CENTRAL AUDITORY PROCESSING IN SEVERELY LANGUAGE DELAYED CHILDREN - SIX CASE STUDY PRESENTATIONS

THESIS

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By

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Responses of six severely language delayed (SLD) children were obtained on three measures of central auditory processing and one measure of language proficiency. The results of these measures were compared to the results obtained from six normal-hearing children, matched in age and Performance IQ on the WISC-R. The 12 children were tested with the Pitch Pattern Sequence Test (PPST), the Dichotic Digit Tests (DDT), and the Pediatric Speech Intelligibility Test (PSI). Differences in the central auditory abilities as well as the history of each child were presented in a case study format. The results of the history information demonstrated no unusual problems among these 12 subjects. Ten out of 12 subjects demonstrated abnormal results on at least one measure of the central auditory battery.

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CHAPTER 1

INTRODUCTION

This study describes the central auditory behaviors of six severely language-delayed children and their matched controls. Matched in age and Performance IQ, the children were evaluated on three tests of central auditory function, as well as a measure of language proficiency. The results are presented in a case study format for each of the six severely language-delayed children. Additionally, similarities and differences among these children and their matched controls are noted.

Review of the Literature

Cerebral Dominance and Dichotic Listening

It has been generally accepted that each of the cerebral hemispheres serve to represent distinct functions, with one hemisphere, usually the left, dominant for the reception and expression of verbal information (Kimura, 1961a,b; Kimura and Archibald, 1967; Rosenzwieg, 1951). Several investigators have studied the human system's response to auditory stimuli in an attempt to understand its representation at the cortex (Broadbent, 1954; Kimura, 1961, 1961b, 1964; Musiek, 1983, Pinheiro, 1977). More specifically, dichotically presented stimuli have proven to be useful in determining which cerebral hemisphere is dominant for language (Broadbent, 1954; Kimura, 1961a; Bryden, 1963; Berlin, Lowe-Bell, Cullen, Thompson, and Loovis, 1972; Berlin, Lowe-Bell, Cullen, Thompson, and Stafford, 1971; Willeford, 1976; Musiek, 1983; and Pizzamiglio, Pascalis, and Vignati, 1974). The term "dichotic" refers to different auditory information presented to each ear simultaneously.

Rosenzweig (1951) sought to demonstrate that binaural perception at the auditory cortex could be represented by electrophysiological responses to monaural click stimuli in anesthetized cats. The study showed that each ear is represented at the cerebral hemispheres by a group of cortical neurons, with the greater number representing the contralateral ear and the lesser number of neurons representing the ipsilateral ear.

In order to study the role of auditory localization in attention and memory span Broadbent (1954) presented simultaneously two different series of stimuli each to a separate ear. He found that the listener would respond to stimuli received at one ear and then to those presented to the other. For example, with the digits 1-5-3 presented to the right ear and 2-4-6 presented to the left ear, the listener would respond either with 153246 or 246153. The subjects of this study responded to the numbers of one ear before ever saying the numbers of the other ear. Broadbent concluded that this pattern of response indicated the sensory channel being used and was, therefore, a perceptual rather than a motor response. Broadbent (1956) elaborated on this phenomenon by changing the channels of sensory input. By presenting simultaneous stimuli to the eye and the ear, he found that responses were obtained more easily when the listener was required to respond in the order in which the stimulus was heard rather than in any other order. The process of attending to different stimuli presented to the ears simultaneously has come to be known as dichotic listening (Katz, 1985).

Kimura (1961a) was the first to adapt Broadbent's procedure when she presented dichotic digits preoperatively to patients who were to undergo left or right temporal lobectomies and then again postoperatively. She found that those patients were impaired in their ability to recognize digits arriving at the ear contralateral to the lesion. Additionally, her results indicated that the efficiency of recognition was affected by a left temporal lobectomy but not by a right temporal lobectomy. She interpreted these findings to mean that the discrepant efficiency was the result of the fact that the crossed auditory pathways in man were stronger or more numerous than the uncrossed pathways. These results also support Rosenzweig's (1951) electrophysiological findings. Kimura also suggested that the left temporal lobe plays a more important role than the right in the perception of spoken material. This is referred to today as the dichotic right ear advantage (REA) (Berlin, 1972).

In a later study Kimura (1961b) investigated the hypothesis that speech represented in the right or left hemisphere would be more efficiently recognized when presented to the opposite ear. One-hundred twenty patients, who had acquired lesions in various parts of the brain resulting in epileptic seizures, were used for this study. Right hemisphere dominance for speech was determined for thirteen of the patients by injecting sodium amytol into the internal carotid artery of one side. The result was that the function of one hemisphere was disrupted temporarily. All of the patients were presented dichotic digits (Broadbent, 1954) in a manner described previously by Kimura (1961a). Results indicated that the digits presented to the left ear were more efficiently recognized for those patients with right hemisphere dominance, and more efficiently recognized at the right ear for those patients demonstrating left hemisphere dominance. These findings confirmed Kimura's previous results (1961a).

Bryden (1963) investigated 92 normal adult responses to dichotically presented stimuli presented in the same manner used in Broadbent's research. By evaluating the total accuracy of report for each ear, the author found that numbers presented to the right ear were more accurately identified than numbers presented to the left ear. In an additional experiment from this same study, Bryden observed the effect that a specific order of report would have on the total accuracy for 32 of his subjects. The subjects were instructed to report the information presented to a specific ear first and then report the information from the opposite ear. This order was then reversed. Responses were reported more accurately for digits arriving at the right ear than for those arriving at the left ear. The author's results supported Kimura's finding (1961b) that the auditory system perceives verbal information more efficiently when it is presented to the right ear.

Further support for Kimura's findings regarding greater representation of pathways contralateral to the dominant hemisphere (1961a, 1961b) can be found in the studies of the physical asymmetries between the two cerebral hemispheres. Geschwind and Levitsky (1968) examined the normal brains of 100 human cadavers. They noted that the upper surface of the left temporal lobe, which contains the primary auditory cortex, is significantly larger than the structures of the right temporal lobe. They concluded that these physical measures of left-right asymmetry were significant enough to support the functional asymmetries found between the left and right ears.

Additional auditory studies support the left cerebral dominance for speech. Milner, Taylor, and Sperry (1968) reported on seven right-handed patients, who had undergone surgical disconnection of the cerebral hemispheres to help control severe convulsive disorders. These patients were required to repeat three-digit pairs of dichotic digits developed by Broadbent. Left-ear results showed that the accuracy of these patients in repeating the digits was only about 10% correct. In fact, five of the seven patients reported that they could hear nothing in the left ear, even though they expected to hear digits in both ears. In monaural presentations of the same material, all of the patients reported the left-ear digits without difficulty. The authors concluded that the ipsilateral auditory pathways could be utilized in conditions where no competition between the ears is presented. However, in the presence of a competing stimulus ipsilateral input is suppressed, a factor which the authors felt supports dominance of the contralateral pathways in man. Musiek, Wilson, and Pinheiro (1980) reported similar results when testing three commissurotomized patients using various dichotic tests that were incorporated in a central auditory battery. The authors noted improved performance for the dichotic tasks when the intensity level of the right ear stimuli was increased by 25 to 30 dB over the intensity level of the left ear.

To further elaborate on the distinct functions of the two cerebral hemispheres, Kimura (1964) compared the perception of dichotically presented melodies to dichotic digits. In a manner similar to that used by Broadbent, she presented dichotic digit pairs and then dichotic melodies to twenty normal-hearing subjects. The melodies test was comprised of eighty, 4-second excerpts from various composers, which were recorded into 20 sets of four. Two separate passages were presented dichotically. The subjects listened to four separate passages and chose the two that were thought to have been heard. Results from this study supported the contention that the right temporal lobe plays a more important role in nonverbal auditory perception than the left temporal lobe.

Dirks (1964) investigated the existence of asymmetry between ears in both dichotic and monotic listening conditions. He first presented different filtered phonetically balanced (PB) words simultaneously to the two ears to 24 normal-hearing subjects. These subjects were required to respond to both stimuli in any order they wished. A second test condition was repeated but the subjects were required to respond only to one ear or the other. The filtered words were then presented in a monaural condition. Finally, dichotic digits were presented and the subjects were instructed to respond to all of the digits. The results of both dichotic presentations, i.e. digits and filtered PB words, demonstrated significant superiority of 2 to 6% for the right ear over the left ear in repeating the verbal material. Results of the monaural presentations indicated no differences between the ears. These findings confirm the hypothesis of Kimura (1964) that competition must exist between the ears for an asymmetry to be observed.

Sparks and Geschwind (1968) presented a theoretical model in order to explain left ear suppression in patients who, following callosal sectioning, demonstrated a left ear deficit. The authors proposed that the less dense ipsilateral pathways are suppressed by the stronger contralateral fibers in the presentation of dichotic stimuli. This would account for the normal cerebral dominance effect. Additionally, when competition of report exists between the two hemispheres, the authors contended that information from the right ear arrives at the dominant left hemisphere via a direct route across the transcallosal pathway. Information from the left ear, however, must follow the decussating pathways to the right hemisphere and cross once again to the dominant left hemisphere. After elimination of the main contralateral pathways, these authors state that only the left ear is prepared to respond to the competing stimuli via the ipsilateral fibers.

Sparks, Goodglass, and Nickel (1970) elaborated on the Sparks and Geschwind (1968) model when they studied 28 left brain-damaged and 28 right brain-damaged subjects who were required to respond to the dichotic presentation of digits and monosyllabic words. Both groups showed deficits in the ear contralateral to the lesion. However, the deficits for the right ear were greater than those for the left ear. The model proposed by these authors suggests that only a lesion of the left hemisphere can affect the information from both the ipsilateral and the contralateral ears. They suggest that a lesion of the left auditory association area inhibits the reception of auditory information presented to the right ear. Therefore, the information is forced to travel the less dense ipsilateral pathway. However, information along this ipsilateral pathway is suppressed by the stronger contralateral fibers delivering information from the left ear. Sparks and his associates conclude that the end result is an ipsilateral extinction of information presented to the right ear.

Other studies which support left cerebral dominance for speech perception include those of Studdert-Kennedy and Shankweiler (1969), and Berlin, Lowe-Bell, Cullen, Thompson, and Loovis (1972). The former study examined the effects of dichotically presented consonant-vowel-consonant (CVC) syllables to twelve subjects aged 18-26 years. They found a significant right ear advantage (REA) for the initial stop consonants. The latter study by Berlin, et al (1972) posed the question of why right ears out-perform left ears upon simultaneous presentation of different information. These authors conducted two experiments in which they altered the time separation between the onset of each stimulus. Using the dichotic presentation of the CV stimuli (pa, ta, ka, ba, da, ga), Berlin and his associates delayed the onset time of the stimuli by 0, 15, 30, and 60 msec.

The second experiment by Berlin et al (1972) delayed the onset time of the CVC syllables from 0 to 500 msec. Their results indicated that CV's were more intelligible when presented 30-60 msec apart than when they were presented simultaneously. Additionally, they found that voiceless consonants were more intelligible than voiced when presented in a simultaneous dichotic condition. The authors proposed that this phenomenon was due to the perception of a voiceless CV being delayed because of its long burst duration. These investigators theorized the presence of a left-hemisphere "speech processor" which suppresses information from the ipsilateral pathways during contralateral stimulation. By switching its operating mechanism in the auditory nervous system, they reported that this so-called "speech processor" may be involved in coordinating simultaneous messages to our two ears into a single message.

Tests of Central Auditory Function in Adults

Among the test formats developed to assess central auditory processes in adults, low-pass filtered speech, competing sentences, dichotic digits, and pitch pattern sequencing have become tools in determining the efficiency of the central auditory system. Various types of these tests have been used to describe differences between normal auditory function and human systems which are abnormal because of pathologies which develop in the neurological system.

The use of speech material to identify lesions impinging on the auditory system appears to have begun with Bocca, Calearo, Cassinari, and Migliavacca (1956). These researchers found that the use of speech stimuli presented auditorily proved to be useful in identifying pathologies and sites of lesion in the auditory system. Specifically, they devised a low redundancy speech test for the detection of central auditory disorders through the use of low-pass filtering above 800 Hz (Bocca, Calearo, and Cassinari, 1954). They found significantly reduced scores for material presented to the ear opposite the hemisphere affected by cerebral tumors, believed to be affecting the temporal cortex.

In a comprehensive summary of audiologic methods for diagnosing disorders in the central auditory nervous system (CANS), Bocca and Calearo (1963) established that since the pathways of the CANS are so rigidly and redundantly structured, any auditory stimuli used to reduce the redundancy of that system would appear appropriate for assessing its efficiency. In general, methods which reduce the redundancy of the CANS entail reducing the redundancy of the primary speech signal. Examples of tests used for this purpose include filtered speech, described above, dichotic speech, binaural fusion, and time compression.

Based on the above implications, Jerger and Jerger (1974, 1975) expanded the Synthetic Sentence Identification (SSI) test (Speaks and Jerger, 1965) in order to differentiate between brain stem and temporal lobe lesions. Using third order sentences from the SSI, these authors developed two test modes that reduce the redundancy of the primary speech signal through a competing message. The term "third order" refers to a sentence which approximates a "real" utterance in that each word is conditional on the two words preceding it but in which the sentence makes no sense. With the first test mode synthetic sentences are presented to one ear while the other ear simultaneously receives a competing message in the form of a narrative, referred to as a contralateral competing message (CCM) test. The order is then reversed to test the opposite ear. A second test mode involves a combination of the sentences and competition presented first to one ear and then to the other, an ipsilateral competing message (ICM) test.

Jerger and Jerger (1974) found poor performance for the ICM and relatively good performance for the CCM condition when they tested eleven patients with confirmed brain stem lesions. The deficits under the ICM condition were observed only on the ear opposite the side on which the pathology occurred. CCM performance was within normal limits for both ears. Additionally, these same authors (1975) evaluated ten patients with brain stem lesions and ten patients with temporal lobe lesions. They reported poor performance on both ICM and CCM, with ICM deficits observed on both ears and the CCM deficit observed on the contralateral ear only. In view of these results, an anatomical explanation was offered. If the lesion is located in the upper brain stem, contralateral deficits are more probable because the majority of ipsilateral fibers have crossed the midline of the brain stem. If, however, the lesion is located in the lower brain stem, ipsilateral deficits are expected because many fibers in this location have not yet crossed the midline. Therefore, a greater performance deficit for an ICM than for a CCM is consistent with brain stem site of lesion. A greater deficit for a CCM than for an ICM is consistent with a temporal lobe site of lesion. Based on these findings, the authors suggest that the SSI-ICM and the SSI-CCM be used to differentiate brain stem from temporal lobe sites.

Two tests used today for the evaluation of central auditory function are from the Willeford Central Auditory Processing Battery (Willeford, 1976). The low-pass filtered speech subtest consists of two 50-word lists of Michigan CVC words which were selected to be highly intelligible to adults even when filtered. Willeford and Billger (1978) reported seeing the same pattern of results as those seen with the adults studied by Bocca, et al (1954). The competing sentence subtest is recorded so that one sentence arrives at one ear and a different sentence arrives simultaneously at the other ear. The subject is required to repeat the primary sentence arriving at the test ear and to ignore the competing sentence from the nontest ear.

Reische (1983) studied the relationship between age and performance on the Willeford Test Battery using 94 normal hearing subjects aged 18-80 years. The subjects were presented with a tape recording of the Willeford battery. Results showed significant age-effects (that is, poorer performance as a function of increased age), or ear differences. These results demonstrated the need to consider age and ear difference factors in using the Willeford battery clinically.

Another method for assessing the central auditory system is through a technique called binaural fusion (Matzker, 1959). This term is defined by Katz (1985) as the "listener's integration of simultaneous but different speech signals, as low-pass filtered speech to one ear and high-pass filtered speech to the other. It enables better understanding of the combined signals than of either one alone" (pg. 1063). While each ear receives a different filtering of the message, a single rather than a different message is used. Matzker (1959) originally developed the binaural fusion procedure in order to demonstrate specific pathological changes with various brain lesions. Using a low-pass filter from 500 to 800 Hz and a high-pass filter from 1815 to 2100 Hz, he presented 41 two-syllable, phonetically balanced (PB) words to over 1,000 subjects. Single words were presented dichotically with low frequency information from that word presented to one ear and high frequency information from the same word presented to the other ear. Matzker found that when a bisyllabic word was presented separately, his normal subjects integrated the information as well as when the complete word was presented simultaneously to both ears. He proposed that this finding indicates the efficient function of the synaptic junctions in the auditory brain stem. He theorized that failure on this task indicates poor synaptic function within the auditory centers of the brain stem.

Based on the work of Matzker (1959), Katz developed the Staggered Spondaic Word Test (SSW) in 1962. He sought to minimize the influence of auditory differences that were unrelated to central auditory disorders. The format for the test includes the simultaneous presentation of two spondaic words, presented in such a way that the first syllable of one spondee is presented monaurally to one ear. The second syllable of that same spondee is presented to the opposite ear dichotically with the first syllable of the second spondee. Finally, the second syllable of the second spondee is presented to the opposite ear without competition. The following example best illustrates the presentation of these stimuli:

right ear - "base" - no competition

left ear - "ball"; right ear - "hot" >competing

right ear - "dog" - no competition

The listener responds after the presentation of the second spondee and repeats both spondees in the order presented. Normative data gathered by Katz (1963) indicates that normal hearing adult subjects show no errors on any of the four conditions. Individuals with temporal lobe damage, however, demonstrate poor performance on the ear opposite the damaged hemisphere for the dichotic presentation of the spondees.

Time-compressed speech has also been used to assess central auditory function (Bocca and Calearo, 1963; Beasley, Forman, and Rintelmann, 1972; Riensche, Konkle, and Beasley, 1976; and Manning, Johnston, and Beasley, 1977). Beasley, Schwimmer, and Rintelmann (1972) studied the effects of time-compressed monosyllables on the auditory discrimination abilities of 90 normal-hearing, adult subjects. The authors varied the degree of time compression in five conditions from 30% through 70%. Each condition was presented at four separate sensation levels up to 32 dB. Their results indicate that the discrimination performance of these subjects worsened gradually as the percentage of time compression was increased, with 70% time compression demonstrating a dramatic decrease in performance. Additional findings indicate that discrimination abilities increased proportionately with increases in intensity. Smaller increases in performance occurred as an optimal listening intensity level was approached.

In order to investigate the intelligibility of time-compressed words as a function of age and hearing loss, Sticht and Gray (1969) obtained discrimination scores from 28 young and old subjects with normal hearing or sensory neural hearing loss. Each subject was presented with 60 time-compressed words (30 for each ear) from the CID W-22 word list at a sensation level of 40 dB. The authors found that for both the normal hearing and the hearing impaired groups the number of errors increased as a function of age rather than a function of hearing loss. Because performance scores on the time-compressed material were greatly deteriorated from their normal audiometric configurations, the authors suggested the presence of a central auditory disorder among their normal-hearing, elderly subjects.

It has been demonstrated that characteristics such as rollover are prevalent with intracranial lesions (Jerger and Jerger, 1971). However, individuals who demonstrate sensory-neural hearing loss without the presence of rollover can not be considered free from disorders within the CANS

(Goodman, 1957). The Dichotic Sentence Identification Test for Hearing Impaired Adults (DSI), developed by Fifer, Jerger, Berlin, Tobey, and Campbell (1983), was designed to assess the central auditory function of hearing-impaired adults. This test sought to minimize poor performance affects due to peripheral hearing loss. The stimuli used by Fifer, and his associates are 90 third-order sentences (Speaks and Jerger, 1965) presented dichotically. Fourteen normal-hearing and 48 hearing impaired subjects were required to listen to two dichotically presented sentences, responding only to one of the sentences in a closed-set response format. The results of this study showed that the DSI test is sensitive to central auditory problems in individuals who demonstrate a sensory-neural hearing loss of up to 49 dB HL (re: pure-tone average for 500, 1000 and 2000 Hz). The magnitude of hearing loss beyond about 50 dB interferes with the ability of the test to detect central auditory disorders.

Musiek (1983) constructed a dichotic digit test which he used to establish normative data for 45 individuals demonstrating normal hearing sensitivity. Two other experiments were conducted to examine the performance of 21 subjects with cochlear hearing loss and 21 subjects with confirmed intracranial lesions. This test was composed of naturally-spoken, single-syllable digits from 1 to 10, recorded so that two digits were aligned on one channel of a tape recorder with an additional pair of digits aligned on the other channel. The test consisted of a total of 20 digit pairs with a total of 40 test items for each ear. All subjects were instructed to repeat all of the digits heard and were encouraged to guess when they were unsure of a stimulus. The number of digits reported correctly for each ear was counted and a percentage score was derived. The performance of the normal-hearing population yielded a 90% or better total correct score, while the population with cochlear hearing loss yielded scores of 80% or better for the total of correct responses. Eleven of the 14 subjects with CANS lesions, but with normal peripheral hearing, showed abnormal results on the dichotic digit test. Six of the seven subjects with CANS lesions complicated by peripheral hearing loss also showed abnormal results. Stated another way, 17 of the 21 subjects with CANS lesions yielded abnormal results on this test, with a mean performance of 60% for the left ear and 83% for the right ear. These results support the sensitivity of the Dichotic Digit Test in identifying lesions of the CANS.

Data on the stability of the dichotic listening test (Broadbent, 1954; Kimura 1961a, 1961b, 1967; and Milner, 1962) was provided by Pizzamiglio, De Pascalis, and Vignati (1974). Ninety-one normal-hearing male adults, aged 19 to 22 years, were tested on two separate occasions with a dichotic digit test. The results of this study indicated a moderate degree of stability for the dichotic digit task, supporting its use in quantitative studies. However, due to a high percentage of inconsistency among some subjects, the authors cautioned other investigators regarding the use of this tool as a predictor of ear preference.

Another test developed to assess the efficiency of the central auditory system is the Pitch Pattern Sequence Test by Pinheiro (1977). Previous research by Pinheiro and Ptacek (1970, 1971) set the foundations for the utility of this test. These authors originally reported on the perception of auditory patterns based on an intensity difference. They presented intensity patterns to 30 normal-hearing subjects under binaural, monaural, and dichotic listening conditions. The patterns were established by varying the combinations of two sounds which differed only in intensity, loud (L) and soft (S). The authors found that an intensity difference of 10 dB was needed in order for the subjects to recognize a pattern correctly 50% of the time. They suggested that this intensity difference indicated that more than simple discrimination is involved in the performance of this task. Thus, a higher auditory function was used to identify correctly these patterns of tone bursts.

A task similar to that of Pinheiro and Ptacek (1970, 1971) was presented by Musiek, Pinheiro, and Wilson (1980) to three "split brain" subjects with normal peripheral hearing. Their study incorporated both intensity and frequency patterns, and the subjects were required to label verbally the sequence of the frequency or intensity patterns. A second task required the subjects to hum the frequency patterns in a three-note sequence. Results indicated that sectioning the corpus callosum dramatically affected the ability of the subjects to report verbally both types of patterns. The authors concluded that for correct verbal report of an auditory pattern, the acoustic information must be transferred to the dominant hemisphere for language.

Tests of Central Auditory Function in Children

Historically, central auditory tests developed for young children have stemmed from two different approaches. In one approach, already existing adult central auditory test procedures were adjusted for use with children by modifying the expected range of normal performance. In the second approach, new central auditory test materials and testing formats that conformed to children's interests and abilities were developed and standardized (Jerger, 1988).

An example of already existing adult central auditory test procedures adjusted for young children is the Willeford Central Auditory Processing Battery (Willeford, 1976). In 1978, Willeford and Billger established normative data for the filtered speech subtest. The study was based upon a total of 200 children, forty children in each age group, from 6 to 10 years. The authors observed a progression of improvement for task performance as a function of age. Additionally, a comparison of these norms to those obtained for 20 college students studied by Ivey (1969) demonstrated similar intra-subject performance for the left and right ears, with a wide range of scores for all ages. Willeford and Burleigh (1985) suggested that scores for children completing the filtered speech subtest be considered abnormal only if one or both ears fall below the expected range of performance for that age group; or when an asymmetry between the ears is greater than 10 to 12%.

A second test of the Willeford battery is the competing sentence subtest (Willeford, 1968). A study by Lynn and Gilroy (1977) demonstrated equal performance for both ears on this subtest for 20 normal adult subjects. The authors noted the importance of utilizing tests which show no abnormalities among normal subjects so that a degree of asymmetry might be determined for individuals with unilateral lesions. Willeford and Burleigh (1985) presented normative data for this task for 225 normal children aged 5 to 10. Their results indicated that right ear performance was superior in 192 of the subjects, while only 13 of the subjects demonstrated greater performance for the left ear. These authors concluded that since abnormal performance on the competing sentences subtest was commonly found in only one ear, this test is not affected by memory constraints. Further support for this conclusion was based on the experience of the authors that normal performance generally resumed when the competing stimulus was removed.

Among the research findings of special note is a study conducted by Berlin, Hughes, Lowe-Bell, and Berlin (1973). These authors studied the REA as a function of age. They presented strings of nonsense CV syllables /pa,ta,ka,ba,da,ga/, differing only in voicing and place of articulation, to 150 children aged five to thirteen. They found that by about the fifth or sixth year of life, human beings, (presumably left hemisphere dominant for speech), develop a distinct REA. That is, information presented to the right ear is heard more distinctly, with a greater sensation of loudness, and sooner than information presented to the left ear.

Hynd and Obrzut (1976) sought to investigate the hypothesis that a progressively greater number of dichotic stimuli would be reported for the right ear for children of increasing grade level and age. They also investigated the effects of gender on the report of dichotic information. With data gathered from four groups of 40 children (20 boys and 20 girls), representing kindergarten, second, fourth, and sixth grades, these authors determined that the magnitude of the dichotic REA did not increase with age. Additional findings suggested that gender differences for the dichotic REA did not exist in these elementary aged children.

In a longitudinal study of the development of ear advantage, Bakker, Hoefkens, and Van der Vlugt (1979) presented four-paired dichotic digits to 55 normal children at the ages of 5 through 12 years. The children were required to repeat as many digits as possible in any order. Although the authors found the expected REA, they did not find changes in the REA's of these children with changes in age. Bakker and his associates, however, did find that the results of children who initially demonstrated a left ear preference were not as stable as those who initially showed a right ear preference. That is, more children who were left ear dominant changed their ear dominance to the right ear, and did so more frequently than those who were initially dominant for the right ear.

In order to report on the diagnostic value of some tests of central auditory function, Pinheiro (1977) administered seven such tests to fourteen children with learning disabilities. All of the children were reported as having normal peripheral hearing. Throughout the seven-test battery, the left ear performance of the learning-disabled children was poorer than the right ear performance. Pinheiro noted that on the Pitch Pattern Sequence Test (PPST) eleven of the fourteen subjects could hum the patterns normally. However, the subjects demonstrated significant difficulty in making a tapping response to the stimuli. The humming task is presumably a right hemisphere function (Kimura, 1964), thereby explaining the ease of response for these learning disabled subjects. The tapping response, however, is a sequencing task and, according to Kimura and Archibald (1964) and Loomas and Kimura (1976), requires the use of the left hemisphere. The PPST was the only test of the battery which required interhemispheric interaction.

Musiek, Geurkink, and Kietel (1982) chose seven central auditory tests to administer to 22 children with known central auditory processing disorders (CAPD) in order to determine the sensitivity of those tests. Results showed that the Frequency Pattern Test by Pinheiro (now known as the Pitch Pattern Sequencing Test), the Competing Sentence Test by Willeford, and the Dichotic Digits Test by Musiek were the most sensitive in identifying CAPD in these 22 children.

Jerger (1983) described the development of a Pediatric Speech Intelligibility Test (PSI) for children aged three to six years. The test was constructed from word and sentence messages generated from children of these ages who exhibited normal receptive language abilities. Two different types of sentences were formed to represent differences in the children's responses. These differences related to chronological age and receptive language ability. The test utilizes ten sentences and twenty words presented to each ear with an ipsilateral or contralateral competing message at varying message-to-competition (MCR) ratios.

In order to avoid the influence of non-auditory factors such as attention, motivation, memory, language, knowledge, reinforcement, and personality, Jerger (1981) built four controls into the PSI: 1) the listening task consists of a closed message set of five items, 2) the primary and secondary messages are spoken by different male voices, 3) target items are presented first in quiet and then in the presence of a competing message, and 4) reinforcement by positive verbal remarks or tangible reinforcers are used in test administration.

The effectiveness of the PSI as a predictor of CAPD in children is still under investigation. Jerger, Johnson, and Loiselle (1988) compared the results of pure-tone audiometry, acoustic reflexes, and performance on the PSI for children with either documented or suspected central auditory dysfunction. In children with confirmed central nervous system (CNS) lesions, results were consistently normal with lesions in the non-auditory areas of the brain and consistently abnormal with lesion in areas of the brain important for auditory perceptual function. These findings were consistent with previous findings in adults performing on the SSI (Jerger and Jerger, 1974, 1975). Results in the CAPD children were more similar to findings in the temporal lobe group than to either the non-auditory CNS group or the brain stem group. Jerger (1988) concluded that the PSI is a test which is sensitive to auditory perceptual rather than linguistic disorders. She does caution, however, that interpretations of the above data are limited by the small number of children involved in the study.

Central Auditory Tests for Learning Disabled Children

The use of central auditory tests to describe the auditory abilities of learning-disabled children is found in the research literature (Sommers & Taylor; Roeser, Millay, & Morrow, 1983; Ferre & Wilber, 1986). According to Public Law 94-142 (1975), which provides educational services to all handicapped children, learning disability is defined in the following amendment:

> `Specific learning disability' means a disorder in one or more of the basic psychological processes involved in understanding or in using language spoken or written, which may manifest itself in an imperfect ability to listen, think, speak, read, write, spell, or to do mathematical calculations. The term includes such conditions as perceptual handicaps, brain injury, minimal brain dysfunction, dyslexia, and developmental aphasia. The term does not include children who have learning problems which are primarily the result of visual, hearing, or motor

handicaps, of mental retardation, of emotional disturbance, or environmental, cultural, or economic disadvantage (Section 121 (a)(5), 1977).

Sommers and Taylor (1972) studied cerebral dominance for speech in twenty language-disordered and normal children using dichotic digits and other words presented dichotically. Both groups reported the expected REA for words. However, the language-disordered children demonstrated a clear left ear preference for digits presented dichotically, while the normal subjects showed a 100% right ear preference.

Bakker, Smink, and Reitsma (1973) found some relationships between ear dominance and reading ability. They tested the hypothesis that reading proficiency is associated with undetermined ear dominance at a young age and with specific ear dominance at a later age. Forty right-handed children aged seven years, zero months to seven years, six months were presented with monaural and dichotic digits. Responses were counted as correct in the monaural task if the digits were repeated in the exact order presented. The dichotic digits were counted as correct if they were repeated correctly, regardless of the order. Ear dominance was determined by subtracting the left ear score from the right ear score for each task. The results of this study showed that younger children who showed the lowest between-ear differences were the best readers, while older children who showed the highest between-ear differences were better readers than those children with no such difference. Bakker and his associates concluded that reading efficiency may be hindered in those children who show early lateralization. The authors stated that this finding was possibly due to the fact that early reading focuses on processing a great deal of both non-lingual and lingual information. Therefore, the approach to reading development which utilizes both lingual and non-lingual information would be facilitated by an interaction between both hemispheres.

Ayres (1977) sought to determine whether learning-disabled children without a distinct REA on a dichotic listening task would differ in performance on academic, language, and sensory integrative tests from children who had a distinct REA. The author presented dichotic pairs of the syllables "pa,ka,ta,ba,ga,da" to 114 learning-disabled (LD) children, aged six to ten years. The children were required to report the sound which was "heard better" rather than reporting all that was heard. Scores based on the differences between the ears were obtained for three groups: children with low ear differences, those with average ear differences, and those with high differences. Since the difference in test scores for the three groups was considered to be too small to be statistically significant, the author could provide no answers for the question of whether LD children have left or right hemisphere dysfunction.

A second question proposed by Ayres (1977) sought to describe the differences on academic, language, and sensory integrative measures among these LD children. The results showed that the scores of the children with low ear differences were higher than the other two groups on five out of six sensory integration measures. Additionally, the children with low ear differences scored most poorly on five out of six measures of auditory-language ability. Ayres concluded that the low ear difference group was less likely to have a somatosensory disorder associated with a diagnosis of an educational handicap, but was more likely to have a language problem. Further results showed that these low-ear difference LD children, with a mean age of eight years, two months, produced total raw scores of about 45 correctly identified syllables when reporting dichotic information. These scores were reported as considerably lower than the raw scores obtained from 48 normal children aged six to ten years.

To test the hypothesis that each cerebral hemisphere directs its attention to the opposite side of space, Hynd and Obrzut (1979) compared ear asymmetries on a dichotic task between 48 normal children and 48 children who were clinically identified as learning-disabled. The ages of these children ranged from seven years, zero months to eleven years, eleven months. The number of correctly identified CV syllables were recorded for each ear for all of the subjects. The authors found that the LD children reported right ear scores between 1.62 and 4.29 greater than left ear scores. The normal children reported right ear scores between 2.50 and 4.21 greater than left ear scores, demonstrating that these two groups of children did not differ in the degree of ear asymmetry for a dichotic task. Rather than a difference in the degree of asymmetry between ears, the authors found instead that these two groups of children differed in terms of their overall efficiency in reporting dichotically presented stimuli. In their final analysis, the authors reported that the LD children demonstrated the same degree of lateralization, but differed from the normal children in their ability to attend to dichotic stimuli. The authors proposed that the structural organization of the brains of normal and LD children are the same. However, the ability of the LD children to use this structural organization was impaired.

Support for the above study can be found in the results of a study by Koomar and Cermak (1981) who sought to establish the reliability of the CV and digit formats of the dichotic listening task. They presented each of these formats to normal and LD children between the ages of seven and ten years. Their results showed that there were no differences in ear advantage between the two groups. On the digit format, however, the LD children performed significantly poorer than the normal group on both the total accuracy for both ears and on the left ear score alone. Finally, reliability for the CV format was higher than that of the digit format in this study. The authors concluded that since information presented to the right ear is processed more quickly than information presented to the left ear, children with poor auditory memory skills tend to forget the information that was presented to the left ear. The authors stated that this is because the left ear information arrived at the dominant hemisphere later than the right ear information.

In 1981, Farrer and Keith evaluated the effects of varying the cut off frequencies for low-pass filtered speech discrimination among "auditory learning-disabled" children and children presumed to have normal auditory perception. These authors presented Phonetically Balanced Kindergarten (PB-K) words filtered at 1000, 750, and 500 Hz. The results indicated a significant difference between the performance of the normal and LD children on their ability to discriminate the PB-K words in the unfiltered condition as well as all of the filtered conditions. While there was an overlap in performance between these two groups on the 500 Hz and 750 Hz conditions, their performance scores were completely separated for the 1000 Hz filtered condition.

The authors concluded that the 1000 Hz cutoff frequency was more efficient than a 500 Hz cutoff frequency in identifying children with central auditory processing disorders.

The performance of children with auditory perceptual disorders on a time-compressed speech discrimination test was assessed by Manning, Johnston, and Beasley (1977). The authors presented the PB-K 50 word lists at 0, 30, and 60% time-compression to 20 children diagnosed as displaying auditory perceptual disorders. The results of this study indicate that these children with auditory perceptual problems were able to discriminate the auditory stimuli equally well in both the 0% and the 30% time-compression conditions. However, performance decreased significantly at the 60% time-compression condition. When the authors compared these results to normative data (Beasley, Maki, & Orchik, 1976), they showed that both the children with auditory perceptual problems and normal children perform similarly at the 30% time-compression condition. However, the children with auditory perceptual problems demonstrated poorer performance at both 0% and 60% time-compression than normal children.

Welsh, Healy, Welsh, and Cooper (1982) used a central auditory test battery, which consisted of competing sentences, binaural fusion, filtered speech, and compressed speech, in addition to auditory brain stem response (ABR) testing to assess the central auditory function of twenty dyslexic children, aged 10 to 13. The authors considered dyslexia as a type of minimal brain dysfunction, which manifests itself in behavioral, perceptual, and cognitive deficits. The results of this study indicated that 95% of the subjects failed at least one segment of the test battery. More than half of these dyslexic children performed poorly on 2,3, or 4 of the tests. The ABR values were analyzed according to the latencies of waves I and the IV-V complex, as well as the amplitude ratios of IV-V/I. Amplitude ratio refers to the morphological wave representation of the auditory click stimulus as the signal travels through the auditory brain stem. Generally, normal amplitude ratio results are presented with the amplitude of wave I as 1/2 the amplitude of wave III, or the amplitude of wave III 1/2 the amplitude of wave V. Fifteen of the children in this study fell within the normal range of the ABR measures. One child exceeded the normal latency values and four children were below normal values for amplitude. The authors judged the binaural fusion test to be the most sensitive instrument for detecting CAPD, evidenced by its high degree of failure (85%) among these dyslexic children. The ABR test, however, was judged to be the least successful in detecting impairment in the auditory system at the level of the brain stem.

A longitudinal study by Roeser, Millay, and Morrow (1983) compared the perceptual abilities of normal and learning-impaired children when they were presented with dichotic CV syllables with no time delay between syllables, and the same stimuli presented with time delays or temporal offsets of 30, 60, and 90 msec between syllables. In the first experiment, the authors reported on the results of 32 normal children between the ages of five and eight, who had a mean full-scale IQ of 114, as measured by the Weschler Intelligence Scale for Children (WISC). In the second experiment, results were reported for 17 learning-impaired children aged 7 to 13. These children had a mean full-scale IQ on the WISC of 99. Performance of the learning-impaired subjects on the dichotic tasks was compared to the performance of the normal control subjects, matched for age and sex. The results showed no differences in performance between the learning-impaired and normal control subjects. Both groups demonstrated a significant REA as well as increased auditory capacity as a function of age. However, neither group demonstrated an advantage in processing the delayed or offset stimuli.

An experimental test battery, designed by Ferre and Wilber (1986), was used to compare the central auditory function of normal and learning-disabled children. These subjects were matched for age, sex, race, and socioeconomic status. The test battery consisted of four central auditory tests including low-pass filtered speech, binaural fusion, time-compressed speech, and dichotic monosyllables. The test results indicated difficulty processing time-compressed speech in 62% of the LD children and 62% of the normal children. However, the low-pass filtered speech test identified difficulty for 92% of the LD children and only 23% of the normal children. The authors concluded that a test battery approach may be more effective than any single test in identifying LD students with central auditory processing problems, given the high false-positive rate of some of the tests used in this study.

In an effort to establish a relationship between auditory-perceptual and language-learning skills, Jerger, Martin, and Jerger (1987) administered a battery of electrophysiologic, electroacoustic, and behavioral tests to an eleven-year, five-month-old LD child with normal peripheral hearing. The birth and developmental history of this child revealed no abnormalities until the age of six years, when the child reportedly began to experience a mild seizure disorder. By the age of nine years, no further seizures had been reported, but the child complained of difficulty understanding verbal instructions in the classroom.

The electrophysiologic tests consisted of the auditory brain stem response (ABR), the middle latency response (MLR) and the late vertex potential, all evoked by click stimuli at 80 dB nHL. The electrophysiologic results revealed relatively normal ABR results for the left ear, but degraded waveform morphology for the right ear. The results of the middle latency response (MLR) and late evoked potentials revealed poor definition and replicability for peak waveforms bilaterally. These two electrophysiologic measures are time-locked to an auditory stimulus and have been reported to measure electrical activity occurring in the upper brain stem and cortex. Electroacoustic immittance results indicated elevated or absent contralateral acoustic reflexes bilaterally. Ipsilateral reflexes were found to be elevated in the left ear and normal in the right ear.

Phoneme and word discrimination and identification measures showed that the child had significant difficulty performing in noise. Language measures, which assessed the syntactic abilities of this child, demonstrated difficulty with auditory identification of sentences, while semantic abilities were found to be normal. Based on the above data, Jerger and her associates reported the presence of an auditory-processing disorder as opposed to a linguistic or cognitive disorder.

The study of adults with confirmed lesions of the CANS (Bocca et al, 1954; Kimura, 1961a, 1961b, 1964, 1967; Milner et al, 1968; Musiek et al, 1979) has led some researchers to investigate the central auditory function of children with confirmed neurological problems (Jerger, 1988; Musiek, 1985). Many children with CAPD, however, do not exhibit known neurological disorders (Ferre et al, 1986; Welsh et al, 1982; Ayres, 1977; and Roeser et al, 1983). Instead, they demonstrate academic difficulties which are reportedly the result of unknown causes and often are attributed to CNS problems. These children are frequently branded with the heterogeneous label of learning-disabled. They are often described as having individually specific visual perceptual and/or auditory perceptual deficits.

Today there are a number of tests to assess the presence of CAPD in children. Some research has suggested that the development of a REA does not occur for the learning/language-delayed child until the age of nine or ten years when the auditory system has matured (Musiek, 1984). Conflicting data is available for the existence of an ear advantage in learning-disabled and language delayed children (Sommers & Taylor, 1972). Many of the auditory studies with LD children have failed to show any conclusive evidence of abnormal performance. A lack of normative data has been a limiting factor.

While many of the auditory studies have described the central auditory performance of LD children (Ayres 1977, Ferre & Wilber 1986, Jerger 1987, Pinheiro 1977, Roeser et al 1983, and Welsh et al 1982), few studies have compared the learning-disabled child's auditory behaviors to that of his normal peers. Even fewer studies have tried to relate central auditory behaviors to academic and language performance. In order to provide a more accurate profile of the learning-disabled population, more research must be conducted to relate the central auditory behaviors of these children to their academic and language skills.

The purpose of this study is to determine whether results, similar to those obtained for adults and children tested on measures of central auditory function (Jerger and Jerger, 1974; Musiek, 1983; Pinheiro, 1977), will be obtained for the children who demonstrate normal performance intelligence but a deficit in language. This study will address how the central auditory test results of such children compares with the results obtained for control subjects, who demonstrate normal IQ scores in both performance and verbal aspects of a standard intelligence test. Additional comparisons between the subjects of this study include the results obtained from each child in intellectual testing, language assessment, and case history information obtained from the parents of the children.

CHAPTER 2

PROCEDURES FOR COLLECTION OF DATA

Subjects

Six normal-hearing children from special education classes in an elementary school from the Fort Worth Independent School District (FWISD) were included in this study. Based on results from intelligence tests, language assessments, and academic achievement scores, these children were identified by psychologists, educational diagnosticians, and speech pathologists as having a severe language delay (SLD) which was the primary handicapping condition interfering with their academic success.

Participation of the SLD subjects in this study was based upon the fact that these children perform normally on tasks which are assessed as performance items on the WISC-R but they are deficient in their verbal abilities. Each SLD subject demonstrated at least a 15-point discrepancy (one standard deviation) between his Verbal and Performance IQ scores.

Once a child is identified as SLD, he is placed in a self-contained classroom designed to provide a learning environment which is appropriate for his specific disability. The FWISD SLD program focuses on enriched language stimulation and provides the child with opportunities to use newly acquired skills in life situations. The program also keeps the SLD child as close to the mainstream curriculum as possible.

The control subjects involved in this study were matched to the SLD subjects in age and Performance IQ. The children who served as control subjects differed from those in the experimental group in that their verbal intelligence, as measured by the WISC-R, was within a normal range. The control subjects also differed in that they were performing on the appropriate grade level of a normal classroom setting in the FWISD. Six normal-hearing children served as controls. A total of twelve subjects, including seven boys and five girls, ranged in age from seven years, six months to ten years, seven months. Parental consent was obtained for all of the subjects in this study.

Instrumentation

Pure-tone testing for each child was performed using a two-channel, Grasen-Stadler GSI-16 audiometer. Pure-tone testing was administered at 20 dB HL for the following test frequencies: 1000 Hz, 2000 Hz, and 4000 Hz. Immittance testing was performed utilizing a Saico AZ7 immittance bridge. The central auditory tests were presented through a two-channel Pioneer 1040W tape deck coupled to the Grasen-Stadler GSI-16 audiometer. TDH 59 earphones, calibrated for the GSI-16 audiometer, were used for both the pure tone and the central auditory tests. Biological calibration of the GSI-16 audiometer and the AZ7 immittance bridge was accomplished by utilizing three reference-test persons with confirmed normal hearing sensitivity. One person served as a reference to be tested on a daily basis. In the event that the hearing of the reference had changed by more than +5 dB for both pure-tone thresholds and the acoustic reflex eliciting signal at 1000 Hz, the other two individuals were available to determine if the change was due to a change in hearing or to a change in the output of the equipment.

Testing was conducted in a quiet room in which the ambient noise level was no greater than 50 dB SPL. This level does not exceed the standards for the frequencies used in the pure-tone screening (i.e., 50 dB for 1000 Hz, 55 dB for 2000 Hz, and 62 dB for 4000 Hz) when the screening is done with the earphones mounted in a MX-41/AR cushion (ANSI 3.1-1977). The ambient noise levels were monitored daily with a Radio Shack #33 2050 sound level meter.

Test Materials

Dichotic Digits Test (Musiek)

Both subtests of the Dichotic Digit Test by Musiek were administered to all of the subjects. The first subtest consists of twenty naturally-spoken, two-digit combinations presented simultaneously, one to each ear, for a total of twenty test items per ear. The second subtest consists of twenty naturally-spoken, four-digit combinations. The first pair of digits was presented simultaneously (one to each ear) followed by the dichotic presentation of the second pair of digits for a total of forty test items per ear. The inter-digit interval established on the recorded tape is approximately 0.5 sec. The interval between trials, however, was examiner controlled. That is, the tape was stopped by the examiner to provide ample time for the listener to respond. The stimulus items were presented at 45 dB HL, or at a level found to be comfortable and intelligible for listening for these twelve subjects. The test tape provides three practice items for each subtest. The listeners were required to repeat all of the digits for both the two-digit and the four-digit combinations in any order that they chose. The total number of digits repeated correctly was recorded for each ear, and a percentage score was obtained.

Data obtained by Musiek (1983) indicates abnormal performance for normal-hearing adults when the combined total correct scores fall below 90%. Caudle (1989) conducted a normative study with children aged 6.5 to 11.8 on the Musiek version of the Dichotic Digit Test. Her results, which support those obtained by Berlin and his associates (1973), show that normal-hearing children performed similarly to adults on dichotic listening tasks with about 90% accuracy by the age of about nine years. Additionally, Caudle found that overall accuracy improves as a function of age. DDT results from her younger subjects indicated that children with a mean age of 7.0 scored with 70% accuracy, children with a mean age of 7.9 performed with about 80% accuracy, and children with a mean age of 8.9 performed with about 85% accuracy. Finally, results from Caudle (1989) support the contention that a distinct right ear advantage exists even among young children. Her study confirmed the data of Berlin, et al (1973) that substantial ear differences occur until about the age of nine years when the difference between ears becomes less defined.

Pitch Pattern Sequence Test (Pinheiro)

The stimulus items of the Pitch Pattern Sequence Test (PPST) consist of a combination of low (L=880 Hz) and high (H=1122 Hz) frequency tone bursts. These tones are presented in a three-pattern series, each tone with a 10 msec rise-fall time. Six different patterns are made by placing a different tone in any one of three temporal positions: HLH, LHL, LLH, HHL, LHH, HLL.

This test provides an adult and a children's version. The children's version, used in this study, increases both the rise-fall time and the interstimulus interval in order to provide more response time for very young or difficult to test populations. The tone duration for the children's version of the PPST is 300 msec and the interstimulus interval is eleven seconds. The subject listens to the stimulus and is required to imitate the pitch pattern. Two tasks are required for completion of the PPST. For the first task, the child is required to hum his response to 15 tone patterns presented to each ear monotically. During the second task, the child must again listen to 15 tone patterns presented to each ear monotically. This time, however, he must respond manually by tapping a tall block for a high tone and a short block for a low tone. All stimulus items were presented at 45 dB HL, the comfortable listening level for these twelve subjects. The test is scored separately for each ear by obtaining a percentage score for the total number of correct responses per task.

Pinheiro (1978) presented data obtained from normal and dyslexic children. The results of her study indicated that normal children, aged 6 to 7 years, performed with 60% accuracy on the PPST, while dyslexic children in that age group performed with only 20% accuracy. Normal children aged 8 to 14 years, on the other hand, performed with almost 90% accuracy, and the dyslexic children in that age range performed with only about 30% accuracy. Caudle (1989) reported on the performance of normal-hearing children aged 6.5 to 11.8 on the PPST. Her results are in agreement with those of the Pinheiro study, indicating that the 6 to 8 year-old children in her study performed with 60-70%

correct responses. Performance after age nine demonstrated correct scores of about 90% or greater.

<u>Pediatric Sentence Intelligibility Test</u> (Jerger)

The Pediatric Speech Intelligibility Test (PSI) utilizes sentences that were generated by three to six-year-old children (Jerger, 1983). Three subtests of the PSI are administered, including a performance-intensity function in competition (PI) for sentences, and two conditions with varying message-to-competition ratios (MCR functions). The PSI-PI subtest utilizes a competing sentence format. Each stimulus sentence is delivered to one ear with a competing sentence delivered simultaneously to the same ear. The PSI-PI sentence stimuli are recorded on the same channel. The two MCR functions include an ipsilateral competing message condition (ICM) and a contralateral competing message (CCM). The ICM and CCM sentences are recorded with the stimulus sentence on one channel and the competing sentence on the second channel. The MCR conditions are determined by adjusting separately the intensity dial for each channel of the audiometer.

The PI function is obtained for each ear by presenting trial blocks of five sentences at an initial intensity level of 40 dB HL. The stimulus items are presented first in quiet. The speech signal and the competing signal are then presented on the same channel at +10 and 0dB MCR. If performance at the initial test level is at least 60% correct, intensity is reduced in 10 dB steps until performance yields a 0 to 20% correct score. If performance is less than 60% correct for any trial, five more stimulus items are presented to the subject. Once the lowest performance intensity is established, intensity is increased in 20 dB steps to a maximum of 80 dB HL. Speech noise is presented to the nontest ear when the intensity of the stimulus is sufficiently loud enough to lateralize to the nontest ear.

The results of the PSI-PI function are plotted in graphic form to represent performance as a function of intensity for each ear. Jerger and Jerger (1984) regard a rollover index ratio (Jerger & Jerger, 1971) on the PSI sufficient enough to suspect a central auditory disorder if the score exceeds 10% for higher level sentences.

A function for the message-to-competition ratio (MCR) is obtained for each ear in the ipsilateral competing message (ICM) condition by presenting the speech signal and the competing signal to the same ear at 30 dB HL with varying MCR's of 0 and +10 dB. An MCR function in the contralateral competing message (CCM) condition is obtained for each ear by presenting the speech signal at 30 dB HL to one ear and the competing signal to the opposite ear at 0 dB MCR and -20 dB MCR.

Percentage results for the ICM and CCM test modes are derived and compared for each ear in both MCR conditions. Scores on the PSI-ICM are considered abnormal when they fall below 100% for the +10 MCR condition or below 80% for the 0 MCR condition. On the PSI-CCM test, scores are considered abnormal if less than 100% for the 0 MCR or less than 90% for the -20 MCR condition (Jerger & Jerger, 1984).

Woodcock Language Proficiency Battery - English Form

The Woodcock Language Proficiency Battery (WLPB) (Woodcock, 1980) consists of eight subtests which measure oral language, reading, and written language skills. This test was normed on individuals from the age of three years to age 80. The purpose of its use in this study is to describe the language characteristics of the 6 SLD subjects and their matched controls. The entire test is contained in one book to be used by both the examiner and the subject. The examiner is provided with a response booklet in which to record the subject's responses, summarize results, and interpret test performance. A brief description of each subtest is indicated below, with the subtests grouped according to the manner in which language ages are determined.

Oral Language Cluster -

a) Picture Vocabulary - The subject must identify 37 pictured actions or objects.

b) Antonyms-Synonyms - This subtest measures the subject's knowledge of word meanings in two parts. Part A (antonyms) requires the subject to state a word whose meaning is the opposite of the test word. Part B (synonyms) requires the subject to state a word whose meaning is approximately the same as the presented word.

c) Analogies - The subject completes phrases with words that indicate appropriate analogies.

Reading Cluster -

d) Letter-Word Identification - The subject must identify as many as 50 isolated letters and words presented in large type. The first seven items are letters, while the last 43 items are words that become increasingly difficult by virtue of the fact that they are used infrequently in English language.

e) Word Attack - This subtest requires the subject to apply phonic or structural analysis skills as he reads nonsense words or syllables. The items become more difficult as the subject progresses through this subtest. The difficulty of each word is determined by its infrequent use in the English language.

f) Passage Comprehension - The subject must read a short passage and identify a key word missing from that passage.

Written Language Cluster -

g) Dictation - The subject must write his answers to a variety of questions, demonstrating his knowledge of letter forms, punctuation, capitalization, and usage.

h) Proofing - The subject is required to identify mistakes in type-written passages and to indicate how to correct each mistake. The subject is informed that each passage contains only one error. Errors include incorrect punctuation or capitalization, inappropriate forms of words, and misspellings.

Weschler Intelligence Test for Children - Revised

The Weschler Intelligence Test for Children - Revised (WISC-R) contains twelve subtests, six verbal tasks and six non-verbal (performance) tasks. Due to their low correlation with other tests of the scale, administration of the Digit Span subtest of the Verbal Scale and the Mazes subtest of the Performance Scale are considered optional in clinical situations and are not necessary to compute IQ scores (Weschler, 1949). A description of all of the subtests of the WISC-R, from both the Performance scale and the Verbal scale is indicated below:

Performance Scale:

1) Picture Completion - This subtest requires the subject to indicate which part of a picture is missing. A

total of 20 items may be administered.

2) Picture Arrangement - Subjects are required to arrange the pictures of objects as well as to sequence story pictures.

3) Block Design - The subject must demonstrate with specific blocks the construction of a design which matches a pictured design. The time limit allowed for each item is indicated on each design card. A response is considered incorrect if the subject exceeds his time allotment per trial, or if the block designs do not match.

4) Object Assembly - The subject is required to assemble object puzzles within a specific time frame for each puzzle.

5) Coding - Subjects are required to match specific symbols to the numbers which they represent. Four rows of numbers are provided in boxes with an empty box below each number. The subject must fill in as many boxes as possible in the allotted time, with a maximum possible score of 50 points.

6) Mazes - This subtest is optional. The subject must mark with a pencil an uninterrupted path through five mazes. The subject may not lift his pencil from any given path.

Verbal Scale:

1) General Information - The subject must verbally respond to a series of 30 oral questions. The examiner may

ask for more information from the subject, but may not ask leading questions nor ask the subject to spell the words.

2) General Comprehension - The subject must answer verbally 14 questions which assess his understanding of cause and effect relationships.

3) Arithmetic - The subject is asked a series of 16 questions which assess his ability to apply his knowledge of mathematical concepts. Each item has a specific time limit for which the subject can not exceed.

4) Similarities - The subject is asked to express how two objects are alike, for a total of 16 items.

5) Vocabulary - The subject must state the meaning of specific words, for a total of 40 possible items.

6) Digit Span - (optional) There are two parts to this subtest. For the first portion, the examiner says a series of numbers out loud and the subject must repeat the digits in the correct order. The second portion of this subtest requires the subject to listen to the digits stated by the examiner, and then repeat those digits in reverse order.

Each subtest from the WISC-R is scored separately, and raw scores are converted to scaled scores. Scaled scores are then added and the sum converted to an intelligence quotient. The mean IQ score that indicates average intelligence is 100 for each scale, with a standard deviation of +15 points. Each subject in this study scored within the range of average intelligence on at least the Performance Scale of the WISC-R.

Procedures

The FWISD Superintendent, the coordinator/supervisor for SLD, and the building principal of one elementary school in the FWISD provided approval for the implementation of this study. The six SLD children were selected for participation in the study based on: 1) an established difference of one standard deviation or more between the Performance and the Verbal scales on the WISC-R, 2) language delay which correlated with the Verbal scale on the WISC-R, 3) normal hearing sensitivity as measured by audiometric screening, and 4) English as a first language. The six control subjects were selected according to: 1) matched age with an SLD subject, 2) academic performance demonstrated to be on the appropriate grade level according to the Essential Elements established by the Texas Education Agency (TEA), 3) matched performance IQ on the WISC-R, 4) normal hearing sensitivity as measured by audiometric screening, 5) and English as a first language.

The parents of each subject supplied information regarding their child's development. The information was obtained through the use of an in-depth case history form and parent interviews. This contact with each parent provided information regarding their child's birth and medical history, motor development, speech and language development, and educational background. Additional information regarding academic performance was obtained from each child's regular classroom and/or special education teacher(s).

Each child was tested individually after school hours at a quiet testing site within the school building. The central auditory tests were administered in two separate test sessions. The WISC-R was completed by a certified school psychologist, while the WLPB was administered by a licensed/certified speech pathologist. The test rooms were generally isolated and free from visual distractions.

Children who participated in the study passed a hearing screening at 20 dB (ANSI, 1969) and an immittance screening test. Both the hearing screening test and the test of middle ear function were conducted in the manner recommended by the American Speech and Hearing Association (ASHA) Guideline for Hearing Screening and the ASHA Guideline for Admittance Testing. The subjects were required to pass a hearing screening before each central auditory test session. Results were considered normal when the individual demonstrated middle ear pressure between -200 to +100 mm H2O and the presence of a contralateral acoustic reflex to a 1000 Hz pure tone at 100 dB HL (ASHA, 1979). Subjects demonstrating normal hearing sensitivity and normal middle ear function were then administered the Dichotic

Digits Test (DDT) and the Pitch Pattern Sequence Test (PPST) in one test session. The subjects then returned at a later date (within two weeks) to complete the auditory testing with the Pediatric Speech Intelligibility Test (PSI). Each test session, including instructions for the tests, was approximately 45 minutes. The same instructions were given to each child for each test prior to administration. The DDT and the PPST were presented at 45 dB HL. The speech stimuli of the PSI-ICM and PSI-CCM were presented at 30 dB HL. Responses were recorded during the testing and scored at a later time.

CHAPTER 3

RESULTS AND DISCUSSION

The following case studies present each severely language delayed child and his or her control subject. These presentations include birth and medical history and information about motor development, speech and language development, and past academic success. Additionally, each SLD child is compared to his matched control in the performance demonstrated on each test of central auditory function. Comparative tables illustrate the similarities and differences between each subject.

Case Presentations

CASE 1/CONTROL 1

Background Information:

At the time of this study, Case 1 was a nine-year, seven-month-old, learning-disabled, right-handed boy, who was enrolled in the SLD program at the age of seven years. This child was referred for placement in an SLD classroom because of his reported language delay and academic failure in first grade. The classroom teacher who referred Case 1 for special placement described him as "highly distractable and unable to follow simple directions". She noticed particular difficulty directing this child's attention when the class was involved in a group activity. She reported further that Case 1 appeared to succeed when instruction was given on a "one-to-one basis".

Case 1 was matched to a nine-year, ten-month-old control subject who attended regular education classes at the same elementary school. At the time of this study, Control 1 was a right-handed, fourth grade boy, whose teachers described his academic skills as "low-average". They stated that Control 1 appeared to have difficulty with listening and following directions. Additionally, the teachers of Control 1 noted that he had a tendency to forget to complete his schoolwork, especially when he was required to finish it at home. It was reported that this child was having some difficulty with spelling and reading. However, Control 1 was never considered for placement in a special education program, as he was achieving the minimum academic requirements that were appropriate for his grade level. Although Control 1 appeared to have significant language and learning problems, he was used as a subject for this study based on the match of his age and Performance IQ score to the age and Performance IQ of Case 1.

Birth and Medical History:

The mother of Case 1 reported a normal nine-month pregnancy with no complications during the prenatal care or delivery of this child. The medical history reported by the child's mother revealed ear infections as the only remarkable childhood illnesses. Three or four ear infections, reportedly occurring between the ages of ten months and 24 months, were treated successfully with antibiotics. Both the first grade teacher and the parents of Case 1 reported that he demonstrated a high level of activity and an inability to attend to short, structured activities. As a result, this child was referred for a medical evaluation to determine possible management strategies for his behavior. Following this medical evaluation, Case 1 was placed under the care of a doctor, who prescribed the drug Ritalin on a daily basis. This drug is reported to help control the activity level and attention abilities overly active children. Case 1 was required to take Ritalin twice daily so that he would be able to attend to academic instruction.

An interview with the parents of Control 1 revealed no prenatal or birth complications. Information regarding medical history was provided by the mother of this child. The mother of Control 1 reported no unusual childhood illnesses. She did not recall any incidents of high fevers or ear infections.

Motor Development:

An interview with the mother of Case 1 revealed that this child did not demonstrate any delays in his gross motor development. Skills such as sitting unsupported, crawling, and walking were reported to occur at the expected age levels. The mother of this child further reported that no difficulties were demonstrated with such fine motor skills as feeding and dressing independently, tieing shoes, or learning to write with a pencil.

An interview with the mother of Control 1 revealed similar information to that obtained for Case 1. Control 1 reportedly demonstrated no delays in the development of gross or fine motor skills. Such skills as sitting unsupported, crawling, and walking were reported to occur at the appropriate age levels. Additionally, no difficulties were reported regarding such skills as feeding and dressing independently, tieing shoes, or learning to write with a pencil.

Speech and Language Development:

A history of language development supplied by the child's mother revealed that Case 1 began to say his first meaningful words by about the age of seven months. His mother stated that at the age of two years he continued to speak in one-word utterances. She did not observe two-word utterances consistently in Case 1 until he was about two-and-a-half years of age. By the age of four years, this child was reportedly speaking in sentences of three to four words in length. At this time the mother reported noticing that her son had some difficulty following directions and attending for more than short periods of time. She reported that Case 1 was evaluated by the school speech pathologist at the age of six years. Following the identification of a speech and language delay, this child was placed in therapy for the development of speech and language skills.

The developmental milestones reported by the mother of Control 1 revealed that the stages of speech and language development appeared to occur at the appropriate age levels. At the time that this child entered the first grade in the public school system, an initial skills inventory administered by the first grade teacher revealed that Control 1 possessed all of the language skills and reading readiness skills necessary to succeed in an academic setting.

Past Academic Experience:

The initial psychological assessment, which was completed at the time of the SLD referral at age seven, revealed that Case 1 demonstrated a performance score on the WISC-R that was within the range of normal intelligence. However, he demonstrated a discrepancy on the verbal scale of more than two standard deviations below his performance IQ.

The SLD teacher of Case 1 reported significant differences in this child's attending behavior while under the influence of his medication. She stated that when Case 1 did not receive the Ritalin, he was unable to attend to a task for periods as long as five minutes. Additionally, he reportedly was unable to complete even one basic mathematical computation, read a complete sentence on a beginning first grade level, or write his name legibly. While receiving the benefits of his medication, however, Case 1 was able to attend to one task for up to 30 minutes, complete approximately 40 basic mathematical computations in five minutes or less, read an entire story from his first grade reader, or write legibly in a cursive style with little difficulty. Case 1 was receiving Ritalin at the time of this study. Precautions were taken to ensure that testing was conducted while the child was receiving the benefits of his medication.

During a parent interview, the mother of Control 1 was asked to report on her child's academic success. She indicated that spelling, and "sounding out words" were the only areas in which he was experiencing academic difficulty. Although these academic skills were considered to be problem areas for Control 1, his teachers did not consider him to be in need of for special education services because he was working on the appropriate grade level in all academic areas. Additional information obtained from both the parents and the teachers of Control 1 indicated that they considered him to be socially immature when compared to his classroom peers.

Psychological and Language Test Results:

The psychological test results obtained for the purposes of this study demonstrated a 35-point discrepancy between Case 1's Verbal and Performance IQ's as measured by the WISC-R. His Verbal IQ was 55 and his Performance IQ was 90. A specific strength measured on the WISC-R was noted for the Object Assembly subtest.

The assessment of language abilities with the Woodcock Language Proficiency Battery (WLPB) indicated oral language, reading, and written language skills to be approximately two-and-a-half years below the chronological age of Case 1. His oral language age in years and months was 7-2, his reading age was 7-2, and his written language age was 7-0.

The psychological test results obtained from Control 1 revealed a Performance IQ of 93 and a Verbal IQ of 94 as measured by the WISC-R. Specific strengths on the verbal scale included the Arithmetic and Comprehension subtests, while a strength on the Performance scale was noted for the Coding subtest. Language results obtained from the WLPB indicated an oral language age in months and years of 8-3, a reading age of 8-8, and a written language age of 8-5. Table 1 presents a comparative summary of the non-auditory information obtained for Case 1 and his matched control.

Table 1. A non-auditory comparison of Case 1 and his matched control.

Parameter	Case 1	Control 1
Sex	male	male
CA	9-7	9-10
IQ-Verbal	55	94
IQ-Performance	90	93
LA-Oral	7-2	8-3
LA-Reading	7-2	8-8
LA-Writing	7-0	8-5
Birth History	unremarkable	unremarkable
Medical History	3-4 ear infections in early childhood	unremarkable
Motor Development	unremarkable	unremarkable
Sp/Language Development	delay identified at age 30 months	language skills about 17 months below chronological age

Key:

CA = chronological age
IQ-V = verbal IQ as measured by the WISC-R
IQ-P = performance IQ as measured by the WISC-R
LA-O = oral language age on the WLPB
LA-W = written language age on the WLPB
LA-R = reading language age on the WLPB

Audiologic Assessment

Dichotic Digit Test (DDT):

The results of the DDT for Case 1 and his control subject indicated a distinct REA for both the two-digit (DDT-2) and the four-digit (DDT-4) test formats. These results were consistent with the data obtained by from various authors whose subjects demonstrated a right ear advantage (Musiek, 1983; Berlin, 1973; Caudle, 1989). The subjects in Musiek's 1983 study who had confirmed CNS lesions, however, demonstrated performance scores which were below 90%, as well as greater ear differences than those demonstrated by both the normal-hearing or cochlear groups. Case 1 and his matched control demonstrated ear difference scores which were similar to the ear differences reported for Musiek's CNS group.

When the DDT results were viewed in terms of total accuracy for each subtest, they indicated an overall performance of 75% for Case 1 and 97% for Control 1 on the DDT-2. The results obtained for the DDT-4 demonstrated an overall accuracy of 76% for Case 1 and 77% for Control 1. The overall scores obtained from both subjects on the DDT-4 were considered abnormal, according to the data obtained by Musiek (1983) and Caudle (1989). The DDT results of Control 1 and his matched control can be seen in table 2.

Table 2. A comparative summary of the DDT and PPST results obtained for Case 1/Control 1. All numbers represent the percentage scores obtained.

Test	Right Ear	Left Ear	Total Score
DDT-2	85/100	65/95	75/97
DDT-4	85/85	67/70	76/77
PPST-H	86/80	73/100	79/90
PPST-M	73/73	86/86	79/79

Pitch Pattern Sequence Test (PPST):

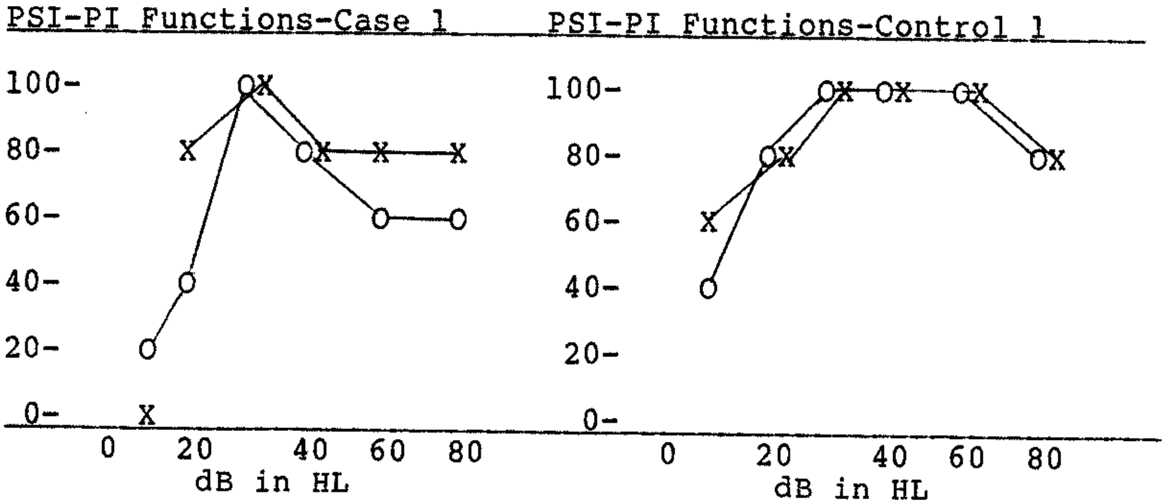
The results obtained for the hummed responses on the PPST (PPST-H) demonstrated an overall score of 79% for Case 1 and 90% for Control 1. The results obtained for the manual responses (PPST-M) indicated overall scores of 79% for both Case 1 and Control 1. Based on the data obtained by Pinheiro (1978) and Caudle (1989) performance on the PPST was considered abnormal for Case 1 on both the humming and the manual tasks. Scores for Control 1, however, were considered abnormal only on the manual task. A summary of the DDT and PPST results obtained for each of these children can be seen in Table 2.

Pediatric Speech Intelligibility Test (PSI):

A summary of the PSI results obtained for Case 1 and his matched control can be seen in figure 1. PSI performance intensity function (PSI-PI) obtained for Case 1 on the right ear indicated a PB-max at 30 dB HL with a rollover index ratio of .40 (40%) occurring at 60 and 80 dB HL. The PSI-PI function obtained for the left ear demonstrated a PB-max at 30 dB HL and a rollover index ratio of .20 (20%) at 80 dB HL. Control 1 demonstrated a rollover index ratio of .20 bilaterally at 80 dB HL. Both subjects showed significant rollover bilaterally according to the criteria presented by Jerger and Jerger (1984).

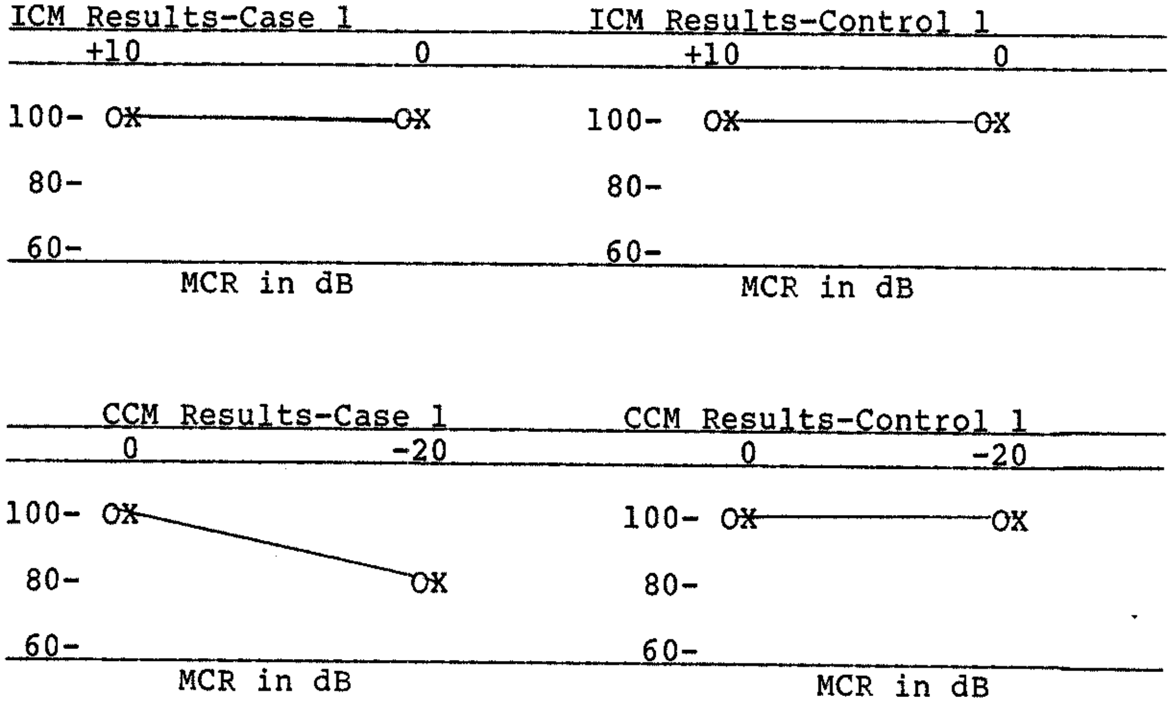
The PSI results obtained for the ipsilateral competing message condition (PSI-ICM) revealed 100% accuracy, bilaterally, for both subjects at both the +10 and 0 dB message-to-competition ratios (MCR). The PSI results obtained for the contralateral competing message condition (PSI-CCM), however, revealed correct scores of 80% bilaterally for Case 1 only at the -20 dB MCR condition. This poorer CCM than ICM score for Case 1 is judged by Jerger (1988) to be compatible with a temporal lobe site of lesion. The PSI-CCM score obtained for Control 1 was 100% bilaterally at both MCR conditions, indicating normal performance. A summary of the PSI results obtained for both subjects can be seen in Figure 1.

Figure 1. Summary of PSI findings for Case 1 and his matched control.



(figure 1 continues)

Figure 1 - (continued)



CASE 2/CONTROL 2

Background Information:

At the time of this study Case 2 was a ten-year, one-month-old, left-handed girl who was referred for SLD placement in the second grade because of academic failure and language delay. It was noted that Case 2 repeated one year of kindergarten. Psychological and language assessments at the time of the referral indicated an expressive/receptive language delay, demonstrating candidacy for placement in the SLD program. At the time of this study, Case 2 had been enrolled in the SLD program for two years.

Case 2 was matched to a ten-year, four-month-old, right-handed boy. At the time of this study, Control 2 attended school in a regular classroom setting. Control 2 was described by his teachers as a "quiet and cooperative" child. The teachers stated that this child appeared to be "low-average" in his intellectual abilities. Because Control 2 was completing the academic requirements determined by the state education agency, his teachers reported that he was not considered as a candidate for special education services.

Birth and Medical History:

The mother of Case 2 reported that this child was delivered by Caesarean Section as a result of complications due to toxemia. She did not recall any complications within the child which might have been caused from the toxemia. Additional information from this mother indicated that Case 2 was born with six fingers on her right hand. Surgery to remove a second index finger, located between the index finger and the thumb, was performed when the child was 2 years old. This surgery reportedly involved severing muscle tissue between the two fingers, resulting in a weak pincer grip for the right hand. The mother of Case 2 reported that her child was forced to use her left hand for the fine motor activities that previously were noted to be achieved with the right hand. For example, the mother reported that her daughter preferred using the right hand for such fine motor skills as feeding, holding a cup, and grasping objects. This mother did not recall any incidents of ear infections nor other remarkable childhood diseases.

An interview with the parents of Control 2 revealed that this child was born without complications at full term. The birth history was reported as unremarkable. No significant illnesses were reported to have occurred during childhood.

Motor Development:

The mother of Case 2 denied that her daughter demonstrated delays in the development of gross motor skills. She reported that this child sat unsupported, crawled, and walked at the appropriate age levels.

With the exception of a weak pincer grip on the right hand, Case 2 reportedly developed in fine motor skills at the expected age levels. The only difficulty, according to the mother's report, was that Case 2 demonstrated difficulty in cutting with scissors, a task for which she continues to use her left hand. This mother denied that Case 2 demonstrated any problems with tieing her shoes or with handwriting.

The mother of Control 2 reported that she did not notice delays in the development of such gross motor skills as sitting, walking, or crawling. Likewise, it was reported that this child did not have problems with fine motor skills such as feeding and dressing independently, tieing his shoes, or learning to use a pencil.

Speech and Language Development:

While the present expressive language skills of Case 2 demonstrate noticeable articulation and syntactical errors, the mother of this child reported that speech and language development were normal. The mother did not recall that the speech and language skills of this child were noticeably different from other children of the same age. However, she did acknowledge the presence of the current speech and language problems demonstrated by Case 2.

The mother of Control 2 did not recall delays in the development of speech and language skills. At the time that this child entered the first grade in the public school system, an initial skills inventory administered by the first grade teacher revealed that Control 2 possessed all of the language skills and reading readiness skills necessary to succeed in an academic setting.

Past Academic Experience:

The teacher who referred Case 2 to the SLD program described the child as "extremely shy" and inattentive. The teacher added, however, that Case 2's inability to attend to an activity was manifested in "daydreaming" states, when this child was not physically involved in a classroom activity. Further information from the regular education teacher revealed that Case 2 was unable to follow oral directions, especially when several activities were being conducted simultaneously in the classroom.

The regular classroom teacher of Control 2 described this child as "shy" but hard-working. She added that he did not learn as quickly as his classroom peers when given verbal instructions. However, once he was given visual instructions, he reportedly performed the required task without hesitation. The teachers and parents of Control 2 reported that he demonstrated no significant academic difficulties.

Psychological and Language Test Results:

The psychological test results obtained for the purposes of this study demonstrated a 28-point discrepancy between Case 2's Verbal IQ and Performance IQ scores as measured by the WISC-R. The test findings of the WISC-R yielded a Verbal IQ of 68 and a Performance IQ of 91. A specific strength on the Performance scale was noted for the Picture Arrangement subtest.

The assessment of language abilities with the Woodcock Language Proficiency Battery (WLPB) indicated oral and written language age scores approximately two years below the chronological age of Case 2. A reading language age score was noted to be three years below her chronological age. The language age scores of Case 2, represented in

Table 3. A non-auditory comparison of Case 2 and her matched control.

Parameter	Case 2	Control 2
Sex	female	male
CA	10-1	10-4
IQ-Verbal	68	92
IQ-Performance	91	95
LA-Oral	8-4	10-2
LA-Reading	7-3	10-2
LA-Writing	8-0	8-11
Birth History	mother had toxemia; delivered by C-section	unremarkable
Medical History	hand surgery at age 2 years	unremarkable
Motor Development	switched handedness right to left at age 2; weak pincer grip in right hand; poor cutting skills with left hand	unremarkable
Sp/Language Development	delay identified at age six years; no delay reported from mother	unremarkable

*Refer to Table 1 for a key to the abbreviations.

years and months, yielded an oral language age of 8-4, a written language age of 8-3, and a reading language age of 7-3.

The psychological test results for Control 2 demonstrated a performance IQ of 95 and a verbal IQ of 92 as measured by the WISC-R. Specific strengths were noted on the Picture Arrangement and Object Assembly subtests of the Performance scale of the test.

The language age scores obtained on the WLPB indicated a language age of 10-2 for both oral language and reading. An age of 8-11 was demonstrated for the written language portion of the test, indicating a delay of one year, five months. Table 3 presents a summary of the non-auditory information obtained for Case 2 and her matched control.

Audiologic Assessment

Dichotic Digit Test (DDT):

The results of the DDT for Case 2 demonstrated equal performance for both ears on the DDT-2 subtest, with 85% accuracy. This finding represented no ear advantage demonstrated for this subtest. In addition, the DDT-4 subtest results indicated a distinct left ear advantage (LEA) for Case 2, with 62% accuracy for the right ear and 82% accuracy for the left ear.

In contrast to Case 2, Control 2 demonstrated a distinct REA for both subtests of the DDT. The results obtained from Control 2 on the DDT-2 subtest yielded a right ear score of 90% and a left ear score of 70%. The results for Control 2 that were obtained on the DDT-4 yielded a 92%

score for the right ear and a 55% score for the left ear.

When the DDT results from these two subjects were viewed in terms of total accuracy for each subtest, they indicated an overall performance of 85% for Case 2 and 80% for Control 2 on the DDT-2. The results obtained for the DDT-4 demonstrated an overall accuracy of 72% for Case 2 and 71% for her matched control. Given the ages of these children and the normative data established by Caudle (1989), both subjects demonstrated abnormal performance on each subtest of the DDT. The DDT results of Case 2 and her matched control can be seen in table 4.

Table 4. A comparative summary of the DDT and PPST results obtained for Case 2/Control 2. All numbers represent the percentage scores obtained.

Test	Right Ear	Left Ear	Total Score
DDT-2	85/90	85/70	85/80
DDT-4	62/92	82/55	72/71
PPST-H	93/66	100/80	96/73
PPST-M	100/80	100/73	100*/76^

*93% of the correct manual responses were reversals.
^56% of the correct manual responses were reversals.

Pitch Pattern Sequence Test (PPST):

Case 2 demonstrated little difficulty with performance on either subtest of the PPST. The hummed responses of the PPST (PPST-H) obtained from this child yielded an overall score of 96%. The hummed responses obtained from Control 2 yielded an overall score of only 73%. This score was considered to be abnormal according the data from Pinheiro (1978) and Caudle (1989). Case 2 demonstrated and overall score of 100% on the manual response task of the PPST (PPST-M). It was noted, however, that 93% of the manual responses obtained from Case 2 were reversals of the original stimulus. For example, when the pattern HHL was presented, Case 2 tapped the pattern for LLH. Each reversal was a "mirror image" of the original stimulus. Pinheiro and Ptacek (1971) found that pattern reversals are common in normal-hearing subjects.

A study conducted by Caudle (1989) demonstrated that normal-hearing children aged 6.5 through 11.5 responded with approximately 20% reversals. Further findings by Caudle showed that these pattern reversals occurred less frequently as a function of age, and were nearly extinguished by the age of 11.6.

The PPST-M results obtained for Control 2 yielded an overall score of 76% for the manual task. These scores were considerably reduced from those obtained by Pinheiro (1978) and Caudle (1989). Additionally, 56% of the correct manual responses obtained from Control 2 were pattern reversals. Although these reversals were not as numerous as those demonstrated by Case 2, this figure was still considerably higher than the percent of reversals found in Caudle's normal population. The performance scores from both subtests of the PPST can be seen in figure 4 for Case 2 and her matched control.

Pediatric Speech Intelligibility Test (PSI):

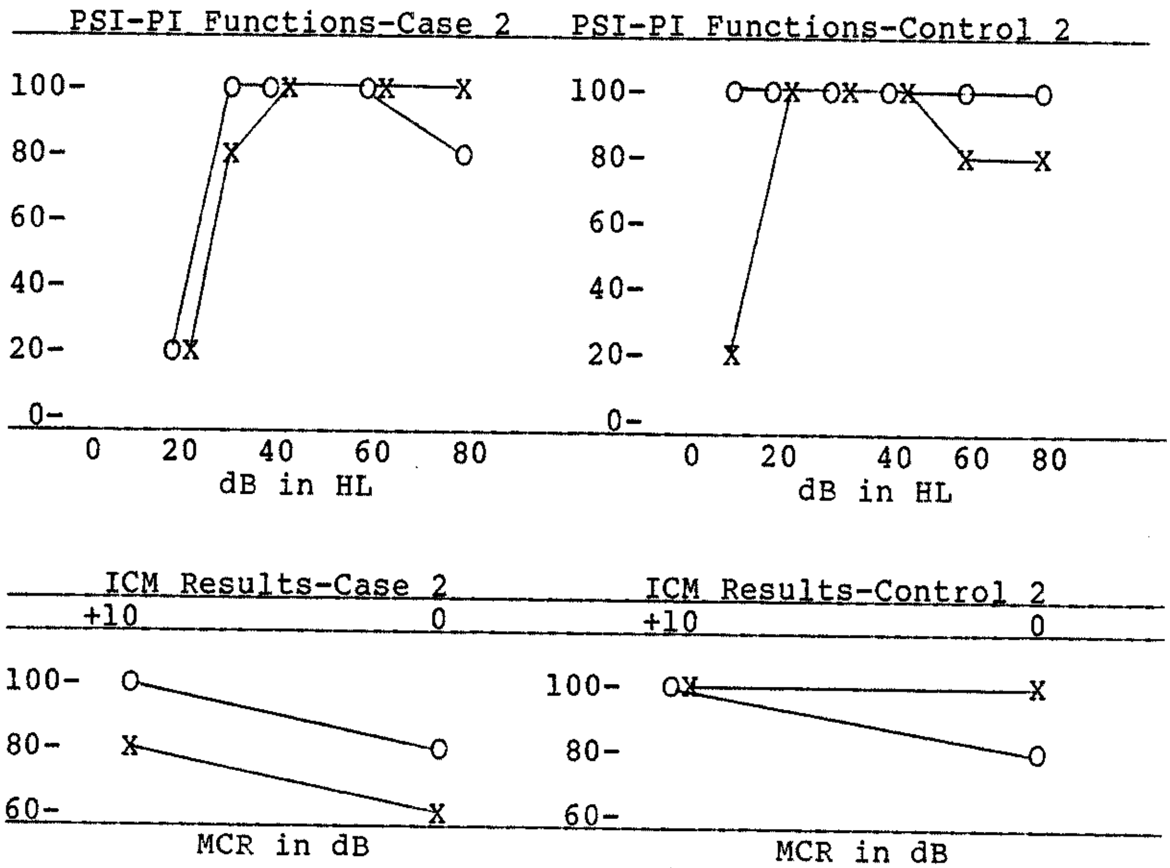
A summary of the PSI results obtained for Case 2 and her matched control can be seen in figure 2. The PSI performance intensity function (PSI-PI) for Case 2 indicated a PB-max at 60 dB HL for the right ear with a rollover index ratio of .20 at 80 dB HL. The PSI-PI performance for Control 2 indicated a PB-max at 40 dB HL for the left ear with a rollover index ratio of .20 at 60 and 80 dB HL. The results obtained for both subjects were considered to be abnormal when compared to the normative data obtained by Jerger and Jerger (1984).

The PSI results obtained from Case 2 on the ipsilateral competing message condition (PSI-ICM) revealed normal performance for both competing conditions in the right ear. Results for the left ear, however, revealed an abnormal performance of 80% at the +10 dB message-to-competition ratio (MCR), and an abnormal performance of 60% for the 0 dB MCR condition. The PSI-ICM results for Control 2 indicated normal performance bilaterally.

The PSI results obtained from Case 2 on the contralateral competing message condition (PSI-CCM) demonstrated abnormal performance for the right ear at 0 and

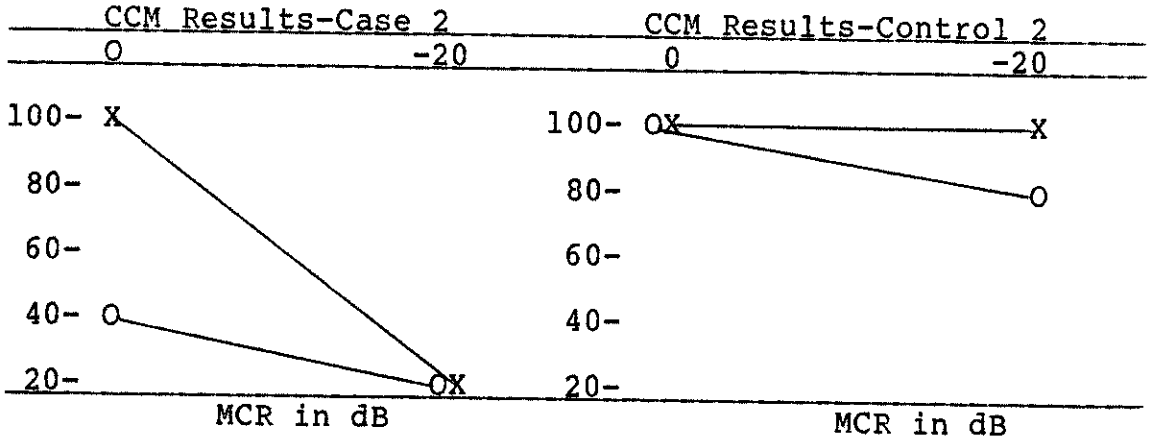
-20 dB MCR, as well as the -20 dB MCR condition for the left ear. The performance of Control 2 on this same subtest of the PSI indicated abnormal performance for the right ear at the -20 dB MCR condition. While Case 2 demonstrated abnormal performance on both the PSI-ICM and PSI-CCM subtests, her performance on the PSI-CCM appeared to be poorer than her PSI-ICM performance. According to Jerger (1988) the performance scores of Case 2 and her matched control were consistent with those of individuals with a lesion located at the temporal lobe.

Figure 2. Summary of PSI results for Case 2 and her matched control.



(figure 2 continues)

Figure 2 - (continued)



CASE 3/CONTROL 3

Background Information:

At the time of this study, Case 3 was a nine-year, nine-month-old girl who had been enrolled in the SLD program at the age of six years. Her mother reported that this child was evaluated in a private center for suspected language delay at the age of four years. The test results at that time indicated delays in speech and language development, which resulted in a referral to the public schools for special education services. Case 3 was then placed in an Early Childhood Program. This type of program provides educational services for pre-school children who have been identified as having language and/or learning disabilities.

Case 3 was matched to a nine-year, ten-month-old, right-handed girl who attended regular education classes at the same school. The teachers of Control 3 described her as an "average" student with no apparent difficulties in following directions or attending to the teacher.

Birth and Medical History:

The birth history reported by the mother of Case 3 revealed no complications during the delivery of this child. Following delivery reportedly was jaundiced during her first two weeks of life. The mother reported that she was unaware of any complications from the jaundiced condition. The reported medical history revealed that Case 3 experienced "infrequent" ear infections during her first year of life. According to her mother, these ear infections were treated successfully with antibiotics. The administration of the tests in this study was delayed for a period of three weeks as Case 3 was experiencing an episode of bilateral otitis media. This infection was treated successfully with antibiotics. At the end of this treatment period, pure tone and immittance audiometry indicated that the child passed the criteria for normal hearing established for this study. Further questioning of the mother of this child revealed that Case 3 reportedly had not previously experienced middle ear problems after the age of one year.

An interview with the parents of Control 3 revealed no prenatal or birth complications. Information regarding medical history was provided by the mother of this child. She denied that her child had suffered any unusual childhood illnesses. She also did not recall any incidents of high fevers or ear infections.

Motor Development:

An interview with the mother of Case 3 revealed that this child did not demonstrate any delays in her gross motor development. Skills such as sitting unsupported, crawling, and walking were reported to occur at the expected age levels. The mother of this child further reported that no difficulties were demonstrated with such fine motor skills as feeding and dressing independently, tieing shoes, or learning to write with a pencil.

An interview with the mother of Control 3 revealed similar information to that obtained for Case 3. Control 3 reportedly demonstrated no delays in the development of gross or fine motor skills. Such skills as sitting unsupported, crawling, and walking were reported to occur at the appropriate age levels. Additionally, no difficulties were reported regarding such skills as feeding and dressing independently, tieing shoes, or learning to write with a pencil.

Speech and Language Development:

The history of speech and language development supplied by the mother of Case 3 revealed that this child began to babble at 14 months of age. One-word utterances were reported to occur at 18 months, while two-word utterances did not begin to emerge until 28 months. By the age of four years, Case 3 was reportedly speaking in only three- to four-word sentences. It was at that time that the mother of this child had her evaluated at a private speech and language center. It was determined from the results of that evaluation that this child had a speech and language disorder of a severe degree. As a result, Case 3 was placed in an early childhood program designed to advance the skills of children with confirmed learning/language disorders.

Information supplied by the mother of Control 4 revealed that the developmental milestones for speech and language appeared to occur at the appropriate age levels. At the time that this child entered the first grade in the public school system, an initial skills inventory, administered by the first grade teacher, revealed that Control 3 possessed all of the language skills and reading readiness skills necessary to succeed in an academic setting.

Past Academic Experience:

The parents and special education teachers of Case 3 described this child as "hard-working and eager to learn". Case 3 attended the Early Childhood program from the ages of four through six years. At the age of seven years she was re-evaluated to determine her eligibility for special education. At that time, a severe language delay was still prevalent and psychological testing revealed a discrepancy of greater than one standard deviation between her Performance IQ and her Verbal IQ. These results indicated that Case 3 would benefit from placement in the SLD program.

The teachers and parents of Control 3 reported that this child was working on the appropriate grade level in all academic areas. According to her parents Case 3 had "never" experienced any kind of academic difficulty. This child was reported to be "reserved" both at home and at school. However, Case 3 did not hesitate to ask parents or teachers to clarify directions or homework assignments.

Psychological and Language Test Results:

The psychological test results of Case 3, obtained for the purposes of this study revealed a Verbal IQ of 80 and a Performance IQ of 98 as measured by the WISC-R. These scores demonstrated a difference that was greater than one standard deviation between the verbal and performance abilities of this child. The language information obtained from Case 3 indicated an oral language age of 6-10 and a reading language age of 7-10 on the Woodcock Language Proficiency Battery (WLPB). These scores were determined to be below her chronological age by approximately three years and two years, respectively. A written language age of 8-11 also was obtained for Case 3, indicating nearly a one-year delay in writing skills.

Table 5. A non-auditory comparison of Case 3 and her matched control.

Parameter	Case 3	Control 3
Sex	female	female
CA	9-9	9-10
IQ-Verbal	80	104
IQ-Performance	98	109
LA-Oral	6-10	7-0
LA-Reading	7-10	9-3
LA-Writing	8-11	10-0
Birth History	unremarkable	unremarkable
Medical History	"infrequent" ear infections in first year of life	unremarkable
Motor Development	unremarkable	unremarkable
Sp/Language Development	Delay identified at age 4 years	two-year, 10-month delay in oral language

*Refer to Table 1 for a key to abbreviations.

The psychological test results for Control 3 on the WISC-R revealed a Verbal IQ of 104 and a Performance IQ of 109. No significant discrepancy between these two scores was noted. The language abilities of Control 3 indicated an oral language age of 7-0, a reading language age of 9-3, and a written language age of 10-0 as measured by the WLPB. It was noted that this child's oral language abilities were two years and ten months below her chronological age. A summary of the non-auditory comparisons between Case 3 and her matched control can be seen in table 5.

Audiologic Assessment

Dichotic Digit Test (DDT);

The percentage scores obtained from Case 3 on the DDT-2 indicated an equal performance of 90% bilaterally. These scores represented no demonstrable ear advantage on this subtest. However, the results from Case 3 on the DDT-4 subtest indicated a right ear score of 82% and a left ear score of 70%, demonstrating a distinct REA. In contrast to Case 3, Control 3 demonstrated a REA on both subtests of the DDT. The results obtained from Control 3 indicated a right ear score of 100% and a left ear score of 85% on the DDT-2 subtest. The DDT-4 subtest results indicated a right ear score of 97% and a left ear score of 82%.

When viewed in terms of the total accuracy for each subtest, Case 3 achieved a 90% score on the DDT-2 while her matched control achieved a score of 92%. The total scores obtained on the DDT-4 indicated 76% accuracy for Case 3 and 88% accuracy for Control 3. An examination of these test results indicated abnormal performance for Case 3 only on the DDT-4 subtest (Caudle, 1989). A summary of the DDT results can be seen for each subject in table 6.

Table 6. A comparative summary of the DDT and PPST results obtained for Case 3/Control 3. All numbers represent the percentage scores obtained.

Test	Right Ear	Left Ear	Total Score
DDT-2	90/100	90/85	90/92
DDT-4	82/97	70/82	76/88
PPST-H	73/93	93/100	83/96
PPST-M	80/100	86/100	83/100

Pitch Pattern Sequence Test (PPST):

The PPST results revealed abnormal performance for Case 3 on both the hummed (PPST-H) and the manual tasks (PPST-M), with only 83% accuracy for each condition. Control 3, however, demonstrated normal performance on both tasks, with a 96% score on the PPST-H and a 100% score on the PPST-M. It is noted that neither subject achieved distinct differences between the test modes, indicating consistent results with those obtained by Pinheiro (1978). A comparison of these PPST results can be seen in table 6.

Pediatric Speech Intelligibility Test (PSI):

The PSI performance intensity function (PSI-PI) obtained for Case 3 indicated a PB-max for the left ear at 60 dB HL with a rollover index ratio of .20 at 80 dB HL. No significant rollover was noted for the right ear of this child. The PSI-PI function for Control 3 indicated no significant rollover for either ear.

The PSI results obtained in the ipsilateral competing message condition (PSI-ICM) for both subjects indicate normal central auditory performance bilaterally. Case 3 demonstrated abnormal performance in the left ear for the PSI-CCM subtest with a 60% correct score at -20 dB MCR. This poorer CCM than ICM score was consistent with the performance demonstrated by children with a lesion of the temporal lobe(Jerger et al, 1988). The PSI results in the contralateral competing message condition (PSI-CCM) demonstrated normal auditory performance for Control 3. A summary of the PSI results obtained for Case 3 and her matched control can be seen in figure 3.

Figure 3. Summary of PSI findings for Case 3 and her matched control.

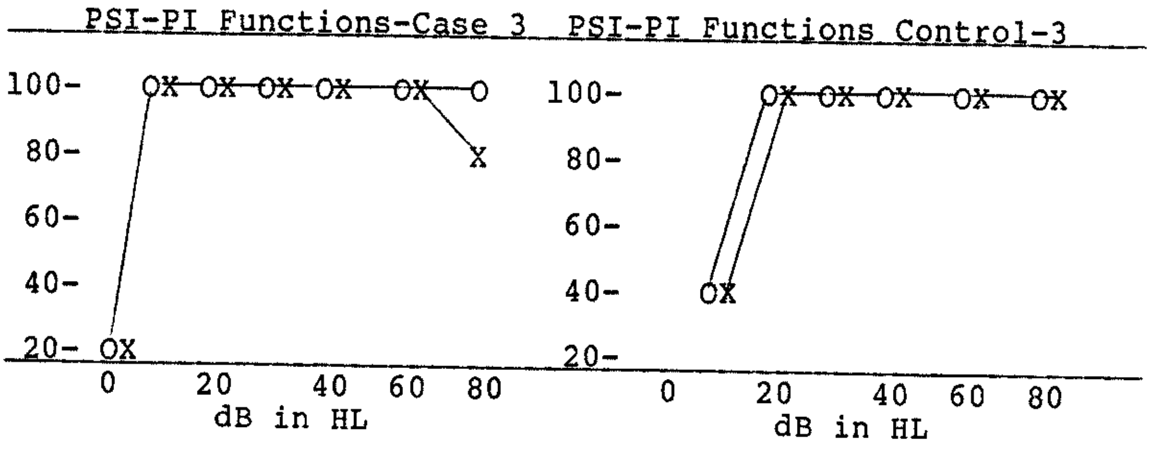


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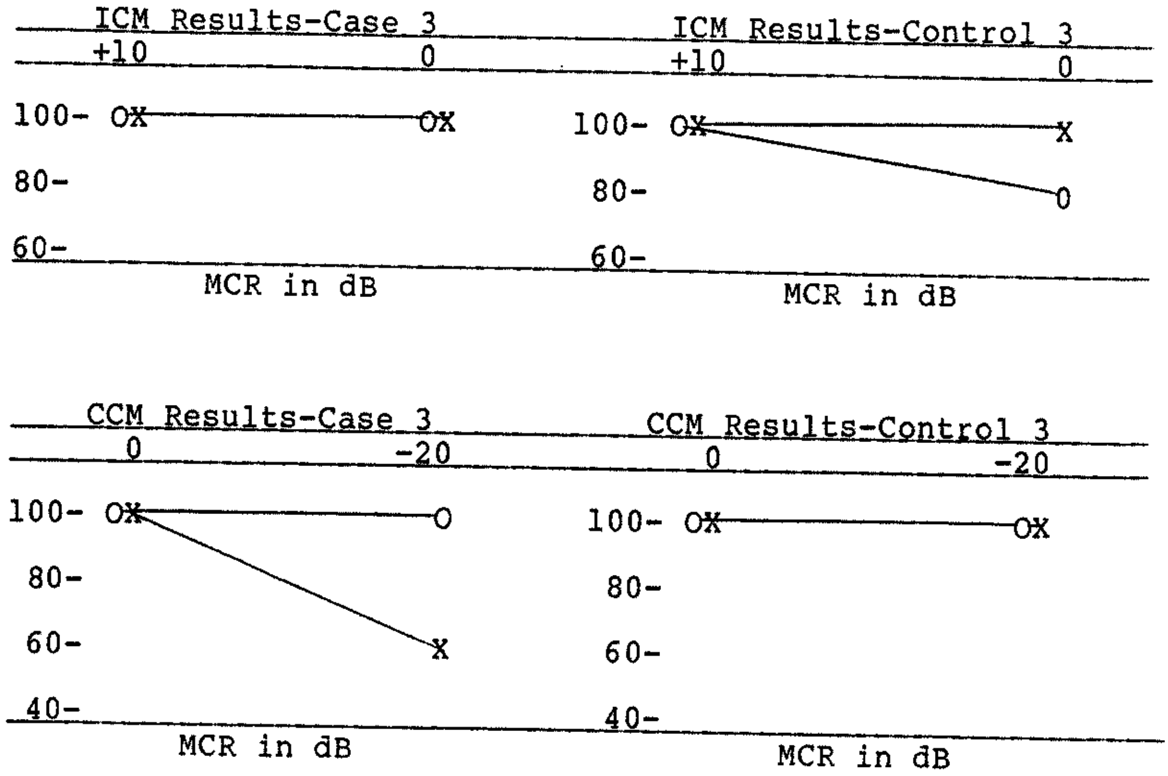
Figure 3 - (continued)



CASE 4/CONTROL 4

Background Information:

At the time of this study, Case 4 was a nine-year, two-month-old, right-handed boy, who entered the SLD program at the age of six years. This child was referred for Early Childhood placement by his kindergarten teacher, when she reportedly noticed that he was unable to follow directions or maintain his attention during group activities. The teacher did note, however, that Case 4 worked well on a one-to-one basis.

Case 4 was matched to a nine-year-old, right-handed girl who attended the same school in a regular classroom setting. Her mother described her as a "calm" child who always wants to help others, especially younger children.

Birth and Medical History:

The prenatal and birth history supplied by the mother of Case 4 revealed no complications. Further report from this child's mother revealed that Case 4 had an extensive history of middle ear infections beginning at the age of three years until about the age of five years. These infections reportedly were treated on a long-term basis with various antibiotics. The mother stated that at the present time Case 4 demonstrates middle ear problems only on a seasonal basis. Additional information obtained from the mother indicated that this child was hospitalized with pneumonia at the age of six years. This illness reportedly began with a 106 degree temperature. The final stages of the pneumonia reportedly resulted with collapsed lungs. No long-standing health problems from that incident were noted. It was reported that Case 4 plays football without any breathing difficulties.

An interview with the parents of Control 4 revealed no prenatal or birth complications. Information regarding medical history was provided by the mother of this child. Control 4 reportedly had a history of upper-respiratory infections, which the mother attributed to allergies and chronic colds. These infections were reported to start at about the age of 18 months and lasted until the age of four years. The mother did not recall any episodes of ear infections.

Motor Development:

An interview with the mother of Case 4 revealed that this child did not demonstrate any delays in his gross motor development. Skills such as sitting unsupported, crawling, and walking were reported to occur at the expected age levels. The mother of this child further reported that no difficulties were demonstrated with such fine motor skills as feeding and dressing independently, tieing shoes, or learning to write with a pencil.

An interview with the mother of Control 4 revealed similar information to that obtained for Case 4. Control 4 reportedly demonstrated no delays in the development of gross or fine motor skills. Such skills as sitting unsupported, crawling, and walking were reported to occur at the appropriate age levels. Additionally, no difficulties were reported regarding such skills as feeding and dressing independently, tieing shoes, or learning to write with a pencil.

<u>Speech and Language Development</u>:

The development of speech and language skills for Case 4 were reported to occur earlier than the expected age range until the age of three years. At that time several incidents of middle ear problems occurred in succession. The mother stated that Case 4, had been highly verbal prior to the ear infections. She added that this child "just stopped talking" during that period. This mother stated further that her son's language problems appeared to be related to those early recurrent ear infections. Middle ear problems were reported to re-occur, but only on a seasonal basis. The mother stated that Case 4 continues to have difficulty with verbal expression and with following verbal directions. She stated that this child tends to remain quiet and asks very few questions when it is apparent to her that he does not understand how to complete a required task.

The milestones reported by the mother of Control 4 revealed that the stages of speech and language development appeared to occur at the appropriate age levels. At the time that this child entered the first grade in the public school system, an initial skills inventory, administered by the first grade teacher, revealed that Control 4 possessed all of the language skills and reading readiness skills necessary to succeed in an academic setting.

Past Academic Experience:

The information supplied by the SLD teacher of Case 4 indicated specific classroom problems and behaviors. This child reportedly demonstrated noticeable difficulty in attending to specific tasks or in organizing his school materials. For example, the teacher noted that Case 4 was unable to focus his attention on one page of a story in his pre-primer reading book. It was also reported that this child avoided eye contact with other children and adults. Further descriptions of the specific behaviors of Case 4 indicated that he had difficulty keeping more than one item on his desk or in his hands. This child reportedly was referred for a medical evaluation to investigate the possibility of medication as an aid in focusing his attention. The family physician, however, reportedly saw no need for Case 4 to use medication to control his lack of attention abilities.

The mother of Control 4 reported that this child never repeated a grade in school, but that she attended summer school following the first grade. This subject's attendance in the summer school program was determined by the child's parents, who stated that she needed to "catch up" on schoolwork that had not been taught previously in another school district. The teachers of Control 4 described this child as socially immature when compared to her peers. However, no problems in the academic setting were reported.

Psychological and Language Test Results:

The assessment of the psychological abilities of Case 4 demonstrated a Verbal IQ of 76 and a Performance IQ of 91 as measured by the WISC-R. These scores reflected a discrepancy of one standard deviation between her verbal and her performance abilities. A specific strength on the Peformance Scale of the test was noted for the Picture Completion subtest. The language abilities measured on the Woodcock Language Proficiency Battery (WLPB) indicated an oral language age of 6-7, a reading age of 7-0, and a written language age of 7-2. These scores reflected approximately a two-year delay in language skills.

The psychological test results obtained from Control 4 demonstrated a Verbal IQ of 88 and a Performance IQ of 96. No significant discrepancy was observed between these two scores. The language assessment results obtained for the purposes of this study revealed an oral language age of 9-2 and a written language age of 8-7, which were appropriate for the chronological age of Control 4. A reading age of 8-0, however, was obtained for this child, indicating a one year delay from the expected performance on this task.
A summary of the non-auditory information obtained for Case 4 and his matched control can be seen in table 7.

Table 7. A non-auditory comparison of Case 4 and his matched control.

Parameter	Case 4	Control 4
Sex	male	female
CA	9-2	9-0
IQ-Verbal	75	88
IQ-Performance	91	96
LA-Oral	6-7	9-2
LA-Reading	7-0	8-0
LA-Writing	7-2	8-7
Birth History	unremarkable	unremarkable
Medical History	long history of ear infections	allergies; chronic colds
Motor Development	unremarkable	unremarkable
Sp/Language Development	normal until ear infections at age 2; about a 2-year delay	one-year delay in reading

*Refer to Table 1 for a key to abbreviations.

Audiologic Assessment

Dichotic Digit Test (DDT):

Case 4 demonstrated a distinct REA on each subtest of the DDT. The results of the DDT-2 subtest revealed a score of 95% for the right ear and 90% accuracy for the left ear. The results of the DDT-4 subtest indicated a greater ear difference for this child, with a right ear score of 92% correct and a left ear score of 65% correct. Control 4 also demonstrated an ear advantage on the DDT-2 subtest with 95% accuracy for the right ear and 100% accuracy for the left ear. These DDT-2 scores represented a LEA for Control 4. The results obtained for this child on the DDT-4 subtest, however, indicated a REA and a greater between-ear difference. Control 4 demonstrated a right ear score of 85% and a left ear score of 72%.

When viewed in terms of the total accuracy for both subtests of the DDT-2, these two children demonstrated the expected performance for children of this chronological age (Caudle, 1989). Case 4 performed with 93% total accuracy on this task while Control 4 performed with 97% total accuracy. However, each subject scored only 78% on the DDT-4, which demonstrated slightly depressed performance from the expected 85% obtained from normal subjects of the same age (Caudle, 1989). A summary of the DDT results for Case 4 and his matched control can be seen in Table 8.

Table 8. A comparative summary of the DDT and PPST results obtained for Case 4/Control 4. All numbers represent the percentage scores obtained.

Test	Right Ear	Left Ear	Total Score
DDT-2	95/95	90/100	93/97
DDT-4	92/85	65/72	78/78
PPST-H	73/100	86/100	79/100
PPST-M	80/100	80/86	80/93

Pitch Pattern Sequence Test (PPST):

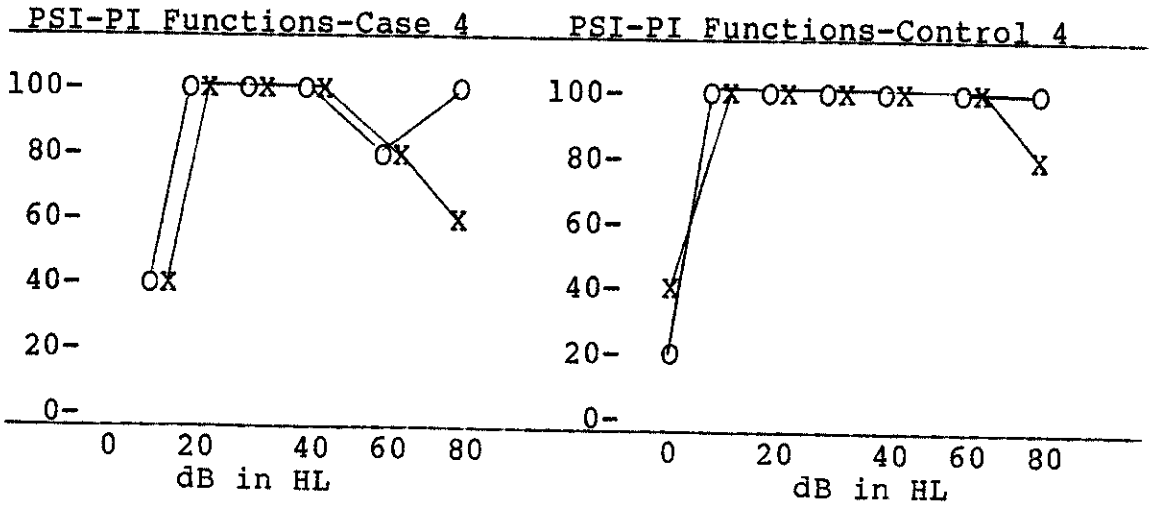
The results of the PPST demonstrated that Case 4 attained an overall performance of 79% on the hummed condition, while his matched control attained an overall score of 100%. The results of the manual task (PPST-M) revealed an 80% overall score for Case 4 and a 93% total score for Control 4. The results from both subtests of the PPST obtained from Case 4 are considerably lower than those found in both the Pinheiro (1978) and the Caudle (1989) studies for children of this age level. Control 4, however, demonstrated the expected performance for children of her chronological age. In agreement with the cited studies is the fact that neither subject demonstrated great differences in scores between the two modes of stimulus presentation. The results of the PPST subtests can be seen in Table 8.

Pediatric Speech Intelligibility Test:

The PSI results obtained for Case 4 and his control can be seen in figure 4. The PSI performance intensity function (PSI-PI) obtained in the left ear of Case 4 indicated a PB-max of 100% at 40 dB HL with a rollover index ratio of .40 at 60 dB HL. Control 4 also demonstrated rollover in the left ear, with a ratio of .20 at 80 dB HL. No rollover was noted for the right ear of Case 4 or his matched control. The rollover scores demonstrated in the left ears of these two subjects are considered to be consistent with abnormal performance (Jerger and Jerger, 1984).

The message-to-competition (MCR) functions obtained on the ipsilateral competing message subtest (PSI-ICM) revealed 100% performance bilaterally for both subjects. The performance of Case 4 on the contralateral competing message subtest (PSI-CCM) revealed abnormal performance bilaterally at the -20 dB MCR condition, with only 60% accuracy on this measure. Control 4 performed with 100% accuracy on the CCM condition for the left ear. However, her accuracy dropped to 80% in the right ear for the -20 dB MCR condition. The PSI-CCM results of both subjects indicated abnormal performance (Jerger & Jerger, 1984). Additionally, the poorer CCM scores observed in both subjects were considered to be consistent with the preformance of children with temporal lobe lesions (Jerger et al, 1988).

Figure 4. Summary of PSI findings for Case 4 and his matched control.



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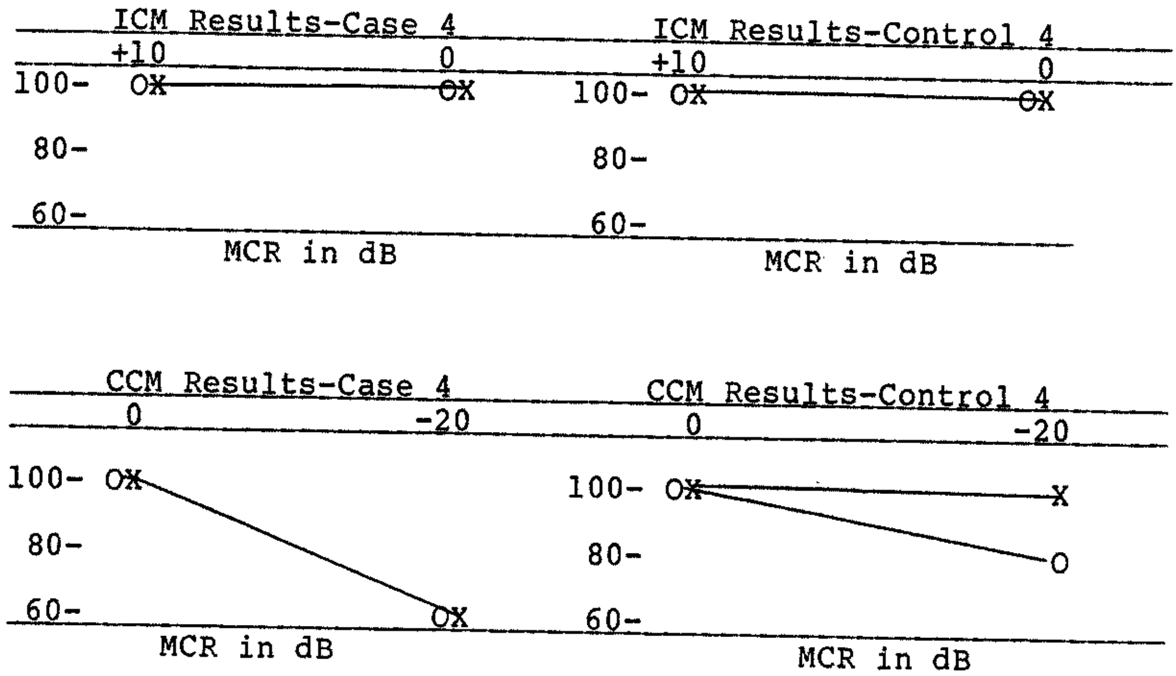


CASE 5/CONTROL 5

Background Information:

At the time of this study, Case 5 was a seven-year, eight-month-old right-handed boy. He is the younger brother of Case 2. This child was originally referred for in-depth speech and language testing at the age of four years, when he failed a school district screening test for the early identification of speech and language problems. Following the confirmation of a severe articulation disorder and a moderate language delay, this child was placed in an Early Childhood program.

Case 5 was described by his mother as having an outgoing, "take-charge" type of personality, a quality which she stated is very different from his older sister. The teachers of Case 5 described him as a highly motivated child who "never has enough work to do". They stated that although Case 5 appears quiet and shy at school he rarely hesitates to ask for additional school work.

Case 5 was matched to a seven-year, six-month-old, right-handed girl who attended regular second grade classes at the same elementary school. Control 5 was described by her teachers as "an extremely shy girl who is afraid to make mistakes". The same description was offered by this child's mother, who added that her daughter is "highly sensitive" to criticism and "expects a great deal" from her own performance in school.

Birth and Medical History:

Information supplied from the mother regarding prenatal and birth history revealed that Case 5 was delivered by Caesarean section. The mother of this child, however, was unable to attribute a reason for the delivery to have occurred in this manner. The medical history supplied by the mother of Case 5 revealed that this child sustained third degree burns on his chest and stomach when, at the age of two years, he pulled down a pan of boiling water from the stove. The burns were medically treated, but scarring on the upper body remains visible to date. Additional information supplied by the mother indicated that

Case 5 had a history of chronic colds. This mother denied, however, that he had ever had an ear infection.

The mother of Control 5 reported no prenatal or birth complications. The information obtained regarding the child's medical history revealed no unusual childhood illnesses. The mother of this child did not recall any incidents of high fevers or ear infections.

Motor Development:

An interview with the mother of Case 5 revealed that this child did not demonstrate any delays in his gross motor development. Skills such as sitting unsupported, crawling, and walking were reported to occur at the expected age levels. The mother of this child further reported that no difficulties were demonstrated with such fine motor skills as feeding and dressing independently, tieing shoes, or learning to write with a pencil.

An interview with the mother of Control 5 revealed similar information to that obtained for Case 5. Control 5 reportedly demonstrated no delays in the development of gross or fine motor skills. Such skills as sitting unsupported, crawling, and walking were reported to occur at the appropriate age levels. Additionally, no difficulties were reported regarding such skills as feeding and dressing independently, tieing shoes, or learning to write with a pencil.

<u>Speech and Language Development</u>:

An interview with the mother of Case 5 revealed little information regarding the development of speech and language skills. Although this child was referred for speech and language testing following an early identification program, his mother reported "normal" development. No additional information could be obtained from the mother.

Information regarding the communication skills of Case 5 was obtained from the school speech pathologist. She stated that her evaluation of this child's expressive language skills at the age of four years was obtained through language sampling and formal testing. The results of that evaluation indicated that Case 5 was approximately 70% unintelligible. This high level of unintelligibility was determined to be the result of a severe articulation disorder, rather than difficulty with syntax. An interview with the speech pathologist working with Case 5 at the time of this study revealed that this child's expressive language skills had improved by approximately 20%.

The developmental milestones reported by the mother of Control 5 revealed that all of the stages of speech and language acquisition appeared to occur at the appropriate age levels. At the time that this child entered the first grade in the public school system, an initial skills inventory, administered by the first grade teacher, revealed that Control 5 possessed all of the language skills and reading readiness skills necessary to succeed in an academic setting.

Past Academic Experience:

Case 5 attended the Early Childhood program until the age of six years, the maximum age for Early Childhood placement. He was then placed in the SLD program when a re-evaluation of his intellectual abilities revealed a significant discrepancy between his verbal and his non-verbal abilities on the Kaufman Assessment Battery for Children (KABC). This child was then placed in an SLD classroom.

The teacher of Control 5 reported that this child's performance in the classroom was on the second grade level in all of the academic areas. A interview with the mother of Control 5 revealed that this child had attended the public school system through the second grade without any significant academic problems.

Psychological and Language Test Results:

The psychological test results obtained from Case 5 for the purposes of this study revealed a Verbal IQ of 80 and a Performance IQ of 106, as measured by the WISC-R. These scores reflected a difference of 26 points, more than one standard deviation, between the two scales. Specific strengths on the Performance scale of this test are noted for the Picture Completion and the Picture Arrangement subtests.

The psychological test results obtained for Control 5 revealed that both her Performance IQ and her Verbal IQ were within the normal range. This child demonstrated a Verbal

Table 9. A non-auditory comparison of Case 5 and his matched control.

Parameter	Case 5	Control 5
Sex	male	female
CA	7-8	7-6
IQ-Verbal	80	102
IQ-Performance	106	101
LA-Oral	6-7	8-4
LA-Reading	6-6	8-0
LA-Writing	6-6	8-0
Birth History	delivered by C-section	unremarkable
Medical History	third degree burns on upper body	unremarkable
Motor Development	unremarkable	unremarkable
Sp/Language Development	Delay identified at age 4 years; no delay reported by the mother	unremarkable

*Refer to table 1 for a key to the abbreviations.

IQ of 102 and a Performance IQ of 101. A specific strength on the Performance Scale was noted for the Mazes subtest.

The assessment of language abilities with the Woodcock

Language Proficiency Battery (WLPB) indicated that the language skills of Case 5 were approximately one year below his chronological age. His performance on the WLPB yielded an oral language age in years and months of 6-7, a reading language age of 6-6, and a written language age of 6-6.

Control 5 performed above her chronological age on all of the measures of the WLPB, with the oral language age nearly one year above the expected performance for this child. Control 5 demonstrated an oral language age of 8-4, a reading age of 8-0, and a written language age of 7-10. A comparative summary of the non-auditory information obtained from Case 5 and his matched control can be seen in table 9.

Audiologic Assessment

Dichotic Digit Test (DDT):

Case 5 demonstrated an equal performance between ears on the DDT-2 with 80% accuracy. This finding reflects no distinct ear advantage on this subtest. The DDT-2 scores obtained from Control 5 also revealed no distinct ear advantage, although this child's scores were 100% bilaterally. The performance of these two children on the DDT-4 subtest, however, demonstrated a distinct ear advantage for each. Case 5 demonstrated a left ear advantage (LEA) on the DDT-4 with 47% accuracy in the right ear and 55% accuracy in the left ear. The results from Control 5 on the DDT-4 subtest were similar to the ear specific results obtained from Case 5. Control 5 demonstrated a LEA, evidenced by a 92% right ear score and a 95% left ear score.

When viewed in terms of total accuracy, Case 5 achieved 80% accuracy, of course, on the DDT-2 subtest. Likewise, Control 5 achieved an overall score of 100%. The results obtained on the DDT-4 subtest revealed a total score of only 51% for Case 5 and 93% for his matched control. The 51% overall score obtained from Case 5 was considerably lower than that of normal children of the same age (Caudle, 1989). However, the performance of Control 5 was considered to be within normal limits even for adults. The DDT-4 performance from Case 5 was approximately 28% lower than the DDT-4 scores obtained by normal children, aged 7-6 to 8-5, in Caudle's study (1989). Additionally, the overall accuracy obtained from Control 5 was 14% higher than the mean score obtained by other normal children of this age (Caudle, 1989). A summary of the DDT results obtained from Case 5 and his matched control can be seen in table 10.

Pitch Pattern Sequence Test (PPST):

The PPST results obtained from Case 5 demonstrated an overall accuracy of 96% on the hummed task (PPST-H) and 80% on the manual task (PPST-M). These scores reflected a 16% difference between the two modes of response for the PPST. This finding was consistent with those from Caudle (1989), who found that children under the age of 8-5 demonstrated a great deal of variability between the two response modes of the PPST. The PPST results obtained from Control 5 yielded 100% accuracy for the hummed task and 89% for the manual task, which was an 11% difference between response modes. A summary of the PPST results obtained from Case 5 and his matched control can be seen in table 10.

Table 10. A comparative summary of the DDT and PPST results obtained for Case 5/Control 5. All numbers represent the percentage scores obtained.

Test	Right Ear	Left Ear	Total Score
DDT-2	80/100	80/100	80/100
DDT-4	47/92	55/95	51/93
PPST-H	93/100	100/100	96/100
PPST-M	80/93	80/86	80*/89*

*60% of the PPST-M responses for Case 5 were reversals. 90% of the correct PPST-M responses for Control 5 were reversals.

Pediatric Speech Intelligibility Test (PSI):

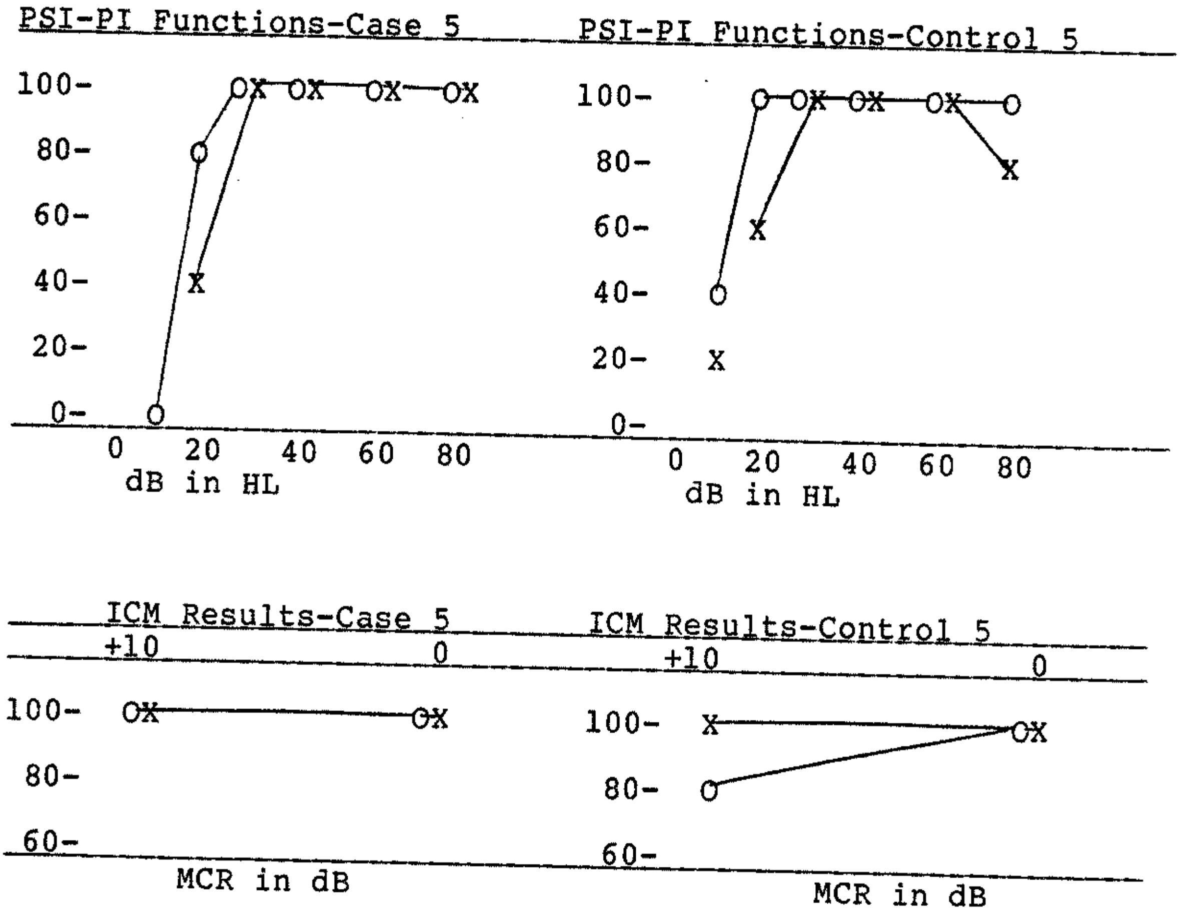
The results of the PSI test for Case 5 and his matched control can be seen in figure 5. The PSI performance intensity function (PSI-PI) for Case 5 indicated that he reached an asymptote at 30 dB HL bilaterally. The PSI-PI results obtained from Control 5 demonstrated the same results in the right ear as those obtained for Case 5. However, the left ear results for Control 5 indicated a PB-max of 100% at 30 dB HL with a .20 rollover index ratio at 80 dB HL. The rollover index ratio demonstrated by Control 5 indicated abnormal performance on the PSI-PI function for the left ear (Jerger and Jerger, 1984).

The PSI results obtained for Case 5 in the ipsilateral competing message condition (PSI-ICM) revealed 100% accuracy bilaterally on both the +10 and 0 dB MCR conditions. The same results were obtained for the left ear of Control 5. However, the PSI-ICM right ear results for this child indicated 80% accuracy at the +10 dB MCR condition and 100% accuracy for the 0 dB MCR condition. The PSI results obtained from Case 5 in the contralateral competing message (PSI-CCM) condition indicated a bilateral score of 100% for the 0 dB MCR condition. This child's accuracy decreased to 40% for the right ear and 20% for the left ear on the -20 dB MCR condition. This poorer CCM than ICM performance is thought to be indicative of a temporal lobe site of lesion.

Control 5 demonstrated 100% accuracy bilaterally for the 0 dB MCR condition on the PSI-CCM subtest. The left ear results for this child on the -20 dB MCR condition indicated 100% accuracy. Her right ear results indicated 80% accuracy for the same condition. When viewed in terms of the criteria presented by Jerger and Jerger (1984) the PSI-CCM results for Case 5 indicated abnormal performance. The right ear results for Control 5 are also considered abnormal for the PSI-ICM test condition at +10 dB MCR, and the PSI-

CCM test condition at -20 dB MCR. These abnormal findings for Control 5 on both the ICM and the CCM tasks is thought to be indicative of a temporal lobe site of lesion (Jerger et al, 1988).

Figure 5. Summary of PSI findings for Case 5 and his matched control.



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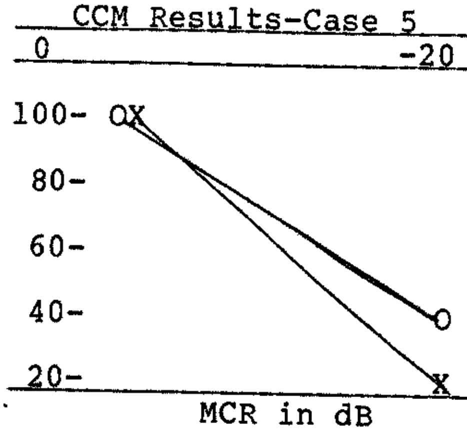
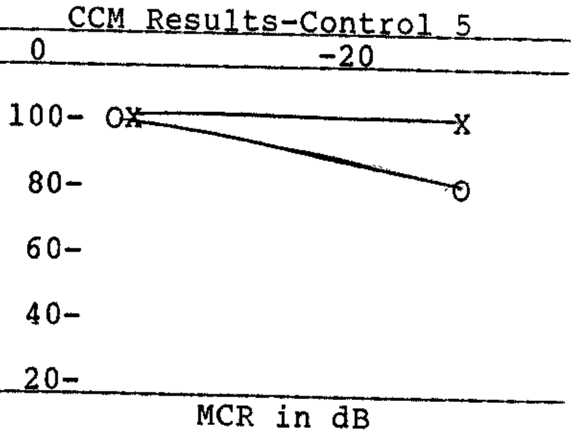




CASE 6/CONTROL 6

<u>Background Information:</u>

At the time of this study, Case 6 was a ten-year, seven-month, left-handed boy who had been enrolled in the SLD program for nine months. Case 6 was described by his teachers as a "highly verbal" child who performed best when lessons were presented utilizing an auditory channel rather than a visual channel. The teachers also stated that Case 6 demonstrated a "vivid" imagination and that he frequently attempted to invent various items for use in the home or at school.

Case 6 was matched to a ten-year, four-month-old, right-handed boy who attended the regular fifth grade at the time of this study. Control 6 was reported as being an "A" student. He reportedly had no academic difficulties, as evidenced by his mastery of the basic skills established by the state education agency. Both the teachers and parents of this child described Control 6 as "quick-witted" around friends and family members.

<u>Birth and Medical History</u>:

The mother of Case 6 reported on the prenatal and birth history of this child. The information obtained revealed that the mother's pregnancy was complicated by high blood pressure and toxemia. These complications continued to be present during the spontaneous delivery of Case 6. However, no complications were reported regarding the child's health. The medical history supplied by the mother of Case 6 indicated that her son had tonsillitis, allergies, chronic colds, and ear infections during his childhood. Further information obtained from the mother revealed that this child had seven sets of pressure equalizing (PE) tubes placed in his ears from the age of six weeks through eight years. Additionally, Case 6 had undergone tympanoplastic surgery within the past year to repair a perforation which had never healed from the longstanding placement of PE tubes in the right tympanic membrane.

The mother of Control 6 supplied the information regarding the birth and medical history of her son. She stated that there were no prenatal or birth complications with this child. Further information provided by the mother indicated that Control 6 had a history of four to five ear infections, reportedly occurring between the ages of one and three years. These infections were treated successfully with antibiotics prescribed by the child's pediatrician.

Motor Development:

An interview with the mother of Case 6 revealed that this child did not demonstrate any delays in his gross motor development. Skills such as sitting unsupported, crawling, and walking were reported to occur at the expected age levels. His mother reported, however, that Case 6 appeared to have difficulty with the development of fine motor skills involving eye-hand coordination, such as writing, coloring, cutting with scissors, and learning to tie his shoes. At the time of this study, the teacher of this child reported that Case 6 demonstrated the same difficulties with eye-hand coordination. The mother of this child reported that skills such as feeding and dressing independently emerged without noticeable difficulty.

An interview with the mother of Control 6 revealed that this child reportedly demonstrated no delays in the development of gross or fine motor skills. Such skills as sitting unsupported, crawling, and walking were reported to occur at the appropriate age levels. Additionally, no difficulties were reported regarding such skills as feeding and dressing independently, tieing shoes, or learning to write with a pencil.

Speech and Language Development:

The mother of Case 6 reported that his development of speech and language skills appeared to be delayed. This child reportedly began to babble by the age of one year, say his first words at 18 months, and speak in sentences at the age of three-and-a-half years. The mother stated that by the time that Case 6 entered kindergarten, he did not appear to have problems with following directions or expressing himself. She did report, however, that Case 6 was not as attentive as other kindergarten children.

The mother of Control 6 reported that her son achieved all of the developmental milestones for speech and language skills at the appropriate age levels. At the time that this child entered the first grade, he reportedly possessed all of the language and reading readiness skills necessary to succeed in an academic setting.

Past Academic Experience:

The mother of Case 6 reported that he repeated the first grade not because of failing grades, but rather because the parents felt that he might mature and, as a result, perform better in school. Prior to his SLD placement, Case 6 attended a regular second grade class at a private school in the Fort Worth area. It was reported that this child was achieving at a "slow rate", even when given the benefit of a smaller class size. His classroom teacher stated that his "slow rate" of achievement seemed to be attributed to his inability to pay attention.

Control 6 reportedly was academically successful throughout his school years. The mother of this child stated that her son had always enjoyed school as well as the extracurricular activities associated with it.

Psychological and Language Test Results:

Case 6 was referred to the SLD program at the age of nine years when psychological test results indicated a 17-point discrepancy, more than one standard deviation, between his verbal and performance IQ scores as measured by the WISC-R. Specific strengths measured on the Verbal Scale of the WISC-R included the Information, Vocabulary, and Comprehension subtests. All of the scores on the Peformance scale of this test were obtained within the normal range, with the exception of the Coding subtest. This subtest was found to be below normal expectations for a child of this chronological age. Additional observations from the WISC-R results indicated a wide scatter of performance between the verbal subtests, indicating that this child's IQ scores may have been affected by his high level of distractibility (Kaufman, 1979).

The language test results obtained from Case 6 for the purposes of this study revealed an oral language age of 9-9, a reading language age of 7-6, and a written language age of

Table 11. A non-auditory comparison of Case 6 and his matched control.

Parameter	Case 6	Control 6
Sex	male	male
CA	10-7	10-4
IQ-Verbal	92	111
IQ-Performance	109	100
LA-Oral	9-9	11-2
LA-Reading	7-6	18-0
LA-Writing	7-10	14-4
Birth History	mother had high blood pressure and toxemia	Unremarkable
Medical History	chronic otitis media; 7 sets of PE tubes	4-5 episodes of otitis media
Motor Development	visual-motor problems (cutting, & writing)	Unremarkable
Sp/Language Development	delay identified at age 9 years	Unremarkable

*Refer to table 1 for a key to the abbreviations.

7-10 as measured by the Woodcock Language Proficiency Battery (WLPB). An examination of these test results indicated that Case 6 was delayed by approximately three years for reading and two-and-a-half years for written language skills.

The psychological test results obtained from Control 6 for the purposes of this study revealed that this child demonstrated a Verbal IQ of 111 and a Performance IQ of 100 as measured by the WISC-R. It was noted that while the verbal abilities of this child appeared to be stronger than his performance abilities, both scores fell within the range of normal intelligence. The results of the WLPB indicated an oral language age of 11-2, a reading language age of 18-0, and a written language age of 14-4. These scores were in agreement with the verbal strengths noted on the WISC-R. However, the reading language age of Control 6 indicated approximately an eight-year difference above his chronological age. His written language age demonstrated a difference of four years above his chronological age. A comparative summary of the non-audiologic information obtained from Case 6 and his matched control can be seen in table 11.

Audiologic Assessment

Dichotic Digit Test (DDT):

The performance of Case 6 on the DDT indicated a distinct REA for each subtest. This child achieved a right ear score of 95% and a left ear score of 85% on the DDT-2 subtest. His performance on the DDT-4 demonstrated similar results with a 95% score obtained for the right ear and 58% accuracy obtained for the left ear. The performance of Control 6 demonstrated no ear preference on either subtest of the DDT. This finding was evidenced by a 100% score achieved bilaterally on the DDT-2 and 98% bilaterally on the DDT-4 subtest.

When viewed in terms of total accuracy for each subtest of the DDT, Case 6 demonstrated a performance of 90% on the DDT-2 subtest and 76% on the DDT-4 subtest. The DDT-4 performance of this child reflected a difference of 15% below the performance of normal children of the same age (Caudle, 1989). Control 6 demonstrated 100% accuracy on the DDT-2 and 98% accuracy on the DDT-4, indicating the expected performance for children of this chronological age (Berlin et al, 1973; Musiek, 1983; and Caudle, 1989). A comparison of the DDT results obtained from Case 6 and Control 6 can be seen in table 12.

Table 12. A comparative summary of the DDT and PPST results obtained for Case 6/Control 6. All numbers represent the percentage scores obtained.

Test	Right Ear	Left Ear	Total Score
DDT-2	95/100	85/100	90/100
DDT-4	95/98	58/98	76/98
PPST-H	100/100	100/100	100/100
PPST-M	86/100	86/100	86/100

Pitch Pattern Sequence Test (PPST):

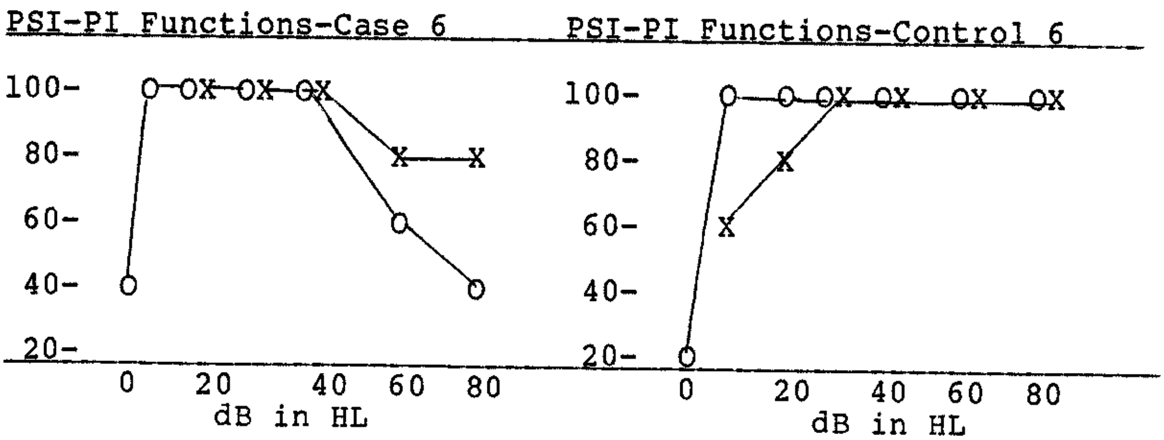
The PPST results obtained from both subjects indicated no difference in accuracy between the two modes of response. Both Case 6 and his matched control demonstrated 100% accuracy for the hummed task (PPST-H). The results from the manual task of the PPST (PPST-M) were similar to those obtained from the PPST-H subtest. While Control 6 demonstrated 100% accuracy on the PPST-M subtest, Case 6 demonstrated only 86% accuracy. Case 6 achieved an accuracy level on the PPST-M that was only slightly below the 90% accuracy level demonstrated by Pinheiro's normal subjects (1978). According to the results of Caudle (1989), however, Case 6 demonstrated an accuracy level which was approximately 13% below the performance scores obtained from her normal subjects of the same age. See table 12 for a summary of the PPST results from Case 6 and his matched control.

Pediatric Speech Intelligibility Test (PSI):

A summary of the PSI results obtained for Case 6 and his control subject can be seen in figure 6. The PSI performance intensity function (PSI-PI) obtained from Case 6 indicated a bilateral PB-max score of 100% at 40 dB HL. A rollover index ratio of .60 is found for the right ear at 80 dB HL and .20 for the left ear at 60 and 80 dB HL. These scores reflected significant rollover for both ears (Jerger & Jerger, 1984). The PI-function obtained from Control 6, however, indicated a PB-max of 100% maintained bilaterally at 40 dB HL through 80 dB HL.

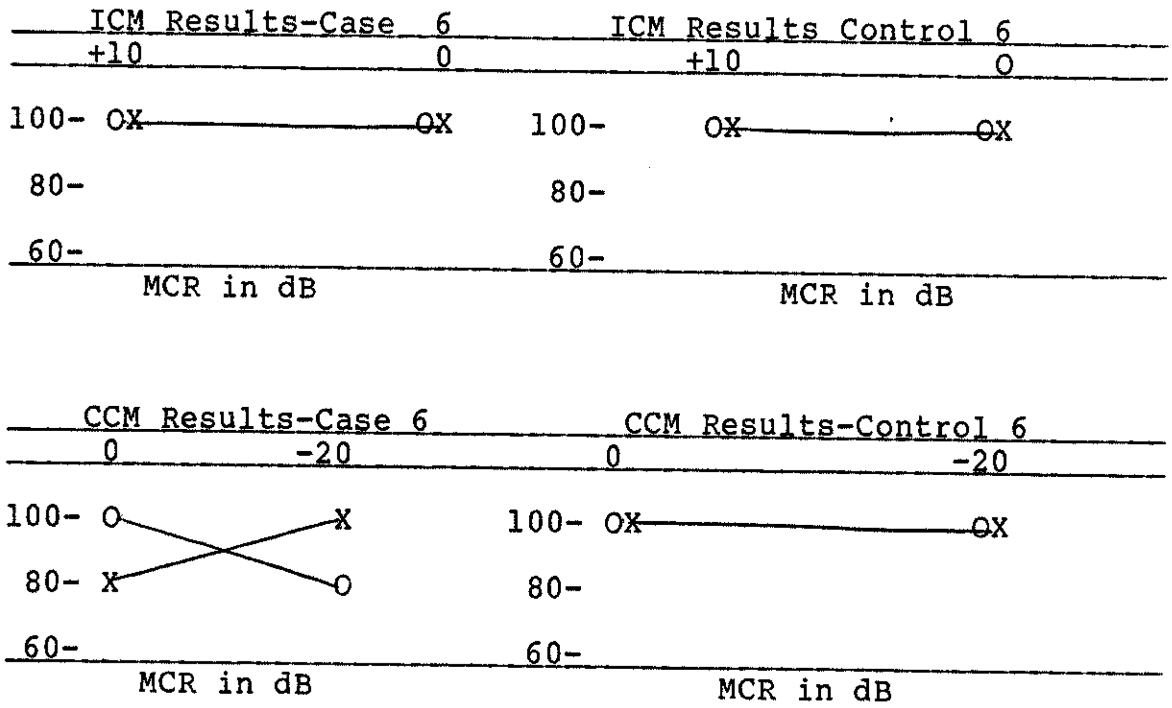
The PSI ipsilateral competing message conditions (PSI-ICM) for both subjects revealed 100% accuracy bilaterally for both MCR conditions. The PSI results obtained from Case 6 in the contralateral competing message condition demonstrated 100% accuracy for the right ear at 0 dB MCR and 80% accuracy at -20 dB MCR. The results for the left ear of this child indicated a mirror image of the right ear, with 80% accuracy for the 0 dB MCR condition and 100% accuracy for the -20 dB MCR condition. These scores indicated abnormal performance for Case 6 for the -20 dB MCR condition in the right ear, and abnormal performance for the 0 dB MCR condition in the left ear. This abnormal performance for the CCM condition is thought to be indicative of a temporal lobe site of lesion (Jerger et al, 1988). Control 6, however, maintained a 100% score for both MCR conditions of the PSI-CCM.

Figure 6. Summary of PSI findings for Case 6 and his matched control.



(figure 6 continues)

Figure 6 - (continued)



A summary of results of this study is provided in tables 13 through 16. The SLD and the control children are grouped separately so that the reader may easily refer to the similarities and differences among each group. Because the history and the non-auditory assessment information for each child provides no new information, only a summary of the central auditory results is provided as a reference for discussion.

Table 13. A summary of the Dichotic Digit and Pitch Pattern Sequence test results for the SLD subjects.

Subject	DDT-2 RE	DDT-2 LE	DDT-4 RE	DDT-4 LE	PPST-H RE	PPST-H LE	PPST-M RE	PPST-M LE
Case 1	85	65	85	67	86	73	73	86
Total	75		76		79		79^	
Case 2	85	85	62	82	93	100	100	100
Total	85		72		96		100*	
*93% of correct responses were reversals.								
Case 3	90	90	82	70	73	93	80	86
Total	90		76		83		83^	
Case 4	95	90	92	65	73	86	80	80
Total	93		78		79		80^	
Case 5	80	80	47	55	93	100	80	80
Total	80		51		96		80*	
*60% of correct responses were reversals.								
Case 6	95	85	95	58	100	100	86	86
Total	90		76		100		86^	

^Subject showed less than 15% reversals (Caudle, 1989).

Table 14. A summary of the Dichotic Digit and Pitch Pattern Sequence test results for control subjects.

Subject	DDT-2 RE	DDT-2 LE	DDT-4 RE	DDT-4 LE	PPST-H RE	PPST-H LE	PPST-M RE	PPST-M LE
Control 1	100	95	85	70	80	100	73	86
Total	97		77		90		79^	
Control 2	90	70	92	55	66	80	80	73
Total	80		71		73		76*	
56% of correct responses were reversals.								
Control 3	100	85	97	82	93	100	100	100
Total	92		88		96		100^	
Control 4	95	100	85	72	100	100	100	86
Total	97		78		100		93^	
Control 5	100	100	92	95	100	100	93	86
Total	100		93		100		89*	
90% of correct responses were reversals.								
Control 6	100	100	98	98	100	100	100	100
Total	100		98		100		100^	

^Subject showed less than 15% reversals (Caudle, 1989).

Table 15. A summary of the PSI results for the SLD subjects. The scores are presented in percentage scores for right/left ears.

Subject	PI-function rollover	PSI/ICM +10	PSI/ICM 0	PSI/CCM 0	PSI/CCM -20
Case 1	40/20	100/100	100/100	100/100	100/100
Case 2	20/no	100/80	80/60	100/40	20/20
Case 3	no/20	100/100	100/100	100/100	100/60
Case 4	no/40	100/100	100/100	100/100	60/60
Case 5	no/no	100/100	100/100	100/40	40/20
Case 6	40/20	100/100	100/100	100/80	80/100

Table 16. A summary of the PSI results for the control subjects. The scores are presented in percentage scores for right/left ears.

Subject	PI-function rollover	PSI/ICM +10	PSI/ICM 0	PSI/CCM 0	PSI/CCM -20
Control 1	20/20	100/100	100/100	100/100	100/100
Control 2	no/20	100/100	80/100	100/100	80/100
Control 3	no/no	100/100	80/100	100/100	100/100
Control 4	no/20	100/100	100/100	100/100	80/100
Control 5	no/20	80/100	100/100	100/100	80/100
Control 6	no/no	100/100	100/100	100/100	100/100

Discussion

This study focused on the central auditory abilities of each severely language-delayed child and his peer, who was equal in terms of chronological age and non-verbal intelligence. The central auditory results from each subject were compared to the normative data established for each test of central auditory function. Additional comparisons were made regarding the developmental history of each child. The parent(s) of these children recalled the birth, medical, motor, speech-language, and academic information to the best of their abilities. Comparisons were also made regarding objective, non-auditory information from psychological and language assessments. Because the non-auditory information regarding these children reveals no insights as to the possible causes for some of the children's inability to process efficiently the presented auditory stimuli, only the results from the central auditory tests are discussed.

Dichotic Digit Test

The available normative information indicates that children score with about 96% correct responses or better on the DDT-2. However, the data available for the DDT-4 demonstrates that children progressively improve their performance on this subtest, demonstrating 88% or better performance by the age of 9.6 (Caudle, 1989). Caudle's study further confirms the fact that this age group performs similarly on the DDT-4 to the adults of Musiek's study who perform on this subtest with about 90% accuracy.

Of the six SLD children in this study, no child scores as high as 96% correct responses on the DDT-2. The highest total score is 93% and one child's score is 75%. Three of the children demonstrate neither a REA nor a LEA for the DDT-2, while the remaining SLD children demonstrate a clear REA for this measure.

The children's responses for the more difficult DDT-4 suggest that this subtest is also a more discriminating task for the SLD children. Two of the children who demonstrate no ear advantage on the DDT-2 perform less well on the DDT-

DDT-4. These two SLD children reveal a marked LEA on the DDT-4. All of the remaining SLD children demonstrate a dramatic REA, with the right ear responses from 12 to 37 percentage points different from the left ear responses. Dirks (1964) demonstrates that an ear difference of at least 2% is a significant representation of ear dominance. The ear differences found on the DDT-4 subtest are greater than those which are demonstrated for the DDT-2 subtest. Thus, it would appear that among these SLD children ear advantage may be more effectively demonstrated for either ear with the DDT-4 than with the DDT-2.

The control subjects of this study demonstrate both verbal and performance abilities to be within the range of normal intelligence. Thus, one would expect normal performance on this measure of central auditory function. However, four of the control children demonstrate language delays which are one or more years below the expected range of performance on at least one measure of the Woodcock Language Proficiency Battery. Of these four control children, only two score as high as the expected 96% on the DDT-2 subtest. One child demonstrates a LEA for the DDT-2, while the remaining three demonstrate a clear REA on this measure.

Two of the control subjects with normal to above normal language proficiency scores demonstrate neither a right nor a left ear advantage on the DDT-2. Both children, however, perform higher than the expected 96% correct response level. Their scores on the DDT-4 demonstrate slightly decreased performance on this more difficult auditory task.

Five of the control subject's demonstrate a greater ear advantage on the DDT-4 than on the DDT-2, with the dominant ear response 5 to 37 percentage points higher than the opposite ear. One child demonstrates no ear preference on the DDT-2 but shows a clear LEA on the DDT-4. This finding also supports the contention that the DDT-4 is the more challenging of the two subtests and, thus, a more sensitive instrument in establishing ear dominance.

Pitch Pattern Sequence Test

The results of this study are consistent with the findings of Pinheiro and Ptacek (1971) in that pattern reversals are common in normal hearing subjects. However, two SLD and one control subject demonstrate a higher number of reversals than the 15% found in normal children of the same age (Caudle, 1989). The auditory pattern reversals found in this study are mirror images of the original stimulus.

The humming responses of the auditory presentations from the PPST demonstrate abnormal performance for three SLD children and two control subjects. It can be said of the subjects in this study that only one SLD subject scored at a mean success rate equal to the mean of the children in

Caudle's study, and two scored only 4% below the mean. Likewise, three of the control subjects in this study scored above the mean values reported in Caudle's study, while one child scored only three points below this mean value. The fact that seven of the subjects of this study performed with a high percent of accuracy on this humming task is an expected finding, since the patterns were probably recognized in the right hemisphere, which has been found to be dominant in the perception of melodies (Broadbent, 1956; Kimura, 1964; and Pinheiro, 1971).

Four SLD children and two control subjects perform on the manual task with decreased accuracy from that of normative subjects (Pinheiro, 1978; Caudle, 1989). One SLD child and one control child below the age of nine years demonstrate decreased performance on the tapping response, however, this performance is consistent with the normative data available for this age group. Kimura (1961) established that sequencing is probably mediated through the left hemisphere. Additionally, Kimura and Archibald (1974) demonstrated that the left hemisphere is also dominant for motor control. Pinheiro et al (1980) demonstrated that the correct verbal report of an auditory pattern is dependent upon interaction between the two cerebral hemispheres. Thus, it appears that six of the subjects in this study demonstrate abnormalities which suppress the effective transmission of an auditory signal to the opposite hemisphere.

While the author of this test has not established the efficiency of the PPST in demonstrating an ear advantage, Caudle's normative information shows that the left ear appears to be superior in sequencing auditory pitch patterns. Her data further demonstrates that there are essentially no differences between the ears or the modes of response for either subtest of the PPST.

Among the SLD children used in this study, ear advantage is not elicited on the PPST-M in four of the six children. Two children demonstrate left ear superiority in sequencing the auditory patterns. Five of the SLD subjects demonstrate ear differences on the PPST-H task of between 7 and 20 percentage points. Four of them demonstrate left ear superiority for this task. One SLD child demonstrates equal recognition of the pitch stimuli.

Of the six control subjects used in this study, only one child demonstrates left ear superiority on the PPST-M. Three of the children demonstrate better performance for the right ear, while two control children show no ear preference in the completion of this task. Three of the control subjects demonstrate ear differences on the PPST-H of 7 to 20 percentage points, with the left ear showing superior performance for this task. The remaining three control subjects show no advantage for either ear in recognizing the pitch stimuli.

It may be observed that while an ear advantage is consistently demonstrated by the normal children from numerous other studies, no ear advantage pattern exists between the PPST and the DDT. This finding demonstrates the lack of consistency between the results of the two measures, indicating that each test measures ear advantage and taps different auditory functions by different means. The disparity between the results displayed for the children on the DDT and the PPST suggests that a test battery using both tests may not serve the purpose of identifying a single ear advantage. The two tests may only display an auditory processing system which fails in different ways according to the type of task with which it is challenged.

Pediatric Speech Intelligibility Test

Jerger and Jerger (1984) established a criteria of abnormality for the PSI measures in children aged three to six years. These authors established that rollover on the PSI test is to be considered significant when the ratio value exceeds 10% for the higher level sentences. This rollover phenomenon suggests CNS pathology which is typically observed in the ear contralateral to the affected hemisphere (Bocca et al, 1954; Goodman, 1957; Jerger & Jerger, 1983). While the children of this study are certainly chronologically old for the PSI tests, the results of the PSI performance intensity function demonstrate positive rollover by these standards in five of the SLD children. Two of these children demonstrate rollover bilaterally, two demonstrate positive findings in the left ear only, and one subject demonstrates rollover in the right ear only. The data obtained for adults with lesions of the central auditory system, however, (Jerger and Jerger, 1971) indicate that positive rollover is found to be significant at values which are greater than 45%. Applying this criteria to the data obtained for the SLD subjects in this study demonstrates that none of the SLD children would demonstrate positive rollover.

Four of the control subjects in this study demonstrate positive rollover in at least one ear. One subject, Case 1, demonstrates rollover bilaterally and the remaining three children demonstrate rollover in the left ear only.

Five of the six SLD children demonstrate perfect scores on the PSI-ICM mode of presentation. The PSI-CCM findings of this group consistently demonstrate abnormalities among five of the subjects for the CCM mode of presentation. One child demonstrates poor performance on both the ICM and the CCM tasks, with CCM scores considerably poorer than ICM scores. It can be said that the deficits of these SLD children are consistent with the performance deficits of children with either confirmed temporal lobe lesions or suspected central auditory problems (Jerger et al, 1988).

The PSI scores of three of the control subjects in this study demonstrate perfect ICM and CCM scores. The remaining three control subjects demonstrate poor CCM performance for the right ear only. However, these three children also demonstrate rollover in the ear which is contralateral to the poor CCM score. This finding suggests the presence of a central auditory disorder associated with a pathology located at the level of the temporal lobe on the contralateral side.

While the PSI standards established in the Jerger studies appear to be somewhat stringent in their application, it is observed that all of the SLD children in this study who demonstrated abnormal performance on the PSI measures also demonstrated abnormal performance on at least two other measures from this central auditory battery. In fact, five of the SLD children demonstrate low performance scores on at least five of the central auditory measures and one SLD child demonstrates poor performance on four of the tests,

The performance of four control children who demonstrate abnormalities on at least one PSI measure also demonstrate abnormalities on at least one other central auditory test used in this study. One control subject demonstrates abnormal performance on six of the seven measures of central auditory function.

The SLD subjects used in this study no doubt exhibit deficiencies in their ability to auditorily process sensory information. This statement is based on the subjective information offered by the adults who have worked and lived with these children. However, due to the subjectivity involved in providing case history information, the auditory behaviors of both the SLD and the control subjects are nearly impossible to describe. The tests used in this study have proved to be an efficient manner in which to obtain objective information concerning the auditory behaviors of these children. These central auditory tests have demonstrated that the performance of the SLD children, as well as some of the matched control children, is consistent with the data of other investigators in terms of an established ear preference, total accuracy of scores, and site of lesion results (Hynd & Obrzut, 1983; Pinheiro, 1977). Several investigators highly recommend the use of a battery of tests in order to determine the presence of a central auditory disorder (Willeford & Burleigh, 1985; Musiek, Geurkink & Kietel, 1980; Jerger, Martin, & Jerger, 1987; Ferre & Wilber, 1986). This investigator is no exception. Each of the tests used in this study have demonstrated their efficiency in identifying at least one aspect of a deficient auditory system.

Conclusions

The results of this study demonstrate that no patterns emerged between the SLD subjects and their matched controls. None of the children possessed medically confirmed lesions of the central nervous system which might account for their poor ability to process the auditory information presented in this study. All of the children demonstrated normal non-verbal intelligence on the WISC-R. Additionally four of the control subjects and all six of the SLD subjects demonstrated at least a one-year delay on at least one subtest of the Woodcock Language Proficiency Battery.

The results of this study demonstrated that:

1. The DDT, PPST, and the PSI are tests of central auditory function which identify at least one aspect of central auditory dysfunction in children with language delays.

2. The presence of a central auditory processing disorder was more consistent among the SLD subjects than their matched controls.

3. The control subjects of this study, while performing within normal limits for intellectual measures, did not consistently demonstrate performance on central auditory measures which is characteristic of children who performed the same tasks in normative studies.

Recommendations for Further Research

Because of the small number of subjects used in this study, no conclusive evidence can be stated regarding the central auditory abilities of SLD children. Perhaps another study which utilizes a larger experimental group can offer some significant insights into the central auditory abilities of these special children. The children should be matched to normal-hearing control subjects who demonstrate the same intellectual abilities as determined by a non-verbal measure of intelligence.

Future researchers should consider that gathering information regarding the development of each child relies heavily on subjective and often incomplete information from the parents. A study of this particular group of children should focus on objective measures of the neuro-audiologic system.

APPENDIX A

INSTRUCTIONS FOR THE DICHOTIC DIGIT TEST

Instructions: Dichotic Digit Test

The children were informed that they were going to play a listening game with numbers. They were told they would hear one number in each ear and that they needed to repeat the numbers in any order that they wanted. They were further instructed to be very good listeners because they would hear both numbers at the same time.

A similar procedure was repeated for the four-digit test. The numbers repeated by each of the children were recorded and a percent of correct responses was derived.

APPENDIX B

INSTRUCTIONS FOR THE PITCH PATTERN SEQUENCE TEST

Instructions: Pitch Pattern Sequence Test

The children were instructed that they were going to play a listening game which involved humming back some notes that they heard. They were instructed to listen for three notes, some high and some low, and to hum back what they heard. Five practice items were presented, and if they were repeated correctly, the tape was presented.

After the humming task was completed, the children were told that they were going to play a new game. They were instructed to listen for three notes and then to tap a tall block for a high note and a short block for a low note. Five practice items were again introduced, and if the child did not understand the instructions, the examiner physically moved the child's hand to the appropriate block until he demonstrated the correct task.

APPENDIX C

INSTRUCTIONS FOR THE PEDIATRIC SPEECH INTELLIGIBILITY TEST

Instructions: Pediatric Speech Intelligibiltiy Test

The children were familiarized with the picture card from which they would respond and were asked to describe the activity in the picture. They were told that they were going to listen to a man talk about the pictures on the card. The children were instructed to point to the picture about which the man was talking. The items for the PI function were then presented in quiet. The children were then told that the same man was going to talk about the pictures, but this time a "trick man" was going to talk about some different pictures at the same time. They were instructed to ignore the "trick man" and point to the pictures described by the "picture man".

For the PSI-ICM subtest the children were instructed to listen to the man talk about the pictures on the response card. They were told that both the "trick man" and the "picture man" were going to talk in the same ear. The children were instructed once again to ignore the "trick man".

A similar procedure was repeated for the PSI-CCM subtest in which the "trick man" would talk in one ear and the "picture man" would talk in the other ear. The children were instructed to listen only to the picture man.

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