estimate scores on the three criterion variables, the total reading, spelling and total language tests of the CAT. One multiple regression analysis was calculated for each criterion variable. These analyses provided estimates of the amount of the variance in the dependent measures that was accounted for by the three independent measures. Once again, the alpha level was set at 0.10.

In theory, the number of subjects required for a multiple regression analysis must exceed the number of predictor variables by at least two. In practice, however, according to Harnett(1982), the sample size must be quite a bit larger. Unless there is a large amount of data, any measure of goodness of fit could be more due to the small sample than an accurate result of the predictor variables. This sample of only 28 subjects is not as large as one would like to have in order to view the results of a regression analysis with confidence.

Confidence Intervals and Summary

When choosing a significance level of $p = 0.10$, one accepts a relatively high risk of a type I error. However, this study was exploratory. The sample size was not large and with the method sample selection employed it was not possible to control all confounding variables. All but one of the subjects were students at the ASD. It was quite likely that the ASD, being a segregated, institutional setting, had a population that was not truly reflective of the deaf population as a whole. Individual differences among students at the ASD may have been greater than what one might have found in the general deaf population; this range may have influenced the outcome of the study.

It would be unwise, regardless of the study's results, not to be cautious in drawing conclusions. Thus, it would be valuable to merely reveal the apparent value of the use of school records for this type of study, since the ASD records contain a large amount of information. It would also be valuable to draw attention to the possibility of a relationship between laterality and language. If the results of the study suggested one or more relationships, it would be appropriate that further studies be undertaken in an attempt to confirm these relationships.

Limitations of the Experimental Design

Smith and Glass (1987) list three conditions that must exist for the establishment of a cause-effect relationship. First, there must be a statistical relationship between the presumed cause and effect. A sample of larger than 28 subjects would be preferable, and would allow conclusions to be made with more confidence, even though 28 is enough to carry out the statistical procedures. Second, there must be a time sequence such that the influence of the independent variable preceded the effect observed in the dependent variable. This condition does not pose a problem for this study. The gender of the subjects, and the nature of their hearing impairments existed before their language skills were acquired. Third, alternate causes must be ruled out. It is the fulfillment of this condition that is particularly difficult for a retrospective analysis of student records.

The internal validity of a study results from the extent to which one can claim that the independent variable was responsible for the dependent variable. Several threats to internal validity are impossible to overcome with this experimental design. Some of these are instrumentation concerns. The independent variables, level of impairment, and laterality of impairment are based on measurements of the speech awareness threshold. Since all measurements were not carried out by the same audiologist, there is a possibility that procedures varied between audiologists and the measurements reflected that.

There were also instrumentation concerns related to the dependent measures. Several different levels of the CAT were employed. Each has different questions, so all subjects were not tested with the same instrument. The test authors claim that raw scores from any levels can be scaled to be made equivalent. This may work for the normal Canadian population, but it is unknown whether this scale is equally effective for deaf test takers. In fact, since the CAT were not designed for deaf students and were not normed for a deaf population, it cannot be known for sure how effective the CAT are for evaluating deaf students.

A second general area threatening the internal validity of the study had to do with the possible nonequivalence of the various subject groups. As this was an ex post facto study, the author could not select subjects for experimental and control groups, and could not manipulate the independent variables at will. Since subjects were not randomly selected to take part in the study and were not randomly assigned to groups, it could not be said for certain that the groups that were compared differed only on the independent variable.

A final concern deals with the external validity of the study. This is due to the fact that almost all of the subjects were students at the ASD. It cannot be said for certain that the population of the ASD was a true representation of the general deaf student population. Therefore, conclusions of this study could not be confidently generalized to deaf students elsewhere.

Null Hypotheses

Four null hypotheses were stated.

Hypothesis1. For female subjects, scores on the total reading, spelling, and total language components of the CAT will not exceed the scores of male subjects. Grade equivalent mean differences will be tested for significance using t-tests and Mann-Whitney U tests with an alpha level of 0.10 (one tailed).

Hypothesis 2. For less impaired subjects (those with a less than 85 dB hearing loss according to SAT scores), scores on the total reading, spelling and total language components of the CAT will not exceed the scores of more impaired subjects (those with a 85 dB or greater hearing loss according to SAT scores). Grade equivalent mean differences will be tested for significance using t-tests and Mann-Whitney U tests with an alpha level of 0.10 (one tailed).

Hypothesis 3. For subjects with a right ear advantage, scores on the total reading, spelling, and total language components of the CAT will not exceed scores of subjects with a left ear advantage. Grade equivalent mean differences will be tested for significance using t-tests and Mann-Whitney U tests with an alpha level of 0.10 (one tailed).

Hypothesis 4. A combination of the factors sex, degree of impairment, and laterality of impairment cannot be used to predict scores on the total reading, spelling and total language components of the CAT. Multiple regression analyses will be calculated to determine the correlation, using an alpha level of 0.10.

Chapter 4
RESULTS

Description of Sample

Tables 4.1, 4.2, and 4.3 describe the nature of the sample used in this study. The difficulties inherent in having access to a sample of only 28 individuals are illustrated. This is particularly so in this study, in which three separate factors; sex, degree of impairment and laterality of impairment have all been hypothesized to have an impact on the dependent variables. It is possible that an individual subjects's particular combination of the three factors may both foster and hinder language development. For example, a subject may be female (hypothesized to have a positive influence on language development) and have a greater degree of hearing loss (hypothesized to hinder language development). Considering that a factor could be adding to another's effect, or cancelling another's effect, a sample of only 28 is restrictive.

In Table 4.1, the sample is divided into two groups according to sex. It had been hypothesized that females would be able to perform better on language tasks than would males. The sample was not evenly split, having fewer females than males. A more significant concern however, was that there were very few females that heard better in the left ear than in the right ear. Having a right ear advantage had been hypothesized to be advantageous for the acquisition of language, and the female group had a greater percentage of individuals with a right ear advantage than did the males. This allowed the possibility that a comparison based on sex could be confounded by the effect of differences in lateralized impairment.

Females had a slightly greater impairment, but the difference was not statistically significant (alpha = .05, two

Table 4.1

Characteristics of Male and Female Subjects

	Males	Females
Number of subjects	16	12
Better hearing in the left ear	6	3
Better hearing in the right ear	10	9
Mean impairment (dB loss)	78	82
Mean age at testing	16.3	17.6
Mean total reading grade equivalent	4.3	5.1
Mean spelling grade equivalent	7.5	8.2
Mean total language grade equivalent	5.5	6.3

tailed). The mean age of females at testing was a bit older. These differences are small, not statistically significant (alpha = .05, two tailed), and not likely to have a noticeable impact on grade equivalent means.

The mean grade equivalents on the three dependent variables were all consistent with the hypothesis. Females had higher scores in total reading, spelling and total language than did males. These differences were analysed for significance using t- and Mann-Whitney tests. These results will be discussed in the section Analysis of the Data.

In Table 4.2, the sample was divided into two groups by degree of impairment. It had been hypothesized that individuals with a lesser impairment would be able to do language tasks better than those with a greater impairment. Individuals with a hearing loss of 85 dB or greater in their better ear on their most recent SAT test were considered to be more impaired. Those with a SAT score of less than 85 dB were considered to be less impaired. This sample contained 10 subjects who were more impaired, with a mean loss in their better ear of 91 dB, and 18 that were less impaired, with a mean loss of 74 dB in their better ear. However, the more impaired group had an equal number of males and females while the less impaired had a majority of males. It was hypothesized that the less impaired would be able to do language tasks better, but it was also hypothesized that the females would do better than the males. The two factors' influences could have counteracted each other.

Furthermore, the more impaired group had a greater percentage of individuals with a right ear advantage than did the less impaired group. This difference also could have countered the influence of the level of impairment on the dependent measures. There was a small difference in age at

Table 4.2

Characteristics of Less Impaired and More Impaired Subjects

	More impaired	Less impaired
Number of subjects	10	18
Mean impairment (dB loss)	91	74
Number of males	5	11
Number of females	5	7
Better hearing in the left ear	2	7
Better hearing in the right ear	8	11
Mean age at testing	16.4	17.1
Mean total reading grade equivalent	4.1	4.9
Mean spelling grade equivalent	8.0	7.7
Mean total language grade equivalent	5.0	6.3

testing (not statistically significant, alpha = .05, two tailed), probably not large enough to affect the grade equivalent means observably.

Grade equivalent means on the dependent measures were in agreement with the hypothesis in two of three cases. These differences were analysed statistically and will be discussed in the section Analysis of the Data. The less impaired group had a higher mean on the total reading and total language tests, but not as high on the spelling test. This may have been partly because spelling had a larger memorization component than the other tests and is not strictly a test of language. As well, the greater percentage of females and individuals with a right ear advantage in the more impaired group may be advantageous to language development.

In Table 4.3, the sample was divided into two groups according to the laterality of the subjects' hearing impairment. All subjects in the sample had at least a 5 dB difference between ears on their most recent SAT test.

Nine of the subjects had a left ear advantage and 19 of the subjects had a right ear advantage. It had been hypothesized that those with a right ear advantage would be able to do language tasks better than would those individuals with a left ear advantage. There was a somewhat higher percentage of males in the left advantage group. Therefore, sex differences between the groups may have had an additive effect on the dependent variables. Thus, grade equivalent mean differences could be larger than they would be if the only difference between the groups was laterality of impairment. There was little difference between the groups in level of impairment or in the age at testing (neither were statistically significant, alpha = .05, two tailed).

Mean differences on the dependent measures were all consistent with the hypothesis that those with a right ear

Table 4.3

Characteristics of Subjects who Hear Better in the Left Ear with those who Hear Better in the Right Ear

	Left advantage	Right advantage
Number of subjects	9	19
Number of males	6	10
Number of females	3	9
Mean impairment(dB loss)	81	79
Mean age at testing	17.6	16.5
Mean total reading grade equivalent	3.9	5.0
Mean spelling grade equivalent	7.5	8.0
Mean total language grade equivalent	5.3	6.1

advantage would do better on language tasks than those with a left ear advantage. The statistical significance of these differences will be discussed in the sections Analysis of the Data. On the total reading, spelling and total language tests, those with a right ear advantage had a higher mean grade equivalent.

Analysis of the Data

To test the null hypotheses, each mean difference was tested using statistical tests of significance. First, each independent variable was compared with all three dependent variables using three t-tests and three Mann-Whitney U tests, one for each dependent variable. Then all three independent variables were analysed using three multiple regression analyses (again, one for each dependent variable).

t-tests.

All t-tests were one tailed since the the direction of the mean differences was predicted. The signficance level was set at alpha = 0.10. For each test the degrees of freedom were 26.

Table 4.4 shows the results of comparing males and females on the three dependent variables. Despite the fact that all means were consistent with predictions, the standard deviations are high. As a result, none of the three mean differences were significant at the 0.10 level (one tailed).

Therefore, null hypothesis 1 was not rejected on the basis of t-test evidence. Based on this study, there was no reason to believe that female deaf subjects perform better on a language task than do male deaf subjects.

Table 4.4

t-Test Results Based on Sex

	Sample		Means		SD				
Variable	F	M	F	M	F	M	t	df	p
Reading	12	16	5.1	4.3	3.6	2.2	.73	26	.24
Spelling	12	16	8.2	7.5	3.6	3.5	.51	26	.31
Language	12	16	6.3	5.5	3.6	3.1	.66	26	.26

Table 4.5 illustrates the comparison of those less impaired with those more impaired. Once again, high standard deviations and standard errors of estimate meant neither reading nor total language scores reached the alpha level of 0.10 (one tailed). On the other test, spelling, the mean difference between groups was in contrast to the prediction and not statistically significant. On the basis of the t-tests, null hypothesis 2 was not rejected. Based on this study, there is no reason to conclude that subjects with a less than 85 dB hearing impairment will perform better on a language task

than will subjects with an 85 dB or greater than 85 dB hearing impairment.

Table 4.5

t-Test Results Based on Level of Impairment

	Sample		Means		SD				
Variable	Less	More	Less	More	Less	More	t	df	p
Reading	18	10	4.9	4.1	3.2	2.2	.73	26	.24
Spelling	18	10	7.7	8.0	4.1	2.4	-.21	26	.58
Language	18	10	6.3	5.0	3.8	2.0	.94	26	.18

However, this sample contained a large number of subjects (16 of the 28) whose hearing loss fell between 80 dB and 90 dB. Therefore, there was not a large difference between the more impaired and the less impaired groups. When subjects were selected from the sample to produce groups with a greater distinction between the less impaired and the more impaired groups, statistically significant differences were found. In this case, subjects whose impairment was 75 dB or less (nine subjects) were considered less impaired, and those whose impairment was 90 dB or more (six subjects) were considered more impaired. Statistically significant differences were found using t-tests for the total reading and total language scores. No significant difference was found between the groups on the spelling scores. While interesting, it must be emphasized that with groups as small as six, not much confidence should be placed in these figures.

Table 4.6 illustrates the comparison of individuals differing in the laterality of their impairment. As in tables 4.4 and 4.5, standard deviations and standard errors of estimate are high. None of the mean differences were significant at the level of 0.10 (one tailed). Therefore, null hypothesis 3 was not rejected. Based on this study, there is no reason to conclude that subjects with a right ear advantage will perform better on a language task than will subjects with a left ear advantage.

Table 4.6

t-Test Results Based on Laterality of Impairment

	Sample		Means		SD				
Variable	R. Ad.	L. Ad.	R. Ad.	L. Ad.	R. Ad.	L. Ad.	t	df	p
Reading	19	9	5.0	3.9	3.0	2.4	.98	26	.17
Spelling	19	9	8.0	7.5	3.4	3.9	.33	26	.37
Language	19	9	6.1	5.3	3.4	3.9	.56	26	.29

When only those subjects whose difference in laterality is 10 dB or greater are included, it is possible to produce two groups whose laterality differences are larger. This produces a group of 11 subjects with a right ear advantage and four subjects with a left ear advantage. No statistically significant differences were found between these groups for total reading, spelling or total language scores using t-tests.

Mann-Whitney tests. Tables 4.7, 4.8, and 4.9 show the data analysed using Mann-Whitney tests. As with the t-tests, eight of nine mean differences, in this case differences in the mean rank of grade equivalent scores, were in the direction predicted. Table 4.7 shows that females had a higher mean rank than did males in total reading, spelling, and total language. However, the mean differences were not great, and, also like the t-tests, variation in within group scores is high. For Mann-Whitney tests, variation is in ranks. For example, in total reading, females had a higher mean ranking, and a female had the highest grade equivalent, but females also had the lowest, second lowest and third lowest grade equivalent. Such inconsistencies were also evident in the spelling and total language scores. Therefore, in no case was the grade equivalent superiority statistically significant. On the basis of Mann-Whitney tests, null hypothesis 1 was still not rejected.

Table 4.7

Mann-Whitney Test Results Based on Sex

	Sample		Mean Rank			
Variable	F	M	F	M	U	p
Reading	12	16	15.3	13.9	87	.34
Spelling	12	16	15.5	13.8	84.5	.30
Language	12	16	15.9	13.4	79	.22

Table 4.8 shows the dependent variables compared against the two levels of impairment using Mann-Whitney

Table 4.8

Mann-Whitney Test Results Based on Level of Impairment

	Sample		Mean Rank			
Variable	Less	More	Less	More	U	p
Reading	18	10	15.3	13.1	75.5	.24
Spelling	18	10	14.4	14.7	88	.54
Language	18	10	15.0	13.6	80.5	.34

tests. As with the t-tests, the mean ranks were consistent with the hypotheses in two of three cases. Once again, the more impaired group were shown to have spelled better than did the less impaired group. As in the case with the male-female comparison, the difference between the sums of ranks is not great due to the large variations of the rankings within the two groups. Therefore none of the differences between groups were shown to be statistically significant, and null hypothesis 2 was once again not rejected.

Table 4.9 displays results of the comparison of subjects divided by laterality of impairment using Mann-Whitney tests. In this case as well, although the differences in mean ranks were consistent with the hypothesis, due to the large variation

Table 4.9

Mann-Whitney Test Results Based on Laterality of Impairment

	Sample		Mean Rank			
Variable	R. Ad.	L. Ad.	R. Ad.	L. Ad.	U	p
Reading	19	9	15.8	11.8	61.5	.13
Spelling	19	9	15.0	13.5	76.5	.33
Language	19	9	15.1	13.2	74	.28

in rankings within each group, the mean differences were not shown to be statistically significant.

Table 4.10

Summary: Probability for All t-Tests and Mann-Whitney Tests*

	Probability	
	t	Mann-Whitney
Sex by total reading	0.237	0.337
Sex by spelling	0.309	0.295
Sex by total language	0.257	0.215
Impairment by total reading	0.237	0.242
Impairment by spelling	0.584	0.540
Impairment by total language	0.179	0.337
Laterality by total reading	0.169	0.131
Laterality by spelling	0.373	0.330
Laterality by total language	0.289	0.284

* None of the group differences were found to be statistically significant (alpha = .10, one tailed) using either t-tests or Mann-Whitney tests.

Summary of t and Mann-Whitney tests. In summary, although eight of the nine mean differences were in the direction predicted, none were shown to be statistically significant at the level of p = 0.10. The between groups differences were not large, and the within group variances were large, creating too much uncertainty to reject chance as a cause of the differences. The greatest mean difference involved the sample divided by laterality of impairment on total reading scores. The t-test revealed a 83% likelihood of a significant difference, and the Mann-Whitney test revealed a 87% likelihood of a significant difference, both in the direction predicted by the hypotheses, however,neither reached the alpha level of 0.10. Therefore, t-test and Mann-Whitney test analyses of this data have not provided reason to conclude that there is a difference in language skill between male and female, less impaired and more impaired, and right ear advantaged and left ear advantaged deaf subjects.

Multiple regression analysis. Tables 4.11, 4.12, and 4.13 show the results of the three multiple regression analyses. Sex of the subject, level of impairment and laterality of impairment served as the three predictor variables. They were chosen as predictor variables since they were the independent variables of the study. These variables were considered together to determine what proportion of each of the three criterion variables could be predicted from the predictor variables. The three criterion variables were the scores on the total reading, the spelling and total language segments of the Canadian Achievement Tests.

The analysis did not yield any significant F scores. As in the previous analyses, there was a very high standard error of estimate in each case, indicating that the obtained scores did not fit neatly onto the regression line. This high standard error was a reflection of the very low r squared value, indicating that only a small amount of the criterion variable variance could be predicted from the predictor variables.

Table 4.11

Prediction of the Total Reading Using the Combined Values of the Three Predictor Variables

R: 0.293

Analysis of Variance

Source	df	Sum of squares	Mean square	F-test
Regression	3	18.702	6.234	0.750
Residual	24	199.555	8.315	p=0.533
Total	27	218.257		

Table 4.12

Prediction of the Spelling Score Using the Combined Values of the Three Predictor Variables

R: 0.113

Analysis of Variance

Source	df	Sum of squares	Mean square	F test
Regression	3	4.272	1.424	0.104
Residual	24	328.129	13.672	p = 0.957
Total	27	332.401		

It is important to note the very low r values. The correlation between the three independent variables with total reading is 0.293, with spelling is 0.113 and with total language is 0.268. Thus, the three independent variables account for only a small proportion of the variance in the dependent variables. Hence, the variation in language scores could probably be accounted for largely by factors other than sex, degree of impairment and laterality of impairment. In the absence of a significant F score, null hypothesis 4 was not rejected.

Table 4.13

Prediction of the Total Language Score Using the Combined Values of the Three Predictor Variables

R: 0.268

Analysis of Variance

Source	df	Sum of squares	Mean square	F-test
Regression	3	21.302	7.101	0.621
Residual	24	274.539	11.439	p = 0.608
Total	27	295.841		

Chapter 5

DISCUSSION

Implications of the Statistical Analyses

To test the hypotheses, it was necessary to analyse each mean difference individually. This was accomplished by submitting each group difference to a t-test and to a Mann-Whitney test. Under this form of analysis, none of the mean differences were significant at an alpha level of 0.10 (one tailed).

The Sample

As discussed in Chapter 3, there was some question about the appropriateness of the Canadian Achievement Tests to serve as sources of dependent variables for this study. However, the CAT would have to be doing an inconceivably bad job to be able to blame the confusion of the data solely on the CAT. Concerns with the dependent measures are certainly minor in comparison to problems inherent to the sample.

In this data, there was a very high error variance in dependent measures unaccounted for by the three independent variables. That was the clear conclusion from the multiple regression analyses, which showed that the majority of the variance seen in the dependent measures was unexplained by the independent variables.

The large component of unexplained variance can also be illustrated by selecting the five subjects who were female, less impaired, and had a right ear advantage. These subjects would be expected to show some consistency in language scores, since they are uniform on three factors considered important for language development (the three dependent measures), and to score well on the language tasks, since they were all in the favored category of the dependent variables. Total Reading, Spelling and Total Language scores for these individuals can be seen in Table 5.1. The mean grade equivalents for these subjects are not especially high. There

Table 5.1

Performance of Less Impaired, Right Ear Advantaged Females on the Three Dependent Measures

	Total reading	Spelling	Total language
Mean grade equivalent	5.6	7.2	6.7
Standard deviation	5.1	5.3	5.5
Standard error	2.3	2.4	2.5
Minimum score	0.5	2.0	2.3
Maximum score	12.9	12.9	12.9

was no statistically significant differences found between these subjects and the rest of the sample on any of the three dependent variables using t-tests (alpha = 0.1, one tailed).

What is most telling however, was the variation in scores within this group. Scores ranged from the grade equivalents of 12.9 to 0.5. Standard deviations among nine subjects of between 5.1 and 5.5 grade equivalents were extremely high. This suggests that factors other than being female, having an impairment of 80 dB or less and having a right ear advantage are valuable for developing the skills needed to perform well on the CAT.

Group Selection

One could argue that the sorting of subjects into groups according to level of impairment and laterality of impairment was imprecise and therefore a source of within group variance. However, the sorting of individuals into groups by sex should pose none of the problems encountered when dealing with the level or laterality of impairment. Defining the groups by sex involves no arbitrary decision, and the sex of the individuals was clearly stated in school records. And yet, this study was unable to replicate results generally found in the literature, that females do significantly better than males on language tasks. Even when the sample was divided by sex, there was a lot of within-group variance. Some of the variance unaccounted for would relate to family and social factors as described by Levine, and intelligence as described by Conrad (see Nature/Nurture and Language Development in the Literature Review for a full discussion). As well, important other handicapping conditions could have gone unreported in the school records. Furthermore, the subjects could have been involved in different educational programs, including preschool experiences. Of course, if the sample size was large enough, and randomly selected, such factors would be expected to equal themselves out between groups. The sample in this case of 12 females and 16 males was simply not large enough.

Moreover, the variance within the groups may be exacerbated by the fact that all but one of the subjects were students at a segregated, residential school. Such an educational setting attracts a wide variety of students, more diverse than one would find in the general deaf population. Some ASD students may be the deaf children of deaf parents, self-confident, secure in their family and their deafness, and comfortable in a deaf-only setting. Others may be the most handicapped of deaf students - emotionally troubled, or intellectually weak, students whose parents feel their children need the shelter of an institution. Once again, the effect of such within-group variance would be reduced if there was a larger sample size, but with a small sample becomes more of a concern.

The Variables

The results of this study were strong evidence that factors other than sex, level of impairment, and laterality of impairment have played a very important role fostering or hindering the development of language skills for at least some of the subjects. That this variance was uncontrolled, in fact that the extraneous variables remain unidentified, alone can explain why the results of the study were inconclusive.

However, improved ability to measure the independent and dependent variables would help to produce more precise results. Dividing a sample by gender poses no problem, but it is more difficult to be precise when dividing a sample into levels of impairment and lateralities of impairment with the use of measured SAT scores. Green (1978) lists reasons why hearing tests can produce varied results. The exact calibration of the audiometer can vary, affecting results, and within the individual, actual hearing thresholds can fluctuate. Recent exposure to sudden noise can alter a threshold, as can taking a large dose of aspirin. Furthermore, getting a precise result on a hearing test depends on motivation to cooperate, as well as the subject's attention span. The latter is especially important since a true threshold is the point at which the subject responds appropriately 50% of the time. Most audiologists do not have the time and most subjects do not have the patience to find true thresholds, and so audiologists abbreviate the procedure in the way that seems most appropriate for them. (K. Gough, Personal Communication, September 24, 1991)

It is important, therefore, that a researcher have greater control over the gathering of hearing loss data than was possible during this study. One person measuring all subjects would ensure that the the same methods were employed for all individuals. It would be possible then to control for factors such as medication and recent exposure to noise, as well as to note incidents where cooperation and motivation may have been a problem. Even still, it may be wise to assume the possibility of measurement error, and therefore to define groups such that there is little chance of overlap.

In the sample used for this study, 16 of the 28 subjects had a loss of between 80 dB and 90 dB in their better ear. Therefore, many of the subjects judged to be less impaired, were not much different in their impairment from many judged to be more impaired. So, while the literature concludes that those less impaired do better on language tasks than those more impaired, perhaps it was necessary to have a greater between-groups difference in impairment, especially given the possibility of measurement error, in order to show such an effect. That appears to be the case given that a comparison of those with a 90 dB or greater loss with those having a 75 dB or less loss yielded some statistically significant results. The fact that this study had access to a small sample exacerbates this problem of the distinction between groups.

Suggestions for Overcoming Measurement Difficulties

As a solution, a more impaired group could have been measured to have a greater than 90 dB loss in the better ear, while a less impaired group could have been measured to have a less than 70 dB loss in the better ear. That would leave out those with a loss of 70 dB to 90 dB to ensure that those with moderate losses do not blur the distinction between the more impaired and the less impaired.

Similar concerns can be raised with regard to assigning subjects into groups according to laterality of impairment. For this study, any subject with at least a 5 dB difference between ears was considered to have a lateralized impairment. Perhaps this difference was not large enough to isolate an effect of laterality on language skill.

Alternatively, a laterality effect could be assumed only if there was at least 20 dB difference between right ear and left ear. The numbers suggested to distinguish more impaired from less impaired, and for determining laterality are purely arbitrary, but reflect the implication resulting from this study that greater caution should be exercised in defining groups.

There was a further problem related to assigning subjects to groups according to lateralization. For this study, the concept of laterality of impairment was tied directly to lateralized language functions of the brain. Because of the nature of the data selection, it had to be assumed that all subjects process language in the left hemisphere. However, it is likely that a small percentage of the subjects processed language in the right hemisphere or bilaterally. Research hypothesis 3 stated that better hearing in the ear opposite the language centre of the brain is a positive factor for language development. If this hypothesis was true, subjects that process language bilaterally or in the right hemisphere could be expected to provide results in contradiction to the majority of subjects. Should this study have had a very large sample size, a small percentage of subjects yielding divergent results would probably be inconsequential. However, when working with a small sample size, including a few subjects with neural organization different from what is assumed could be a crucial flaw.

Difficulties with the measurement of the dependent variable are more difficult to overcome. While the CAT undoubtedly measure some aspect of language, exactly what they were measuring in the deaf students is an open question. This problem was exacerbated in this study by the use of various levels of the tests. It may simply not be possible to find a set of language tests appropriate for the population from which the sample was drawn. However, it would be wise in the future to employ only one level of whatever test is chosen, so that at least all subjects' scores are based on the same items.

Experimental Design

When carrying out an ex post facto study such as this one, some difficulties cannot be overcome. The independent variables for this study were determined by fixed characteristics that had exercised a long-term effect on the subjects. Therefore, it was not possible to randomly assign subjects to groups or to administer pre- and post-tests. Since it was not possible to have direct contact with the subjects, the opportunity to eliminate extraneous variables was limited. For reasons such as these, it is almost impossible in an ex post facto study to establish a causal relationship. In the case of this study, even correlations were elusive.

Having access to subjects more representative of the deaf population as a whole, by being able to go beyond the Alberta School for the Deaf, might have reduced the standard deviations from the means, providing even greater clarity to the results. As well, having access to a larger source of possible subjects would have allowed more freedom to be cautious in ensuring that the subjects truly had a lateralized hearing loss and that the groups truly differed in level of impairment. In summary, having access to a larger sample, and one which would be expected to be representative of young deaf people in general would have greatly improved the ability to conclusively test the null hypotheses and improve the chances of isolating an effect which appears to be in the data.

Implications for Future Research

Given the inconclusive nature of the data, some questions will have to remain unanswered for the time being. It cannot be stated with certainty whether or not a hearing impairment that differs laterally is a significant factor in the acquisition of language. Therefore, this study has generated no supportive or refutive data about whether or not the human brain is adaptable enough to be able to alter neural routes, thus ensuring that the most efficient auditory signals arrive in a direct fashion to the language processing centre of the brain. The possibility of a laterality effect outlined in Chapter 2 must remain a possibility. However, the hint from the data of this study that the possibility might be real should be enough to maintain an interest in the search for a laterality effect on the acquisition of language.

Something that can be commented on with more certainty is the value of school records for a study of this type. In this particular case, employing school records appears to have been of limited value. That can be concluded because differences reported in the literature; sex differences and differences in terms of level of impairment, were not observed using student records as a source of data.

Of course, that the student records analysed for this study didn't replicate findings reported elsewhere does not mean that student records have no research value. Having access to a larger number of student records that were more representative of the general population would have helped greatly. If a researcher can scrutinize school records conservatively, excluding any individuals for whom there is the slightest question about, and still come up with group sizes of over 30 subjects, school records probably can be a good source of data for some types of studies.

That measurements for school records are performed by others, under conditions which the researcher can not control will remain a source of methodological concern. Uncertainty about the reliability of measurement procedures is by necessity a limiting factor for data collected from school records. Nonetheless, school records contain a vast supply of information, and it would be unwise in the future not to try to make use of it. If used with judicious caution, the information contained within school records could be a revealing source.

REFERENCES

Alder, H., & Roessler, E. (1968). Introduction to probability and statistics (4th ed.). San Francisco: W. H. Freeman and Company.

Allen, T. (1986). Patterns of academic achievement among hearing impaired students: 1974 and 1983. In A. Schildroth, & M. Karchmer (Eds.), Deaf children in America (pp. 139-159). San Diego: College-Hill Press.

Arnold, P. (1983). Does pure oralism cause atrophy of the hearing-impaired child's brain? Volta Review, 85, 229-234.

Bamford, J., & Saunders, E. (1985). Hearing impairment, auditory perception and language disability. London: Edward Arnold Ltd.

Bellugi, U., Poizner, H., & Klima, E. (1989). Language, modality and the brain. Trends in Neurosciences, 12, 380-388.

Bellugi, U.,Poizner, H. & Klima, E. (1983). Brain organization for language: Clues from sign aphasia. Human Neurobiology, 2, 155-170.

Best, C. (1988). The emergence of cerebral asymmetries in early human development: A literature review and a neuroembryological model. In D. Molfese, & S. Segalowitz (Eds.), Brain lateralization in children (pp. 5-34). New York: The Guilford Press.

Borchgrevink, H. (1982). Cerebral mechanisms of complex sound perception: Consequences for the functional evaluation of hearing. Scandinavian Audiology, Suppl 16, 135-139.

Brown, J., & Jaffe, J. (1975). Hypothesis on cerebral dominance. Neuropsychologica, 13, 197-210.

Bryden, M. (1982). Laterality: Functional asymmetry. New York: Academic Press.

Bryden, M. (1988). Does laterality make any difference? Thoughts on the relation between cerebral asymmetry and reading. In D. Molfese, & S. Segalowitz (Eds.), Brain lateralization in children (pp. 509-526). New York: The Guilford Press.

Campbell, R., & Wales, R. (1970). The study of language acquisition. In J. Lyons, (Ed.) New horizons in linguistics, (pp. 242-260). Baltimore: Penguin Books.

Canadian Achievement Tests. (1983). Technical bulletin. Toronto: CTC/ McGraw-Hill.

Coldeway, A. (1989). Using basic statistics in the behavioral sciences. Scarborough: Prentice-Hall, Canada.

Conrad, R. (1979). The deaf school child. London: Harper & Row.

Corina, D. (1989). Recognition of affective and noncanonical linguistic facial expressions in hearing and deaf subjects. Brain and Cognition, 9, 227- 237.

Cumming, C. & Rodda, M. (1985). The effects of auditory deprivation on succesive processing. Canadian Journal of Behavioral Sciences, 17, 232-245.

Dorman, M., & Geffen, D. (1974). Hemispheric specialization for speech perception in 6 year old black and white children from low and middle socio economic classes. Cortex, 10, 171-176.

Entus, A. (1977). Hemispheric asymmetry in processing of dichotically presented speech and non speech stimuliby infants. In S. Segalowitz & F. Gruber (Eds.) Language development and neurological theory, New York: Academic Press.

Furth, H. (1966). Thinking without language. New York: The Free Press.

Frisina, R. (1962). Audiometric evaluation and its relation to the habilitation and rehabilitation of the deaf. American Annals of the Deaf, 107, 478-481.

Geffen, D. (1976). Development of hemispheric specialization for speech perception. Cortex, 12, 337-346.

Gibson, C., & Bryden, M. (1984). Cerebral laterality in deaf and hearing children. Brain and Language, 23, 1-12.

Goldberg, E. & Costa, L. (1981). Hemisphere differences in the acquisition and use of descriptive systems. Brain and Language, 14, 144-173.

Green, D. (1978). Pure tone air-conduction testing. In J. Katz (Ed.), Handbook of clinical audiology. Baltimore: The Williams and Wilkins Company.

Harnett, D. (1982). Statistical methods. Reading, Massachusetts: Addison-Wesley Publishing Company.

Heffner, H., & Heffner, R. (1989). Unilateral auditory cortex ablation in macques results in a contralateral hearing loss. Journal of Neurophysiology, 62, 789-801.

Kimura, D. (1973). The asymmetry of the human brain. Scientific American, 228, 70-78.

Kimura, D., Battison, R., & Lubert, B. (1976). Impairment of non-linguistic hand movements in a deaf aphasic. Brain and Language, 3, 566-571.

Kimura, D. & Durnford, M. (1974). Normal studies on the function of the right hemisphere in vision. In Diamond & Beaumont (Eds.), Hemisphere function in the human brain, New York: Willy.

Kimura, D., & Harshman, R. (1984). Sex differences in brain organization for verbal and nonverbal function. Progress in Brain Research, 61, 423-441.

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

Levine, E. (1974). Psychological tests and practices with the deaf: A survey of the state of the art. The Volta Review, 76, 298-319.

Levine, E. (1981). The ecology of early deafness. New York: Columbia University Press.

Levine, S. (1986). Hemispheric specialization and implications for the education of the hearing impaired. American Annals of the Deaf, 131, 238-242.

Marcotte, A., & LaBarba, R. (1985). Cerebral lateralization for speech in deaf and normal children. Brain and Language, 26, 244-258.

Marshall, J. (1980). On the biology of language acquisition. In D. Caplan (Ed.), Biological studies of mental processes (pp. 106-148). Cambridge, Mass.: The MIT Press.

Marshall, J. (1986). Signs of language in the brain. Nature, 322, 307- 308.

McGlone, J. (1978). Sex differences in functional brain asymmetry. Cortex, 14, 1-12.

Netley, C., & Rovet, J. (1988). The development of cognition and personality in X aneuploids and other subject groups. In D. Molfese, & S. Segalowitz (Eds.), Brain lateralization in children (pp. 401-416). New York: The Guilford Press.

Neville, H., Kutas, M., & Schmidt, A. (1984). Event-related potential studies of cerebral specialization during reading: A comparison of normally hearing and congenitally deaf adults. Sixth International Conference on Event-Related Slow Potentials of the Brain (EPIC VI): Normal and aberrant development (1981, Lake Forest/Chicago, Illinois). Annals of the New York Academy of Sciences, 425, 370-376.

Panou, L., & Sewell, D. (1984). Cerebral asymmetry in congenitally deaf subjects. Neuropsychologica, 22, 381-383.

Poizner, H. (1980). Hemispheric specialization in the deaf. In B. Frokjaer-Jensen (Ed.), Proceedings from: Recent developments in language and cognition. Copenhagen: University of Denmark.

Rasmussen, T. & Milner, B. (1977). The role of early left-brain injury in determining lateralization of cerebral speech function. Annals of the New York Academy of Science, 299, 355-369.

Rodda, M. & Grove, C. (1987). Language, cognition and deafness. Hillsdale, N. J.: L. Erlbaum Associates.

Ross, P. (1983) Cerebral specialization in deaf individuals. In S. Segalowitz (Ed.), Language functions and brain organization. New York: Academic Press.

Samar, V. (1983). Evoked potential and visual half-field evidence for task-dependent cerebral asymmetries in congenitally deaf adults. Brain and Cognition, 2, 383-403.

Sanders, G., Wright, H., & Ellis, C. (1989). Cerebral lateralization of language in deaf and hearing people. Brain and Language, 36, 555-579.

Sarno, J., Swisher, L., & Sarno, M. (1969). Aphasia in a congenitally deaf man. Cortex, 5, 398-414.

Scherg, M., & von Cramon, D. (1986). Psychoacoustic and electrophysiologic correlates of central hearing disorders in man. European Archives of Psychiatry and Neurological Sciences, 236, 56-60.

Scholes, R., & Fischler, I. (1979). Hemispheric function and linguistic skills in the deaf. Brain and Language, 7, 336-350.

Smith, M., & Glass, G. (1987). Research and evaluation in education and the social sciences. Englewood Cliffs, New Jersey: Prentice-Hall Inc.

Springer, S., & Deutsch, G. (1981). Left brain, right brain. San Francisco: W. H. Freeman and Company.

Strauss, E., & Wada, J. (1983). Lateral preferences and cerebral speech dominance. Cortex, 19, 165-177.

Streng, A., Kretschmer, R., & Kretschmer, L. (1978). Language, learning and deafness. New York: Grune & Stratton.

Surr, R., Montgomery, A., & Mueller, H. (1986). Effect of monaural hearing aid use on dichotic test results for individuals with high frequency hearing impairment. Journal of Speech and Hearing Disorders, 51, 161-169.

Thompson, R. (1984). Language, the brain, and the question of dichotomies. American Anthropologist, 86, 98-105.

Turkewitz, G. (1988). A prenatal source for the development of hemispheric specialization. In D. Molfese, & S. Segalowitz (Eds.), Brain lateralization in children (pp. 73-81). New York: The Guilford Press.

Vygotsky, L. (1962). Thought and language. Cambridge, Mass.: MIT Press

Weston, P., & Weinman, J. (1983). The effects of auditory and linguistic deprivation on lateral preference of deaf children. Developmental Medicine and Child Neurology, 25, 207-213.

Whyte, L. (1985). Canadian Achievement Tests, Form A. In J. Mitchell (Ed.) The Ninth Mental Measurement Yearbook, Vol 1, (pp. 257-258). Lincoln, Nebraska: The Buros Institute of Mental Measurement.

Witelson, S. (1977). Early hemisphere specialization and interhemispheric plasticity: An empirical and theoretical review. In S. Segalowitz & F. Gruber (Eds.), Language development and neurological theory, New York: Academic Press.

Wolk, S., & Schildroth, A. (1986). Deaf children and speech intelligibility: A national survey. In A. Schildroth, & M. Karchmer (Eds.), Deaf children in America (pp. 139-159). San Diego: College-Hill Press.

Yoshino, T. (1983). Dichotic right ear advantage for speech perception in hearing impaired children: Relation of lateralization-score and aided ear in dichotic listening. Japanese Journal of Special Education, 21, 12-20.

Young, S. (1977). Manual specialization in infancy: Implications for lateralization of brain function. In S. Segalowitz & F. Gruber (Eds.), Language development and neurological theory, New York: Academic Press.

Appendix I, Raw Data, continued:

Sex	Age at Testing	Year Tested	Better Ear	dB loss Right	dB loss Left	Grade Equivalents Total Reading	Spelling	Total Language
M	16.8	1990	L	85	80	1.9	3.3	2.6
F	18.1	1990	R	80	85	12.9	12.9	12.9
F	17.8	1988	R	85	95	3.7	9.6	4.9
M	18.1	1987	R	50	60	4.0	4.7	7.8
M	18.6	1990	R	65	75	7.9	9.8	3.3
F	19.0	1989	R	70	80	2.4	4.4	2.3
F	16.4	1987	R	80	100	0.5	3.9	2.4
F	15.8	1988	R	75	85	8.5	12.9	12.6
M	9.7	1988	R	90	100	4.2	12.2	8.0
M	13.8	1988	R	75	80	6.4	7.4	9.4
F	14.7	1990	R	80	85	3.5	2.0	3.4
M	15.7	1990	R	80	85	2.6	3.4	3.0
F	17.7	1987	L	80	70	4.6	11.9	8.2

APPENDIX I

Raw Data: Hearing and CAT Scores for all the Subjects

Sex	Age at Testing	Year Tested	Better Ear	dB loss Right	dB loss Left	Grade Equivalents Total Reading	Spelling	Total Language
F	15.5	1985	R	85	95	9.8	9.9	6.7
M	18.9	1989	L	105	75	4.4	9.6	5.1
M	14.6	1990	L	95	90	2.3	3.9	2.5
M	17.7	1987	R	85	100	2.6	5.9	3.2
F	19.9	1987	L	106	75	3.4	7.4	5.3
M	14.2	1984	R	75	80	4.2	12.2	5.9
M	16.8	1987	R	90	95	3.2	8.0	3.2
F	18.7	1987	R	85	90	5.5	9.0	8.2
M	17.3	1987	R	55	85	6.2	10.8	9.7
F	18.8	1987	R	100	110	3.2	5.8	3.4
M	17.3	1989	L	85	80	1.9	1.6	2.1
M	18.3	1987	L	90	80	3.5	8.0	4.0
M	16.3	1987	L	85	80	9.8	12.9	12.6
F	18.4	1989	L	NR*	100	3.0	9.0	5.3
M	16.1	1985	R	95	100	3.5	6.9	4.9

* no response

APPENDIX II

Summary of Raw Score Statistics for the CAT*

Level 12 of the CAT

		Grade 1.7 subjects				Grade 2.7 subjects			
CAT test	Number of items	mean	SD	SEM	KR20	mean	SD	SEM	KR20
T. Read	71	28.1	12.95	3.82	.91	48.0	14.99	3.38	.95
Spell.	20	9.7	3.07	2.15	.51	13.0	3.45	12.4	.69
T. Lang.	46	19.2	6.50	2.91	.80	27.7	6.69	2.58	.85

Level 13 of the CAT

		Grade 2.7 subjects				Grade 3.7 subjects			
CAT test	Number of items	mean	SD	SEM	KR20	mean	SD	SEM	KR20
T. Read	73	39.1	13.93	3.73	.93	50.4	14.51	3.39	.95
Spell.	20	11.3	3.35	2.04	.63	13.8	3.26	1.82	.69
T. Lang	46	25.2	7.68	2.94	.85	31.1	7.32	2.73	.86

Appendix II, Summary of Raw Score Statistics for the CAT, continued:

Level 14 of the CAT

		Grade 3.7 subjects				Grade 4.7 subjects			
CAT test	Number of items	mean	SD	SEM	KR20	mean	SD	SEM	KR20
T. Read	70	37.5	14.24	3.62	.94	45.4	14.38	3.47	.94
Spell.	20	11.4	3.85	1.94	.75	13.3	4.01	1.84	.79
T. Lang	64	34.5	10.42	3.50	.89	40.6	10.01	3.41	.88

Level 15 of the CAT

		Grade 4.7 subjects				Grade 5.7 subjects			
CAT test	Number of items	mean	SD	SEM	KR20	mean	SD	SEM	KR20
T. Read	70	41.0	13.27	3.55	.93	45.3	12.52	3.47	.92
Spell.	20	12.6	3.49	1.92	.70	13.6	3.45	1.85	.71
T. Lang	64	41.2	9.87	3.41	.88	44.0	9.18	3.32	.87

Appendix II, Summary of Raw Score Statistics for the CAT, continued:

Level 16 of the CAT

		Grade 5.7 subjects				Grade 6.7 subjects			
CAT test	Number of items	mean	SD	SEM	KR20	mean	SD	SEM	KR20
T. Read	70	41.0	13.27	3.55	.93	45.3	12.52	3.47	.92
Spell.	20	12.6	3.49	1.92	.70	13.6	3.45	1.85	.71
T. Lang	64	41.2	9.87	3.41	.88	44.0	9.18	3.32	.87

Level 17 of the CAT

		Grade 6.7 subjects				Grade 7.7 subjects			
CAT test	Number of items	mean	SD	SEM	KR20	mean	SD	SEM	KR20
T. Read	70	44.4	13.09	3.52	.93	47.5	13.10	3.42	.93
Spell.	20	12.9	3.99	1.84	.79	13.8	3.78	1.79	.78
T. Lang	63	41.0	9.24	3.34	.87	42.4	9.33	3.34	.87

Appendix II, Summary of Raw Score Statistics for the CAT, continued:

Level 18 of the CAT

CAT test	Number of items	Grade 7.7 subjects mean	SD	SEM	KR20	Grade 9.7 subjects mean	SD	SEM	KR20
T. Read	70	40.1	11.38	3.64	.90	47.8	11.15	3.41	.91
Spell.	20	11.9	3.13	1.96	.61	13.8	3.34	1.84	.70
T. Lang	63	41.0	9.74	3.39	.88	45.6	9.18	3.20	.88

Level 19 of the CAT

CAT test	Number of items	Grade 9.7 students mean	SD	SEM	KR20	Grade 12.7 students mean	SD	SEM	KR20
T. Read	70	41.5	11.86	3.60	.91	51.9	11.55	3.20	.92
Spell.	20	11.7	3.74	1.96	.72	14.5	3.74	1.77	.78
T. Lang	63	37.7	9.02	3.47	.85	43.6	9.15	3.22	.88

*data from the Canadian Achievement Tests, Technical Manual