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Dichotic Auditory Training in 6 to 15 year olds

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DICHOTIC AUDITORY TRAINING IN 6 TO 15 YEAR OLDS

by

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ABSTRACT

The purpose of this study was to determine if participants with normal auditory processing skills would improve after receiving the Dichotic Auditory Training (DAT) when compared to a group of normal participants who only received pre- and post-testing. Twenty participants, age 6:0 to 15:11 years, participated in this study. A standard audiological evaluation was completed for each participant. Pretest and posttest were completed that included (1) DAT testing, (2) *SCAN-C/A*, (3) *Staggered Spondaic Word* test, and (4) *Dichotic Digits* (Single/Double). The results were analyzed for statistically significant differences between pre- and post-testing results and between groups. Any significant results were thought to be the evidence of the plastic changes desired. It was found that statistically significant differences existed between the two groups for 4 of the 22 testing conditions. Also, when comparing pre- to post-test results, 7 of the 22 conditions were found statistically significant.

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CHAPTER I

INTRODUCTION

In 1996, the American Speech-Language-Hearing Association (ASHA) appointed a Task Force of individuals who were experienced with central auditory processing to address concerns related to (central) auditory processing disorder [(C)APD]. These were related to a lack of uniformity and controversy surrounding the definition, identification procedures, and intervention practices concerning (C)APD. According to the ASHA Task Force on Central Auditory Processing Consensus Development (1996), a (C)APD is the inability of the auditory system to process acoustic signals in one or more of the following ways: "sound localization and lateralization; auditory discrimination; auditory pattern recognition; temporal aspects of audition to include: temporal resolution, temporal masking, temporal integration, and temporal ordering; auditory performance decrements with competing acoustic signals; and auditory performance decrements with degraded acoustic signals" (p.43). The ASHA Working Group on Auditory Processing Disorders (2005) supported this definition and discussed the role of the audiologist, diagnosing, and management of (C)APD. Many researchers clearly agree that the deficit lies with a person's inability to process auditory information in unfavorable environmental conditions (i.e. background noise) while maintaining normal hearing sensitivity (ASHA, 1996, 2005; Jerger & Musiek, 2000; Keith, 1997, 1999; McFarland &

Cacace, 1995). A (C)APD is considered by some to be a disorder that can coexist with other disorders such as attention deficit disorder/attention deficit hyperactivity disorder (ADD/ADHD), language impairment or language disorders (ASHA, 2005; Chermak, Somers, & Seikel, 1998; Jerger & Musiek, 2000; Keith, 1999, 2000). There are instances where some disorders, such as ADD/ADHD, share some of the same symptoms as (C)APD such as inattention and distractibility (Chermak et al., 1998). Typically an individual with (C)APD has normal hearing, but exhibits the signs of a hearing impairment. Other symptoms may include difficulty comprehending a message in a noisy background or in reverberant environment; misunderstanding messages; inconsistent or inappropriate responding to sounds; frequent requests for repetitions, saying "what" and "huh" frequently; taking longer to respond in oral communication situations; difficulty paying attention; being easily distracted; difficulty following complex auditory directions or commands; difficulty localizing sound; difficulty learning songs or nursery rhymes; poor musical and singing skills; and associated reading, spelling, and learning problems (ASHA, 2005; Chermak & Musiek, 1992; Heine & Slone, 2008; Jerger & Musiek, 2000; Keith, 1997, 1999; Smoski, Brunt & Tannahill, 1992). According to some (Clarkson, Eimas, & Marean, 1989; Mody, Schwartz, Gravel, & Ruben, 1999), if there are any interruptions to the acoustic signal, whether it be temporary (i.e., otitis media, maturation) or permanent (i.e., sensorineural hearing loss), during the critical years when language development occurs, the development of language and long term effects on academic performances can be detrimental to an individual.

There has been extensive research directed at assessing, diagnosing, and defining (C)APD: however, little research exists as to the efficacy of treatment methods or management of this disorder. Current interventions include compensatory strategies (e.g., preferential seating, use of FM systems, and slowing the rate of speech, etc.), cognitive therapy, and a few commercially available auditory training programs (e.g., Earobics and FastForWord). According to Musiek, Baran, and Schochat (1999), remediation of (C)APD is in the beginning stages and much research is still needed.

Stephenson (2008) used an auditory training program [i.e., Dichotic Auditory Training (DAT)] with the goal of strengthening the auditory system of those individuals who were suspected of having a (C)APD. The study consisted of eight participants, between the ages of 7-12 who had normal peripheral hearing and a diagnosis of (C)APD. These participants were administered pre- and post-testing that consisted of the *Staggered Spondaic Word (SSW)* test, *SCAN-C: A Test for Auditory Processing Disorders in Children* or *SCAN-A: A Test for Auditory Processing Disorders in Adolescents and Adults* (*SCAN-C/A*), Baseline DAT, and Post-DAT. The DAT was given two days a week for four weeks and was comprised of 96 exercises with each exercise containing twenty dichotic presentations presented at different interaural timing differences.

The results of this study yielded statistically significant differences for the DAT conditions: R300, R150, 0 msec, and overall DAT score. According to Stephenson (2008), based on these results, it was assumed that the DAT did improve the dichotic listening skills for these participants resulting in plastic changes within the central auditory system. For the *SSW*, the total errors and left competing (LC) conditions were found to be significant. There were no statistically significant differences observed with the SCAN-C/A. However, an effect size was observed for some of the conditions (i.e., DAT-150, DAT-L300, SSW-RNC, SSW-RC, SSW-LNC, SCAN-C/A-Auditory Figure Ground Left subtest, and SCAN-C/A-Competing Words Left subtest), suggesting that there was improvement between pre- and post-test scores.

In order to fully understand the complexity of a (C)APD, it is important to know the anatomy and physiology of a normal auditory system, what happens to the CANS when it malfunctions, a (C)APD diagnosed, and what treatment programs are available to help manage this disorder. There is a tremendous amount of literature focused on diagnosing a (C)APD and what possible treatments may work; however, the development of these treatments for commercial use is very limited. The DAT shows promising results as a therapy program for managing a (C)APD. However, the DAT is currently in its infant stage of development and much research is still needed before the DAT could make the leap as a commercially used therapy program. Therefore, the purpose of this study is to determine if participants with normal auditory processing skills would improve after receiving the DAT when compared to a group of children with normal auditory processing skills who only received pre- and post-testing.

CHAPTER II

REVIEW OF LITERATURE

Anatomy

Peripheral auditory system

A brief discussion of the pathway of sound is included to give the reader an understanding of how the auditory system functions and to better understand where the break-down of sound may arise. Therefore, this discussion starts with the outer portion of the ear that collects sounds present in the environment. Air-bone acoustical waveforms are directed into the external auditory canal (ear canal) towards the tympanic membrane (eardrum). The accumulation of sound pressure in the external auditory canal results in the vibration of the tympanic membrane, thus changing the sound from an acoustical stimulus to a mechanical energy. The first in a series of three bones, the malleus is embedded within the tympanic membrane. The malleus is attached to the second middle ear bone, incus, by a double saddle joint. The third and final bone, stapes, attaches to the incus by way of the lenticular process and is firmly embedded within the oval window via the annular ligament. The three bones are collectively called the ossicles. A combination of the ossicles and tympanic membrane create a very efficient lever motion that helps the sound overcome the resistance that is met by the fluid in the inner ear. The movement of the stapes footplate in and out of the oval window changes the mechanical transmission of the sound into a hydrodynamic transmission and causes a ripple affect along the fluid in the inner ear. This ripple affect or traveling wave causes the basilar membrane to vibrate. The basilar membrane runs the entire length of the cochlea and supports a structure called the organ of Corti. The organ of Corti contains numerous supporting cells (i.e., Hensens' cells, Claudius' cells, inner/outer pillar cells, Deiters' cells) and four to five rows of hair cells (i.e., inner hair cells, outer hair cells). These hair cells within the organ of Corti are tonotopically arranged; the higher frequencies are located in the basal end of the cochlea and the low frequencies are located towards the apex. The vibration, as a result of the traveling wave, causes the hair cells to move and change shape resulting in a change of the hydrodynamic vibration into an electrochemical transmission of the sound. Once this occurs, this ends the peripheral portion of hearing and begins the central portion of hearing (Bhatnagar, 2002; Yost, 2007).

Central Auditory System

Due to the complexity of the central auditory nervous system (CANS), the functions of some of the neural sites (i.e., cochlear nucleus, superior olivary complex, lateral lemniscus, inferior colliculus, medial geniculate body) within the CANS are not fully understood; however, a great deal is known about the physical description of the structures and pathways. The CANS contains two of each neural site and only one receptive language center (Wernicke's area, Broadmann area 22), which is typically located in the left temporal lobe. The tonotopic arrangement seen in the cochlea continues to be present in the CANS. The CANS consist of tonotopically arranged nerve fibers and neural sites that analyzes and transfers the electrical signal thorough ipsilateral

The auditory nerve enters the brainstem at the level of the pontomedullary junction and finds itself at the first neural site, the cochlear nucleus. The cochlear nucleus maintains the tonotopic organization of the nerve and is divided into three sections, dorsal cochlear nucleus (DCN), anterioventral cochlear nucleus (AVCN), and posterioventral cochlear nucleus (PVCN). The function of the cochlear nucleus is unclear. However, it is speculated that the complexity of the cochlear nucleus is responsible for refining the sound as it leaves the peripheral auditory system (Yost, 2007). The nerve fibers leave the cochlear nucleus by way of ipsilateral and contralateral pathways. The ipsilateral pathway passes thorough the ipsilateral superior olivary nucleus and onto the ipsilateral lateral lemniscus. The contralateral pathway is the stronger of the two pathways and crosses the brainstem to the other side and connects to the contralateral superior olivary nucleus.

The superior olivary nucleus consists of several groups of nuclei, including the medial superior olivary nucleus (MSO), lateral superior olivary nucleus (LSO), and the medial nucleus of the trapezoid body (MNTB). The MNTB is responsible for sending the signal to the contralateral LSO. The functional roles of the MSO and LSO directly enable a person to locate the source of a sound by comparing time and intensity differences received from both ears (Bhatnagar, 2002).

The nerve fibers traveling from the ipsilateral cochlear nucleus and superior olivary nucleus form the lateral lemniscus which preserves the combined information from both ears. These culminations of fibers help protect the transfer of the signal from the affects of pathology and combine the information (i.e., spectral information and *interaural timing information) received concerning the stimulus in order to provide* processing of the sound in two or three dimensions (Yost, 2007).

The nerve fibers leave the brainstem arriving at the fourth neural site, inferior colliculus, located in the tegmentum of the pons. The inferior colliculus maintains the information received from the lateral lemniscus and communicates this information with other structures (i.e., superior colliculus, reticular formation, and cerebellum) to aid in reflexive movements of the eyes, head, and body toward the sound source.

The fiber tract continues to travel ipsilaterally to the fifth neural site, medial geniculate body, located in the thalamus where it serves as a relay station. Once the nerve fibers leave the thalamus, the signal is sent to the primary auditory cortex, Heschl's gyrus (Broadmann area 41). The primary auditory cortex is responsible for auditory discrimination and is the main site for auditory sensation and perception (Bhatnagar, 2002). The primary auditory cortex, located in each hemisphere, connects to the language association cortex, also known as Wernicke's area (Broadmann area 22). Wernicke's area is usually located in the left superior temporal gyrus and is responsible for recognizing, interpreting, and comprehending the auditory signal based on previous auditory memory, linguistic experiences, visual and somesthetic information (Bhatnagar, 2002). However, the pathway of the left ear takes a less direct route to the location of the language center than the right ear.

The brain is divided into two parts, left hemisphere and right hemisphere, which are connected and communicate with each other by a bundle of nerve fibers called the corpus callosum (Chermak & Musiek, 1997). Unlike the right ear, the nerve fibers for the left ear are located in the right hemisphere and cross the corpus callosum to the left the left ear are located in the right hemisphere and cross the corpus callosum to the left hemisphere where the language center is located (Bhatnagar, 2002; Keith, 1997). The corpus callosum does not reach full maturity until approximately age 12, which causes a longer transfer time of the stimuli (Chermak & Musiek, 1997). Due to this later maturation of the corpus callosum, the left ear transfer of auditory information is traditionally slower to reach the language center of the brain, thus resulting in decreased performance of the left ear. This longer transfer time enables the right ear to have an advantage over the left ear.

Diagnosing (C)APD

In order to assess the above anatomical structures, a battery of tests is administered in an attempt to identify the specific auditory processes affected. Therefore when an individual displays the symptoms of (C)APD as described in Chapter I, a comprehensive central auditory processing evaluation is performed. Originally, behavioral assessment procedures were developed to identify the presence and location of lesions within the CANS (Keith, 1999; Kimura, 1961). Kimura was one of the early pioneers to use an auditory processing test (i.e. Dichotic Digits) to localize lesions within the auditory system. She found that patients exhibited reduced scores in the ear contralateral to the temporal lobe ablation. Also, the ablation of the left temporal lobe affected the individual's ability to correctly identify the digits more than the ablation of the right temporal lobe. She concluded that the contralateral pathways of the right ear were far more efficient than that of the left ear due to the role of the left temporal lobe in the perception of spoken material. Therefore, many central auditory processing (CAP) tests originated from studies conducted on participants, with some form of brain lesion or ablation, where their responses to specific stimuli was analyzed and compared in relation to the location of the lesions present (Jerger, Weikers, Sharbrough, & Jerger, 1969; Kimura, 1961). Many of the tests used today are standardized and have norms for various age groups, specific to a particular area of dysfunction and may be sensitive to peripheral hearing losses. Therefore, it is important to be familiar with the limitations of each test and what specific location the test can assess.

Since the inventions of computed tomography (CT) scans and magnetic resonance imaging (MRI), CAP tests are seldom used to locate lesions within the CANS. Instead, CAP tests are now used to assess the function and abilities of the auditory system, especially since those individuals who have auditory deficits exhibit some of the same deficits as those with lesions, but without the lesions present. Assessing the function of the auditory system can be time consuming and costly. Therefore, screening procedures were developed to make the necessary referrals for a more comprehensive evaluation, expedite the assessment process, and control expense.

The Role of Screeners

According to Medwetsky (1994), a screening tool is used as an efficient way to identify those individuals who are at risk for a particular disorder. Questionnaires [e.g., Children's Auditory Processing Performance Scale (CHAPPS), Fisher's Auditory Problem Checklist,] and CAP screening tools [A Screening Test for Auditory Disorders (SCAN), Dichotic Digits] have been used to assess the auditory system of individuals who are suspected of having a (C)APD (Fisher, 1985; Jerger, Chimiel, Tonini, Murphy, & Kent, 1999; Smoski, 1990). When using a screening tool, one must take into account the sensitivity and specificity of the tool and the time and expensive of administering the tool versus a diagnostic approach (Medwetsky, 1994). The main goal of a screening tool is to identify those individuals who need further testing and make the necessary referral for a comprehensive evaluation.

Central Auditory Processing Evaluation

The beginning of any CAP evaluation should start with a comprehensive audiological case history to gain insight into the problems an individual may be experiencing, which ultimately guides the audiologist in the appropriate tests selection (ASHA, 1996, 2005; Chermak & Musiek, 1997; Jerger & Musiek, 2000; Keith, 1997, 1999; Musiek & Lamb, 1994). A peripheral hearing evaluation including pure-tones and speech testing is the second component of a CAP evaluation. In addition, electroacoustic procedures (i.e., otoacoustic emissions, tympanometry, acoustic reflex threshold, and acoustic reflex decay) can be used as objective measures (Jerger & Musiek, 2000; Mueller & Bright, 1994; Musiek & Lamb, 1994) in assessing a (C)APD.

Due to the complex nature of the auditory system, it is important to keep in mind that every individual is unique and a (C)APD can manifest differently from one individual to the next (ASHA, 2005). As was mentioned, (C)APD tests were originally designed to identify anatomical lesions. Therefore, the available test procedures assess different functions and anatomical locations. With this knowledge some researchers (ASHA, 1996; Jerger & Musiek, 2000; Keith, 1997; McFarland & Cacace, 1995; Musiek & Lamb, 1994; Parthasarathy, 2000; Stach, 2000; Willeford & Burleigh, 1985) have suggested a test battery approach is necessary for a thorough evaluation of the auditory system. This test battery approach should incorporate tests based on the complaints and symptoms of the individual.

Test Battery Approach

According to McFarland and Cacace (1995), a battery approach is necessary to help differentiate between a (C)APD and other system malfunctions that may exhibit the same symptoms. The same symptoms exhibited in a (C)APD, may also be seen in other disorders such as learning disorders, language impairments, ADHD, and Asperger's syndrome (ASHA, 2005). Keith (1999) postulates that it is often difficult to determine which process may be contributing to the deficits whether a (C)APD causes a language disorder or is a (C)APD the same as attention deficit disorder (ADD). Therefore, the test battery approach usually contains sensitized tests that assess all the aspects of a functioning auditory system to determine where the deficit lies (Jerger & Musiek, 2000; Keith, 1997, 1999). As recommended by ASHA (2005) and Keith (2000), the test battery should contain verbal or linguistic and nonlinguistic stimuli that assess each one of the skills necessary for a normal central auditory processing. Finally, a multidisciplinary approach is needed to assess an individual's speech, language and cognitive abilities to distinguish between a (C)APD and speech-language disorder (ASHA, 2005; friel-Patti, 1999; Jerger & Musiek, 2000; Musiek & Chermak, 2008).

When testing individuals who exhibit the symptoms of a (C)APD, it is essential to use a test battery that includes objective as well as subjective testing measures (Jerger & Musiek, 2000; Keith, 1997; Medwetsky, 1994; Musiek & Lamb, 1994). By including these measures, it increases the confidence in the clinical diagnosis of a (C)APD, especially when both objective and subjective tests used reveal the same results (Parthasarathy, 2000). Jerger et al. (1999) recommended including both objective and subjective approaches due to a 'check and balance' system. According to Jerger et al.

(1999), the purpose of their research was to support the idea that (C)APD truly exists and to help bring validity to some of those behavioral tests being used in diagnosing (C)APD by using electrophysiological measures and test subjects (i.e., fraternal twins) that reduce extraneous variables. Test subjects consisted of two 9 year old boys, fraternal twins, which were born 4 weeks prematurely. One of the boys had been diagnosed with (C)APD. The boy with (C)APD was labeled as experimental twin (ET) and the other boy had no symptoms of (C)APD and was labeled control twin (CT). According to Jerger et al. (1999), the ET was experiencing difficulty "processing spoken and written information and applying it to the task independently".

Prior to the study the ET had several evaluations that included a comprehensive audiological, cognitive, and linguistic evaluation. Initial testing for ET consisted of an evaluation conducted by a speech-language pathologist, which the Screening Test for Auditory Processing (SCAN) was given and resulted in within normal limits relative to the normative data. The ET was then referred for extensive audiological assessment, due to the parent's request, and given the SCAN, Staggered Spondaic Word (SSW) test, Rapidly Alternating Speech Perception (RASP), Willeford Battery, and the Phonemic Synthesis Test (PST). Two of the Four subtests on the SCAN revealed scores that were 2 standard deviations below the mean. The SSW and PST were abnormal while the RASP was within normal limits. ET returned for further testing three months later and was given a repeat of the SCAN, Dichotic Digits test, and Pitch Pattern Sequence test (PPST). The results revealed a normal SCAN and abnormal Dichotic Digits and PPST indicating difficulty with auditory memory and sequencing abilities.

During the study, both twins were administered a cognitive/linguistic evaluation [i.e., Wechsler Intelligence Scale for Children-III (WISC-III), Test Token for Children (TTC) with and without background noise, and Clinical Evaluation of Language Functions (CELF)], basic audiometry testing [i.e., air-conduction thresholds, word recognition scores, and sentences in competition (SSI), and immittance measures], an auditory brainstem response (ABR), and behavioral and electrophysiological responses to a dichotic stimuli. There were no remarkable differences between CT and ET when comparing basic audiometry testing, ABR, and TTC in quiet. However, there were significant differences in scores, with CT scoring better than ET, when comparing WISC-III, CELF, TTC with noise, and behavioral and electrophysiological responses to dichotic stimuli.

Often times the SCAN is used to screen children that are suspected of a (C)APD to determine if further testing is warranted. In this study, it was proven that by using only one tool to assess (C)APD, rather than a test battery, it decreased the chances of identifying a child with (C)APD. This study also revealed that (C)APD can occur with both cognitive and language deficits. Because there were measurable differences between the ET's ears during the behavioral and electrophysiological responses to dichotic stimuli, this proves that (C)APD can be differentiated from cognitive and language disorders. Even though electrophysiological measures can sometimes be cumbersome, it is important to help identify those individuals who fall victim to (C)APD.

It is equally important to use a test battery that targets the individual's complaints and includes cognitive and linguistic measures in identifying a child with (C)APD. As discussed earlier, it is also important to add objective measures to the test battery to ensure confidence in the clinical diagnosis of a (C)APD.

Objective Measures

The use of electrophysiological measures and clinical observations as well as behavioral tests should be used in diagnosing a (C)APD (friel-Patti, 1999; Jerger & Musiek, 2000; Keith, 1997). The electrophysiological measures provide information on the integrity of the brainstem and central auditory pathways. However, due to the high cost (i.e., equipment, maintaining equipment, and the actual test) and length of testing, certain electrophysiological (i.e., ABR, MLR, LLR, and P300) and imaging measures (i.e., CT and MRI) are typically avoided. There are some less expensive and time efficient objective measures that could be used such as otoacoustic emissions (OAEs) and acoustic reflex (AR) thresholds and acoustic reflex decay. However, these two measures provide information on cochlear function and the integrity of the low brainstem, but not the cortical areas of the brain. Therefore, many behavioral measurements are used to assess hemispheric, inter-hemispheric and cortical areas of the brain.

Behavioral Measures

According to Mueller and Bright (1994), there are three factors that should be considered when choosing a CAP test (1) sensitivity/specificity of the test, (2) the mode of delivery (i.e., monotic, diotic, or dichotic), and (3) difficulty of the test. The degree of redundancy (i.e., extrinsic and intrinsic) will determine the sensitivity and specificity of a given CAP tests. Extrinsic redundancy refers to the amount of overlapping cues in

Intrinsic redundancy refers to the multiplication of neural pathways within the auditory system and sources of information (i.e. memory) for processing speech (Mueller & Bright, 1994). If either one is reduced, a normal hearing individual with a normal auditory system is able to compensate and understand the stimuli (Stach, 2000). However, if both are reduced, abnormal performance will be seen. Therefore, many CAP tests are designed to reflect a decrease in extrinsic redundancy in order to assess the CANS (i.e., intrinsic redundancy). In order to evaluate the CANS, many researchers (Keith, 1997; Stach, 2000) suggest using sensitized speech material. Sensitized speech tests include removing high frequencies or low-pass filtering removing segments to increase speech rate, speech presented at a high intensity, speech presented in background noise or competing speech, and presenting different but similar signals to both ear simultaneously. When using sensitized speech, individuals with a (C)APD, perform poorer than those with normal auditory processing abilities.

Sensitized speech can be delivered in one of three modes: monotically, diotically (binaural), and dichotically. Monotic occurs when the stimulus is presented to just one ear and is usually used to measure asymmetries between the two ears. Diotic (binaural) presents an identical stimulus to both ears at the same time. This mode of delivery is sensitive to timing and/or intensity differences. The last mode of delivery is the dichotic mode. The dichotic mode presents two different stimuli, one to each ear simultaneously. According to Keith (1997), this mode is used to determine the maturation of the auditory system, the hemisphere that is dominant for language, the ability of the auditory system to access short-term memory storage and retrieval, and identify cortical areas of dysfunction.

In selecting a test, the easier the tests, the less it taxes the CANS. Some audiologists favor certain CAP tests based on the ease of administering the test (i.e., materials used, set-up, easy instructions, and interpretation), amount of time it takes to complete the tests, and remediation suggestions [i.e., Staggered Spondaic Word (*SSW*) Test]. Some CAP tests can alter the difficulty level of a test by controlling the individual's response mode. Often times, the individual is instructed to give a response using free recall or directed ear approach. A free recall approach is when the individual repeats what is heard regardless of order in which the stimuli were presented. A directed ear approach requires the individual to recall what was heard in a particular order (e.g., repeat the word heard in the right ear first). After considering these factors, three CAP tests (i.e., *SSW*, *SCAN-C/A*, and *Dichotic Digits*) are highlighted especially since they are of particular interest in this research.

CAP Tests

One of the early and most widely used test of today is the *SSW*. According to Katz and Ivey (1994), the *SSW* has remained one of the most widely used test because it is (1) resistant to peripheral hearing distortions, (2) able to be used on a variety of patient populations such as the disabled and some patients with neurological deficits (i.e., Alzheimer's disease), (3) normalized for ages 5 to 70 years old, (4) reliable and valid, and (5) very cost effective. The *SSW* was designed by Jack Katz in 1962 and was initially used for the sole purpose of identifying and locating the site of dysfunction with individuals who were suspected of brain or brainstem lesions. The *SSW* is a dichotic test and is considered a binaural integration test that is very sensitive to cortical/hemispheric, interhemispheric, and brainstem lesions (Musiek & Pinheiro, 1985). Binaural integration presented to both ears. The *SSW* can be administered in approximately 20 minutes and analyzes each ear separately in a normal and difficult listening condition. The *SSW* is a semi-dichotic presentation of overlapping spondees (second portion of the first spondee and the first word of the second spondee are given at the same time). The *SSW* has four testing conditions: right competing (RC), right non-competing (RNC), left competing (LC) and left non-competing (LNC). The participants are asked to repeat all words heard. The total number of errors are calculated and scored by using the Number of Error (NOE) Analysis. The scores obtained for all four conditions include the total number of errors, as well as any qualifiers or reversals, are compared to the normative data provided in the test manual (Katz, 1998). According to Katz and Ivey (1994), the *SSW* categories auditory processing dysfunctions into four categories that help contribute in the management of a (C)APD. The four categories are decoding, tolerance-fading memory, integration, and organization. Individuals with decoding problems exhibit poor phonic skills, receptive language, and articulation difficulties. Those individuals who display difficulties blocking out background sounds and short-term memory problems are often labeled as having tolerance-fading memory issues. Tolerance-fading memory can lead to poor reading comprehension and expressive difficulties in speaking and writing such as poor handwriting. The integration category contains two types of individuals. The first type exhibit poor phonics and are often labeled as dyslexic. The second type fails to follow directions in a consistent manner. Lastly, the organizational category contains individuals who tend to be disorganized and poor spellers.

Similar to the *SSW*, the *SCAN-A*: A Screening Test for Auditory Processing Disorders in Adolescents and Adults (*SCAN-A*; Keith, 2000) and the *SCAN-C*: A Screening Test For Auditory Processing Disorders in Children (*SCAN-C*; Keith, 2000) can be administered in approximately 20 minutes and contains binaural integration task. It also contains binaural separation tasks that require the individual to respond to only the stimulus presented to a designated ear while ignoring the stimulus in the other ear. Both the *SCAN-A* and *SCAN-C* consists of four subtests (e.g., filtered words, auditory figure ground, competing words, and competing sentences) that measures an individual's ability to understand a speech signal that has been distorted, understand a speech signal in the presence of background noise, recognize a word when two words are given simultaneously, and recall sentences presented to one ear while ignoring the sentence presented to the other ear. Another binaural integration task is the *Dichotic Digit* test.

Lastly, the *Single Dichotic Digit* (*SDD)* test is a random presentation of two numbers (e.g., 8 in the right ear and 2 in the left ear) and the *Double Dichotic Digit* (*DDD*) test contains four numbers (e.g., 4, 8 in the right and 3, 9 in the left), both ranging from 1 to 9, excluding 7, that are given simultaneously to each ear. A total of 25 presentations are given to each ear. The *SDD* test is administered to children who are eight years and younger. The *DDD* test is administered to children and adults starting with children who are nine years old. The individuals repeat the numbers heard in a free recall mode. The total number of errors is calculated and yields the total percent correct for each ear. A total percent of at least eighty is considered to be normal. According to

Musiek & Pinheiro (1985), dichotic digit tests are sensitive to brainstem lesions, cortical/hemispheric, and interhemispheric disorders. Often times, a right ear advantage can be seen when administering these CAP tests.

Right Ear Advantage

A right ear advantage (REA) is common for children before the age of 11. By age 11, children should perform more adult-like on the dichotic tests (e.g., digits, competing words and sentences, and consonant vowels [CV]). According to Moncrieff and Musiek (2002), a child that exhibits a significantly larger REA with very poor left ear performance or a REA after age 11 is suspected of a (C)APD. Moncrieff and Musiek (2002) hypothesized that both groups (i.e., dyslexic/experimental group, non-dyslexic/control group) would exhibit left hemispheric dominance for language and a REA, but children with dyslexia may present an even larger REA on the dichotic tests (e.g., digits, competing words, and CV) than normal children.

In their study, twenty 11 year old children (14 males and 6 females) who met the following criteria participated: an IQ of at least 85, strongly right handed, native English speakers, normal hearing sensitivity, and normal middle ear function bilaterally. The participants were separated into two groups. The experimental group consisted of 7 males and 3 females who were diagnosed as dyslexic; a dyslexic diagnosis was based on school history of reading difficulty and test results that showed below normal on phonological awareness and reading ability. The control group consisted of 7 males and 3 females that were in age appropriate grades and performing at age appropriate levels with no known diagnosis of dyslexia, attention deficit disorder with or without hyperactivity, mental disorders, or neurological disorders.

Each listener participated in four experimental conditions (e.g., dichotic digit free recall, dichotic digit directed response, competing words directed response, and dichotic CV free recall) given at 50 dB SL. For the free recall response, the participant was able to repeat the numbers/words in any order. In the directed response, the participant responds in a manner that is directed by the tester.

The results of the study indicated that when trying to determine hemispheric dominance for language, it is better to use the directed response condition rather than the free recall condition. The directed response condition is less influenced by attentional bias when compared to the free recall condition. In the free recall condition, participants were more adapt to choose the response that is the easiest or the most difficult.

Therefore, it is more reliable to use the directed response condition when given dichotic tests. The competing words test, using the directed response conditions, was the only test where the group with dyslexia had an excessive large REA over the control group suggesting that the competing words test is more susceptible to REA as opposed to the other tests (i.e., dichotic digits, consonant vowels [CV]) used in the study.

Plasticity

Plasticity can be defined as the ability of neurons to alter their structure and function due to experiences or learning new behaviors (Kleim & Jones, 2008). The ASHA Task Force on Central Auditory Processing Development (1996) agrees that plasticity can be observed when neural pathways are forced to reorganize or modify itself due to pathology/lesions, deprivation, maturation, experience, learning, or habilitation;

however, what happens to the neurons themselves remains a mystery. Menning, Roberts, and Pantev (2000) suggested that plastic changes that occur as the result of practice or experience may be an increase in neuronal firing ratio or the synchronizational firing of neurons.

According to Aoki & Siekevitz (1988), the brain's structure and function remain plastic for some time after birth. Experiences reinforce certain neural pathways, but when those experiences are no longer present those pathways tend to degenerate. Aoki & Siekevitz (1988) attempted to compare the brain to a highway system, suggesting that if neural pathways are not used they become abandoned and popular pathways or new pathways are developed. Although the focus of Aoki and Siekevitz (1988) study was based on the cats' visual system and not the auditory system, this research represents what happens to neurons when they are deprived of stimulation. Their research revealed that restrictions or limited experiences, determined the plastic ability of neurons. They also suggested that there may be a critical window in which to gain or regain neuronal activity. This critical window was explored in a research study, conducted by Sharma, Spahr, Dorman and Todd in 2002, involving prelinguistic children who were implanted with a cochlear implant prior to 3.5 years of age. Their research suggested that the central auditory pathways begin to develop normally and remain minimally degenerative up to 2-3 years after deprivation occurs.

Therefore, if a child is implanted within 3 to 4 years of life their central auditory pathways develop normally. For these very reasons, it is imperative to identify and test those individuals exhibiting the signs and symptoms of a (C)APD early to help alleviate the impact a (C)APD can have on the lives of those individuals by providing therapy.

Treatment for (C)APD

The treatment/management of a (C)APD is based on the cumulative test results as determined by the audiological tests and CAP evaluation, case history, and other speech and language tests. Habilitation can focus on improving those skills and alleviating the impact of these deficits (ASHA, 2005). There are some forms of remediation therapy/strategies that include auditory training, compensatory strategies training, and environmental modifications (ASHA, 2005; Chermak & Musiek, 1992; Keith, 1997). According to Chermak and Musiek (1992), some individuals with (C)APD may need to use a combination of the above therapies/strategies listed to help interpret the receiving message.

Compensatory Strategies Training

Compensatory strategy training reduces the effects of (C)APD by enhancing listening, communication, social and learning outcomes through the use of metalinguistic and metacognitive strategies (ASHA, 2005; Chermak & Musiek, 1992). Metalinguistic strategies concentrate on building context vocabulary, phonological awareness, and semantic network expansion, while metacognitive strategies rely on improving self instruction, cognitive problem solving, and assertiveness training (ASHA, 2005). Both of which are equally important in improving an individual's sense of self-efficacy and motivation.

Environmental Modifications

According to ASHA (2005), environmental modifications consists of increasing the intensity of the signal compared to the surrounding noise (i.e., increasing the signal-to-noise ratio) through the use of assistive listening systems; change positions of the listener in relation to the acoustic signal (i.e., preferential seating), use of visual aids; reduce competing signals and reverberation time (i.e., using curtains, carpet, acoustic dividers or changing location); and advising speakers to speak more slowly, pause more often, and emphasize key words (Chermak & Musiek, 1992). One or a combination of these remediation strategies can be used to facilitate communication for individuals with (C)APD.

Auditory Training

The goal of auditory training is to target, reduce or eliminate the auditory behavior that is contributing to the (C)APD (ASHA, 2005). According to ASHA (2005), auditory training programs may contain activities that center on intensity, frequency, and duration discrimination; phoneme discrimination and phoneme-to-grapheme skills; temporal gap discrimination; temporal ordering or sequencing; pattern recognition; localization/lateralization; and recognition of auditory information presented within a background of noise or competition.

Auditory Training and Plasticity

According to Kujala, Karma, Ceponiene, Belitz, Turkkila, Tervaniemi, and Näätänen (2001), signs of plasticity were observed when comparing participants' pre electrophysiological measurements [i.e. mismatch negativity (MMN)] to their post electrophysiological measurements after undergoing treatment for dyslexia. The MMN is a recording of neural activity in response to an auditory stimulus in which the amplitude and latency of the recording is measured. The results indicated that the post MMN latency was shorter for the experimental group than for the control group. In addition, the post MMN amplitude for the experimental group was greater when compared to the control group and the pre MMN amplitude of the experimental group, suggesting that the changes were a direct result of the therapy.

According to Kujala et al. (2001), the effectiveness of their training not only supported the idea that rehabilitation leads to neural plasticity, but it also supported the idea that immature brains are more susceptible to plastic changes than mature brains. The brain continues to grow and change after birth (i.e., mature) and is modified by experiences, but if the experiences are restricted in some way deprivation occurs.

As mentioned earlier, children that are approximately 11 years of age and younger tend to exhibit weaker performances for the left ear than the right ear. English, Martonik, and Moir (2003) hypothesized that using auditory training to exercise the left ear would strengthen the ear's pathway, thus increasing the use of the left ear and resulting in an increase in myelinization along the auditory pathway which increases the neural firing of the nerves that affects the transfer of the stimuli.

The study was divided into two experiments. Experiment one consisted of ten children, age 5 years 10 months to 10 years 9 months, with reduced scores on the *Dichotic Digit* (*DD*) Test – Double Pairs for one or both ears, normal hearing sensitivity and normal middle ear function bilaterally. All of the children in experiment one exhibited at least two or more auditory processing problems (i.e., dichotic listening, auditory discrimination, auditory sequential memory, and temporal resolution) and 6 of the 10 children displayed atypical language development. Therefore, the experimental treatment and other auditory training exercises, although not named, were administered.

The experimental treatment consisted of listening to a chapter audio book (*Arthur's Chapter Books*, Vol. 1) in the left ear only and answering questions every two minutes that pertained to the story to ensure the child was paying attention to the story. The experimental sessions took place one hour per week for 10 to 13 weeks. During the 5th to 7th week, the *DD* test was re-administered and if yielded normal results the experimental treatment was stopped and the child resumed other auditory training exercises. The *DD* test was administered a third time, four to six weeks after the child reached appropriate norms to determine if the experimental treatment had lasting effects.

Since the children in experiment one received the experimental treatment and other auditory training, a second experiment was conducted using only the experimental treatment. Therefore, an eleventh child was recruited with a reduced score for the left ear on the *DD* test. However, it was not determined if this eleventh child had other auditory processing problems or language deficits, despite several attempts. The same materials and procedures that were used for experiment one were used for experiment two. However, the only exception was the experimental treatment was given in eight 20 minute sessions.

For all but one child, post-test data for experiment one showed an improvement on the *DD* test. Specifically, these participants were within normal limits for their age and remained stable four to six weeks after the experiment. Likewise, post-test data obtained for experiment two showed improvement, stability, and age appropriate norms for the *DD* test and revealed that the experimental treatment worked by increasing the performance of the left ear on the *DD* test.

Tremblay and Kraus (2002) stated that, "changes in neural activity can precede behavioral learning" (p. 564). In addition, they state the neural activity that has been induced by auditory training will be greater in the left hemisphere than the right hemisphere and provide early detection of learning. According to Tremblay and Kraus (2002), mis-match negativity (MMN) evaluates the discrimination processes without the subject having to pay attention to the stimuli. Unlike the MMN, the N1-P2 complex evaluates the encoding of a stimulus and speech detection. Therefore, the purpose of this research article was to determine if auditory training has the same affect on N1-P2 as it does on MMN.

Seven participants, (4 men, 3 women), ranging in age from 21 to 31 years old were used for this study. The stimuli used for this study consisted of voice-onset-times (VOTs) that varied +/- 50 ms in 10 ms steps for a constant duration of 180 ms. According to Tremblay and Kraus (2002), for a burst (centered at 2500-4000 Hz) to be simulated, a turbulent noise source 10 ms in duration and 60 dB in amplitude must be added to the VOT. The study lasted approximately ten days and included VOT training in which the participants were trained to differentiate between -20 ms and -10 ms. Each day after therapy, the participant's ability to identify the stimulus was tested. A pre- and post-test, consisting of behavioral and electrophysiological measures, was given to determine the effects of the training on the VOTs.

Tremblay and Kraus (2002) reported that the results of N1 and P2 amplitude increased and P1 decreased during VOT, indicating that the participants realized that the /ba/ had important temporal cues. Therefore, the onset of voicing triggered changes in neural activity.

Commercial Training Programs

According to Hayes, Warrier, Nicol, Zecker, and Kraus (2003), children that have reading problems tend to have difficulty understanding speech sounds at the phonemic level and greater difficulty in noise than quiet. Earobics is an example of a commercially available auditory training program available today. According to Hayes et al. (2003), Earobics provides training on "phonological awareness, auditory processing and language processing skills through interactive games" (p. 675). This study attempted to identify the effects that Earobics has on the plasticity of cortical and subcortical pathways. In order to determine this, auditory pathway neurophysiology was examined for all participants prior to the study and at the end of the study regardless if treatment was received. Hayes et al. (2003) hypothesized that Earobics would produce an increase in waveform morphology when using cortical speech-evoked stimuli in quiet resulting in cortical responses that are less affected by background noise. Also, the training would not affect the responses required by the brainstem.

A total of 49 children between the ages of 8 and 12 were used for this study. The study consisted of three groups (LP-trained, LP-control, and NL-control). The LP-trained group was consisted of children that had a learning problem and received the experimental treatment (i.e., Earobics). The LP-control group consisted of children that had a learning deficit but did not receive the experimental treatment. The NL-control group consisted of children without a learning deficit and did not receive the experimental treatment. According to Hayes et al. (2003), the LP-trained group were administered the Earobics program with each session lasting 35 to 40 minutes over an 8 week span. Pretesting was conducted 6 months before training started and post-testing 3 months after training started.

The phonemes /da/ and /ga/ were used as the stimuli for collecting neuro-physiologic data. According to Hayes and colleagues (2003), these phonemes were chosen because they are difficult for LP children to differentiate, but not for NL children. The stimuli (/da/ and /ga/) were recorded on a compact disc (CD) with the presence of noise at a signal to noise ratio (SNR) of 0 dB. The auditory brainstem response test was performed using a click (0.1 ms) presented at 80 decibels (dB) sound pressure level (SPL), and randomly presenting alternating polarities of /da/ at a sampling rate of 20,000 Hz. While using this stimulus, the participant watched a movie with the volume setting below 40 dB SPL to help the participant ignore the incoming stimulus. A cortical response in quiet was elicited by using the /ga/ stimulus presented at 75 dB, while monitoring the peaks of the waveform (i.e., P1 and N2). A cortical response in quiet and in noise was elicited by using the /da/ stimulus presented at 80 dB SPL, while monitoring the P2 and N2 peaks.

According to Hayes et al. (2003), the results revealed that there were no significant differences between the groups when comparing pre- and post-testing for the auditory brainstem response test that used a click with alternating /da/ and /da/ in quiet. However, there was a significant change for the LP-trained group when comparing pre- and post-testing for /ga/ in quiet and the /da/ in noise. According to Hayes et al. (2003), these results indicated plasticity at different levels of the auditory system. The participants that originally had delayed responses in the brainstem, exhibited the greatest improvement in the cortical representation of speech sounds in noise (Hayes et al., 2003).

This indicates that these participants benefited from Earobics training. Auditory training has shown plastic changes in neuronal activity at the cortical level, but little is known of the plastic changes within the human auditory brainstem in response to auditory training.

A similar study conducted by Russo, Nicol, Zecker, Hayes, and Kraus (2005), used neurophysiological testing to examine plasticity at the level of the brainstem in response to receiving auditory training and determine if the neural timing to a sound increased after receiving auditory training (i.e., Earobics). Also, the ability of the brainstem to sustain these plastic changes over time was evaluated.

The inclusion criteria for the study included (1) 8-12 years of age, (2) native English speakers, (3) normal IQ (i.e., $\geq$ 85 on Brief Cognitive scale or Test of Nonverbal Intelligence), normal hearing sensitivity (i.e., =/$\leq$ 20 dB HL for 500 to 4000 Hz). The experimental group consisted of 9 learning disabled (LD) children that received 8 weeks of 35-40 independently supervised one-hour sessions of Earobics. The control group did not receive Earobics and was consisted of 5 children with normal learning and 5 children with a learning disability. The experimental group received pre- and post-testing that was given prior to the experimental treatment and within three months following the completion of the training program, which consisted of auditory neurophysiological and perceptual/cognitive testing. The control group received the same pre- and post-testing at similar time intervals.

The speech stimulus /da/, in quiet and in background noise (Gaussian background noise) at a +5 dB SNR, was administered at 80 dB SPL to elicit an auditory brainstem response in the test ear while the child watched and listened to a video of their choosing in the non-test ear at less than 40 dB SPL. The onset (i.e., transient) and the frequency-following response (FFR) (i.e., sustained) are two components of the brainstems response to speech sound and are used to transient and sustained components of this response were used to analyze subcortical areas of the brain. The consonants in speech are considered transient components and are easily affected by noise. The sustained component is usually much larger than the transient component of the wave and is caused by the vowels in speech which are not as affected by noise. The same stimulus was used with a 0 dB SNR to record a cortical response. As in Hayes et al. (2003), this study also monitored the cortical response by analyzing the peaks of P2N2.

The pre- and post-measures of the control group revealed that the responses to the /da/ stimulus did not change over time resulting in stability of the brainstem response. When comparing the experimental group to the control group, the experimental group revealed significant improvement on the perceptual/cognitive test. However, with the exception of the Listening Comprehension test, the other perceptual/cognitive tests used could not be linked to changes in the brainstem. Russo et al. (2005) postulated that the correlation between the improved Listening Comprehension test and the decrease in amplitude for the FFR in noise for the experimental group was directly related to the changes in brainstem response in noise. The pre- and post-neurophysiological results revealed that there was no change or difference for the first 11 milliseconds post stimulus for either of the two groups. However, there were changes of the neural coding for the experimental group that was observed 12-40 milliseconds post-stimulus. Russo and colleagues postulated that these changes within this time frame was a direct result of plasticity occurring within the inferior colliculus (IC) and sites immediately peripheral to the IC. Also, the neurophysiological results revealed quiet-to-noise inter-response correlations of the FFR increased, suggesting that the experimental group's neural coding ability of the stimulus became less affected by noise following training. Russo and his fellow colleagues suggested that auditory training improves neural synchrony within the brainstem resulting in the enhancement of the cortical response.

Auditory Training and Dichotic Listening

According to Katz, Chertoff, and Sawusch (1984), children with central auditory processing (CAP) difficulties often do poorly with dichotic listening skills. Dichotic listening tests are often used in determining hemispheric dominance for language and ear advantage. Binaural integration and binaural separation are two dichotic listening tasks being assessed when using dichotic speech testing. A binaural integration task (i.e., dichotic digits, *SSW*) assesses an individual's ability to recall the stimuli presented to both ears. A binaural separation task (i.e., competing sentences) assesses an individual's ability to recall the stimulus presented to a designated ear while ignoring the stimulus that is presented to the other ear. According Musiek and Pinheiro (1985), these tasks are sensitive to brainstem lesions and hemispheric/cortical lesions.

In Katz et al. (1984), ten children, age 7 years 11 months to 10 years 11 months, diagnosed with learning disabilities and problems with CAP difficulties served as the participants for this study. The participants were separated into two groups. The experimental group consisted of 4 males and 1 female and the control group consisted of 5 males. The experimental group received the experimental treatment and the control group did not receive the experimental treatment, but continued to receive any regular or special services that they were already receiving at school. All participants were administered a battery of pretest and posttest that included pure tone air conduction, word discrimination scores, speech-in-noise discrimination (S-in-Noise), Staggered Spondaic Word (*SSW*) test, Phonemic Synthesis (PS), and Staggered Dichotic Digit (SDD) test.

The SDD was a test generated for this study. The test consisted of 80 items with numbers from 1 through 10 (excluding number 7) that was recorded on audiotape in a staggered dichotic format with varying offset conditions in a particular order (i.e., 0, 500, 400, 300, 200, 100, 0, and 200 milliseconds). The level of difficulty increased as the varying offset conditions decreased from 500 to 0 milliseconds. This staggered dichotic format delivered a pair of digits to each ear with the second digit of the right ear given at the same time as the first digit of the left ear and vice versa. The stimuli for the experimental treatment (dichotic offset training [DOT]) consisted of 125 items that were developed and presented in the same staggered dichotic format with varying offset conditions as the SDD. The DOT was given in 1 hour sessions twice a week for 8 weeks starting with the easiest varying offset condition (i.e., 500 milliseconds). Although in some cases, it took 13 weeks. The control group did not receive the treatment, but did continue to receive speech services. Both groups were administered the posttest at the end of the eighth week.

According to Katz et al. (1984), the DOT indicated there was significant improvement from sessions 5 to 15 when compared to the pre-therapy baseline for the experimental group. The SDD pretest and posttest revealed a significant decrease in error rate with the experimental group, while the control group showed no change. Using the Mann-Whitney U statistical analysis, the experimental group scores on the *SSW*, S-in-N, and PS showed no significant improvement between pretest and posttest. However, there was an improvement in the scores on the SSW and S-in-N when comparing the total mean score.

Since the experimental group increased in performance from pre- to post-testing on the SDD, while the control group remained approximately the same, the researchers suggested that this increase in performance was due to the experimental treatment. Especially since the DOT material was an extension of the SDD. Although there were no statistically significant difference on the other pre- and post-test (i.e., SSW and S-in-N), there was still improvement after the experimental treatment. These results indicate that the DOT treatment works and can help individuals with CAP problems.

A similar study, conducted by Stephenson (2008), used an auditory training program [i.e., Dichotic Auditory Training (DAT)] with the goal of strengthening the auditory system of those individuals who were suspected of having a (C)APD. The DAT was given two days a week for four weeks and was comprised of 96 exercises with each exercise containing twenty dichotic presentations presented at different interaural timing differences (i.e., R300, L300, R150, L150, 0). The DAT consisted of professionally recorded words, Northwestern University Test #6, in which the carrier phrase "are you ready" was removed leaving the monosyllabic word in tact and copied onto the Sound Forge program. The stimulus R150, with R meaning right ear, the word for the right ear was presented 150 milliseconds sooner than the word for the left ear.

The study consisted of 8 participants, whose first language is English, between the ages of 7-12 years old, with normal peripheral hearing and previously identified as having (C)APD. These participants were administered pre- and post-testing that consisted of the *SSW*, *SCAN-C/A*, and DAT testing. The DAT testing [i.e., Baseline DAT (pre-test) and Post-DAT (post-test)] consisted of 50 pairs of NU-6 words, manipulated and pre-recorded in the same manner as the DAT, that were randomly presented with varying timing differences (i.e., R300, L300, R150, L150, and 0) in order to assess the participant's ability to distinguish between words.

The results of this study yielded statistically significant differences for the DAT conditions: R300, R150, 0, overall DAT score. According to Stephenson (2008), based on these results, it can be assumed that the DAT did improve the dichotic listening skills for these participants resulting in plastic changes within the central auditory system. For the *SSW*, the total errors and left competing (LC) conditions were found to be significant as well. There were no statistically significant differences observed with the *SCAN-C/A*. However, an effect size was observed for some of the conditions (i.e., DAT-150, DAT-L300, *SSW*-RNC, *SSW*-RC, *SSW*-LNC, *SCAN-C/A*-Auditory Figure Ground Left subtest, and *SCAN-C/A*-Competing Words Left subtest), suggesting that there was improvement between pre- and post-test scores. However, Stephenson (2008) postulated that these changes could become significant if more focus was directed toward those conditions that had an effect size.

It was the intention of myself to determine if the DAT is effective in improving dichotic listening performance in participants who did not have a (C)APD. Performance, both before and after the training period, was assessed to determine if there were any statistically significant differences within the participants and between the group that received the DAT and the group that did not receive the DAT. The hypothesis of this study was that a significant improvement in the dichotic performance would be measured within the participants and the group that received the DAT as opposed to the participants that did not receive the DAT.

CHAPTER III

METHODS AND PROCEDURES

Participants

Fourteen children, age 6:0 to 15:11 years, participated in this study. The inclusion criteria included: (1) native speakers of English, (2) normal binaural hearing thresholds ($\leq$ 20 dB hearing level [HL] for octave frequencies from 250 to 8000 Hz), normal middle ear functioning (middle ear pressure =/< -150 daPa and =/> +50 daPa with static compliance measures of $\leq$ .2 mmho or patent pressure equalizing tubes), and (3) no known cognitive, neurological, or learning deficits as reported by the participant's parent or guardian, and (4) no more than 1 condition on the *SCAN-C/A* or *SSW* being greater than one standard deviation below the mean for their chronological age. Participants who were found to have a hearing loss or an auditory processing disorder were not included in this study and appropriate referrals made. All participants, who met the above criteria, were assigned to one of two groups by convenience sampling. The experimental group (N = 6) received the experimental treatment for four weeks while the control group (N = 8) did not receive the experimental treatment. Participants were recruited through the Louisiana Tech University Speech and Hearing Center, friends and faculty via phone and personal contact.

Instrumentation & Procedures

Prior to assessment, participant's parents completed a case history form (Appendix A) signed a release form (Appendix B) and one of two consent forms based group placement. The release form gave the experimenter permission to review the participant's record and to make contact with them regarding inclusion into the study. Consent form A (Appendix C) was used for those participants who received the experimental treatment and consent form B (Appendix D) was used for those participants who received only pre- and post-testing. During pre-testing each participant received an audiological evaluation (i.e., otoscopy, impedence testing [tympanometry and acoustic reflexes], speech reception threshold, word recognition and pure tone audiometry) and a battery of tests (i.e., *SSW* and *SCAN-A/C*) to ensure normal hearing sensitivity and age appropriate central auditory processing skills. A sub-group consisting of 3 participants from the experimental group and 6 participants from the control group also received the *Dichotic Digits* test (DD; Musiek & Guerkink, 1982) to assess the auditory system using a measure with reduced linguistic content. All participants received the dichotic auditory training (DAT) pre-test (Appendix E) and post-test (Appendix F). See Stephenson (2008), for a detailed explanation on the development of the stimuli.

Instrumentation

The audiological exam included an otoscopic examination that was performed using a Welch Allen otoscope. Impedence testing (Tympstar, Serial # AL051305), calibrated to ANSI standards S3.6-1969 and S3.39-1987, was performed to evaluate middle ear status. Pure tone hearing thresholds (i.e., 250 – 8000 Hz), speech reception thresholds (SRTs), and word recognition testing were obtained using a Grason-Stadler

GSI-61 audiometer (Med-Acoustics, Stone Mountain, GA) calibrated to ANSI standard S3.6-1996 with EARTone 3A insert earphones (Med-Acoustics, Stone Mountain, GA) in a sound-treated booth (IAC; 9'3" by 9'7") with acceptable ambient noise levels (ANSI, S3. 1- 1991). The results for the audiological evaluation were recorded on an audiogram (Appendix G).

Auditory Processing Tests

Using a calibrated Grason-Stadler GSI-61 audiometer (Med-Acoustics, Stone Mountain, GA) and sound treated booth, the following auditory processing tests were administered to all listeners: *SCAN-A*: A Screening Test for Auditory Processing Disorders in Adolescents and Adults, (*SCAN-A*; Keith, 2000), *SCAN-C*: A Screening Test For Auditory Processing Disorders in Children (*SCAN-C*; Keith, 2000), and the *Staggered Spondaic Words* test (*SSW*; Katz, 1998). A sub-group consisting of three participants from the experimental group and six participants from the control group received the *Single Dichotic Digits* test (*SDD*; Musiek & Guerkink, 1982) or the *Double Dichotic Digits* test (*DDD*; Musiek, F., 1983) depending on the participant's age (i.e., less than 8 years of age received the *SDD*, 9 years of age and older received the *DDD*). With the exception of the *SSW*, all stimuli were delivered through a compact disk player (Tascam CD-160, Serial # 0231289) routed through a clinical audiometer (GSI-61, Serial # AA063067) to EARTone 3A insert earphones (Med-Acoustics, Stone Mountain, GA). The *SSW* was delivered through a cassette player (Yamaha Kx-930, Serial # M090290VX) routed through the same audiometer and inserts. The *SCAN-C/A*, *SSW*, *Single Dichotic Digits*, and *Double Dichotic Digits* were administered and scored according to test protocols.

SCAN-C/A Test. The *SCAN-C/A* test consisted of four subtests (e.g., filtered words, auditory figure ground, competing words, and competing sentences). Specifically, the filtered words subtest consisted of 40 monosyllabic words, 20 for the right ear and 20 for the left ear, which have been low-pass filtered. Filtered words measure the participant's ability to understand a speech signal that has been distorted by applying a 1000 Hz low pass filter to the words presented for the *SCAN-C* and a 750 Hz low pass filter to the words presented for the *SCAN-A*. The auditory figure ground subtest is presented in the presence of a +8 dB signal-to-noise ratio for the *SCAN-C* and a +4 dB signal-to-noise ratio for the *SCAN-A* with the noise consisting of a multi-talker babble and the signal comprised of 40 monosyllabic words, 20 for the right ear and 20 for the left ear. The auditory figure ground subtest measures the participant's ability to understand speech in the presence of background noise. The competing words subtest consists of 60 monosyllabic words, 30 given to the right ear and 30 given to the left ear and attempts to measure the participant's ability to recognize a word when two words are given simultaneously, one word to each ear. The competing sentence subtest consists of 40 sentences given in pairs simultaneous with an offset time of less than 10 milliseconds. The competing sentence subtest assesses the participant's ability to recall sentences presented to one ear while ignoring the sentence presented to the other ear. In order for a participant to be considered normal, the standard score for each subtest and total test standard score, which is the calculated score for the sum of the standard scores for all the subtests, could not be more than one standard deviation below the mean.

Staggered Spondaic Word (SSW) Test. Likewise, the *SSW* is a semi-dichotic presentation of overlapping spondees (second portion of the first spondee and the first word of the second spondee are given at the same time). The *SSW* has four testing conditions: right competing (RC), right non-competing (RNC), left competing (LC) and left non-competing (LNC). The participants are asked to repeat all words heard. The total number of errors are calculated and scored by using the Number of Error (NOE) Analysis. The scores obtained for all four conditions include the total number of errors, as well as any qualifiers or reversals, were compared to the normative data provided in the test manual. Scores that were within two standard deviations from the mean were considered normal.

Dichotic Digits (Single/Double). Lastly, the *Single Dichotic Digits* (*SDD)* are a random presentation of two numbers (e.g., 8 in the right ear and 2 in the left ear) and the *Double Dichotic Digits* (*DDD*) contain four numbers (e.g., 4, 8 in the right and 3, 9 in the left), both ranging from 1 to 9, excluding 7, that are given simultaneously to each ear. The *SDD* was given to those participants who were eight years and younger. The *DDD* was given to those participants who were nine years and older. The participants were asked to repeat back all the numbers that they heard. The total number of errors was calculated and yielded the total percent correct for each ear. The percent for each ear had to accumulate to at least eighty percent to be considered normal.

Dichotic Auditory Training (DAT) Test

The DAT test consisted of a pre-test and post-test that consisted of the same words in the exact same order and was delivered through the same system as the auditory processing tests. The DAT tests consisted of 100 professionally recorded Northwestern

University Test #6 (NU6) words, 50 presented to the right and 50 presented to the left. The words were presented two at a time (i.e., one to the right and one to the left) with varying onset times (i.e., R300, L300, R150, L150, and 0). For example, the words presented for the R150 condition, with R meaning right ear, was received by the right ear 150 milliseconds before the presentation of the word for the left ear. The participants were instructed:

You are going to hear two words at about the same time and you are to repeat both words back. If you are unsure of the words heard, it is okay to take a guess.

Dichotic Auditory Training

The Dichotic Auditory Training (DAT) was designed in the same manner as the DAT test. However, it differed in that there were forty words, 20 for the right and 20 for the left, at a time with varied timing differences for each exercise (See Appendix H for examples). Meaning that for exercise 1 (R300), all the words used for that exercise was given to the right ear first with the left ear word given 300 milliseconds later than the right ear. The exercises were designed to reflect a gradual decrease in timing from 300 milliseconds to 0 milliseconds (dichotic). A DAT schedule was designed for the experimental group to receive dichotic auditory training for 45 minutes two times a week for four weeks (see Table 1).

Table 1

DAT Treatment Schedule

Week	Day One	Day Two
1	300R Exercises 1-6 300L Exercises 1-6	300R Exercises 7-12 300L Exercises 7-12
2	300R Exercises 13-15 300L Exercises 13-15 150R Exercises 1-3 150L Exercises 1-3	150R Exercises 4-9 150L Exercises 4-9
3	150R Exercises 10-15 150L Exercises 10-15	Dichotic 1-12
4	Dichotic 13-24	Dichotic 25-36

A total of 15 exercises per condition were developed for R300 ms, L300 ms, R150 ms, and L150 ms and 36 exercises were developed for the 0 ms condition. If a session was missed, a make-up session was scheduled for that same week or the next week starting with the missed exercises. The DAT exercises were presented at comfortable presentation levels using a compact disc player with headphones. The participants were asked to repeat both words that were heard. The words that were announced by the participants were recorded on the exercise sheets for that specific exercise. The participants were given a five minute break between every fourth exercise to reduce fatigue. During which time, an age appropriate game was played between the participant and the researcher.

Post-Testing Protocol

The post-testing took place after all the DAT exercises were completed for the experimental group approximately five to eight weeks from pre-testing. The control group was scheduled to return to the clinic approximately five to eight weeks after pre-testing to complete post-testing. The same collection method, standards for what was considered normal, and tests (i.e., audiological evaluation and auditory processing tests) used during pre-testing were also applied to post-testing. The only change that was made was that the Post-DAT was given in place of the Baseline-DAT. Post-testing data and pre-testing data was compared to determine if any statistically significant improvements existed between the two groups and within the groups.

CHAPTER IV

RESULTS

In this chapter, the results are presented for the following variables: Dichotic Auditory Training (DAT) (total errors, R300, L300, R150, L150, Dichotic), SCAN-C/A (filtered words right ear, filtered words left ear, auditory figure ground right ear, auditory figure ground left ear, competing words right ear, competing words left ear, competing sentences right ear, and competing sentences left ear), SSW (total errors, right competing, right non-competing, left competing, left non-competing), and Dichotic Digits (right ear and left ear). Means, standard deviations, and confidence intervals are presented for each variable. A repeated measures ANOVA was performed on each variable to identify Box's test, Levene's test, main effects, and interactions. A Bonferroni correction of p = .0023 (p = .05/22) was used to determine the significance of the main effects and interactions of the repeated measures ANOVA. A multivariate analysis of variance (MANOVA) was performed on each variable to identify which test was significant between the two groups.

Prior to the analysis, each variable was examined through the SPSS 16.0 program to evaluate the accuracy of data entry, skewness, kurtosis, and outliers. All variables were transformed using the rationalized arcsine transform (Studebaker, 1985) to adjust for error variance when using percentages. All percentages were transformed into a rationalized acrsine unit (RAU) and were evaluated again for skewness, kurtosis, and outliers. No additional transformations were performed.

Table 2 presents the means, standard deviations, and confidence intervals for each group on the Dichotic Auditory Training Total (DATTOT).

Table 2

Means, Standard Deviations, and Confidence Intervals:
Dichotic Auditory Training: Total

Group	Condition	M	SD	95% Confidence Interval	
				Lower	Upper
Experimental					
	Pre	78.823	10.643	68.293	89.354
	Post	93.067	12.989	80.558	105.575
Control	Pre	78.015	12.624	68.895	87.135
	Post	84.573	14.781	73.740	95.405

A repeated measures ANOVA was performed on the DATTOT revealing no significant main effects, [F (1, 13) = 13.266, p = .003, partial η^2 = .525] or interactions [F (1, 13) = 1.8111, p = .203, partial η^2 = .131] for the groups when using a Bonferonni correction of .0023 (see Figure 1).

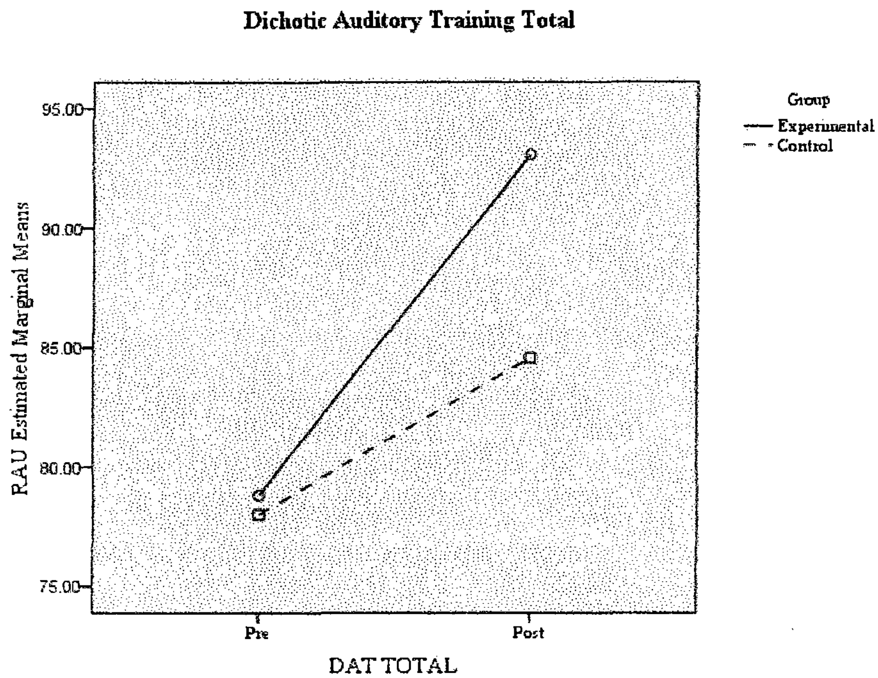


Figure 1. Dichotic Auditory Training: Total: Pre- to Post-Testing.

Table 3 presents the means, standard deviations, and confidence intervals for each group on the Dichotic Auditory Training Total: Right 300 (DATR300).

Table 3

Means, Standard Deviations, and Confidence Intervals:
Dichotic Auditory Training: Right 300

Group	Condition	M	SD	95% Confidence Interval Lower	Upper
Experimental					
	Pre	71.172	12.944	54.155	88.189
	Post	91.560	20.340	75.117	108.003
Control	Pre	66.226	22.533	51.489	80.963
	Post	74.156	17.038	59.916	88.396

A repeated measures ANOVA was performed on the DATR300 revealing no significant main effects, [F (1, 13) = 10.178, p = .008, partial η^2 = .459] or interactions [F (1, 13) = 1.970, p = .186, partial η^2 = .141] for the groups when using a Bonferonni correction of .0023 (see Figure 2).

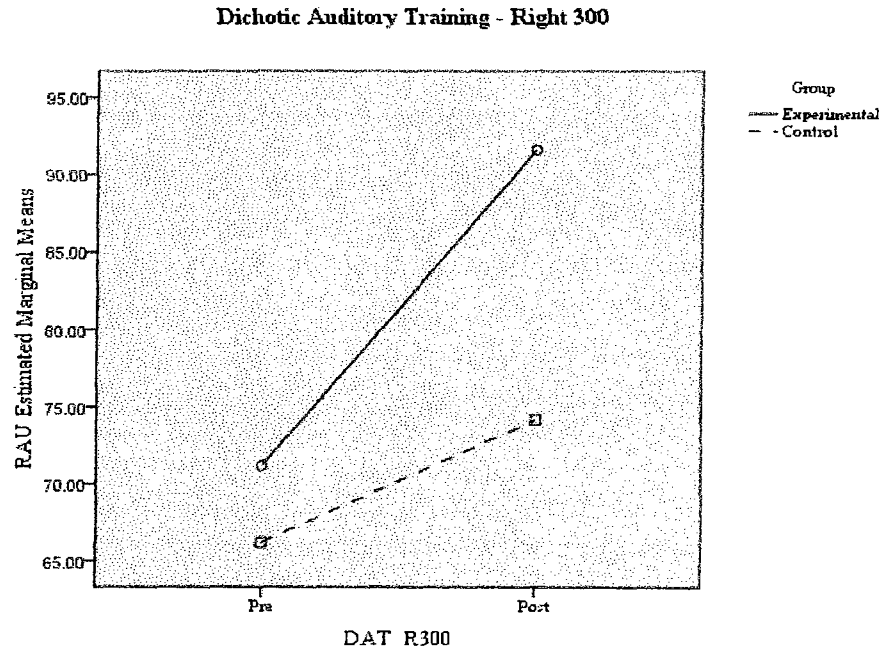


Figure 2. Dichotic Auditory Training: Right 300: Pre- to Post-Testing.

Table 4 presents the means, standard deviations, and confidence intervals for each group on the Dichotic Auditory Training Total: Left 300 (DATL300).

Table 4

Means, Standard Deviations, and Confidence Intervals:
Dichotic Auditory Training: Left 300

Group	Condition	M	SD	95% Confidence Interval Lower	Upper
Experimental					
	Pre	76.187	19.115	59.747	92.626
	Post	82.850	15.773	67.846	97.854
Control	Pre	71.011	18.016	56.774	85.248
	Post	78.011	17.608	65.018	91.005

A repeated measures ANOVA was performed on the DATL300 revealing no significant main effects, [F (1, 13) = 6.860, p = .022, partial η^2 = .364] or interactions [F (1, 13) = 0.004, p = .950, partial η^2 = .000] for the groups when using a Bonferonni correction of .0023 (see Figure 3).

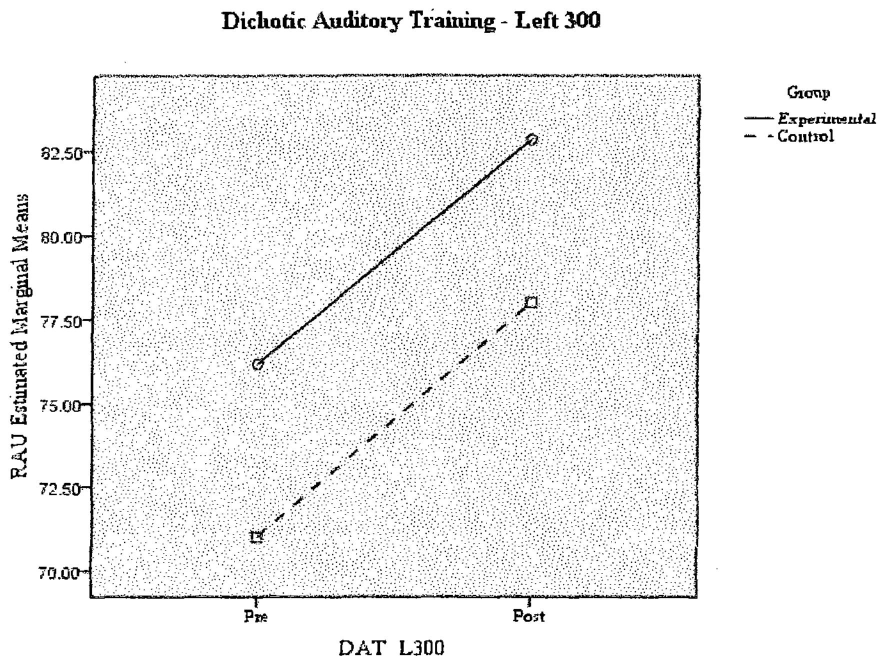


Figure 3. Dichotic Auditory Training: Left 300: Pre- to Post-Testing.

Table 5 presents the means, standard deviations, and confidence intervals for each group on the Dichotic Auditory Training Total: Right 150 (DATR150).

Table 5

Means, Standard Deviations, and Confidence Intervals:
Dichotic Auditory Training: Right 150

Group	Condition	M	SD	95% Confidence Interval Lower	Upper
Experimental					
	Pre	63.368	14.571	47.056	79.681
	Post	88.735	21.465	70.410	107.060
Control	Pre	62.758	20.613	48.630	76.885
	Post	69.716	19.961	53.847	85.586

A repeated measures ANOVA was performed on the DATR150 revealing significant main effects for the groups, [F (1, 13) = 19.061, p = .001, partial η^2 = .614], but no significant interactions [F (1, 13) = 6.181, p = .029, partial η^2 = .340] for the groups when using a Bonferonni correction of .0023 (see Figure 4).

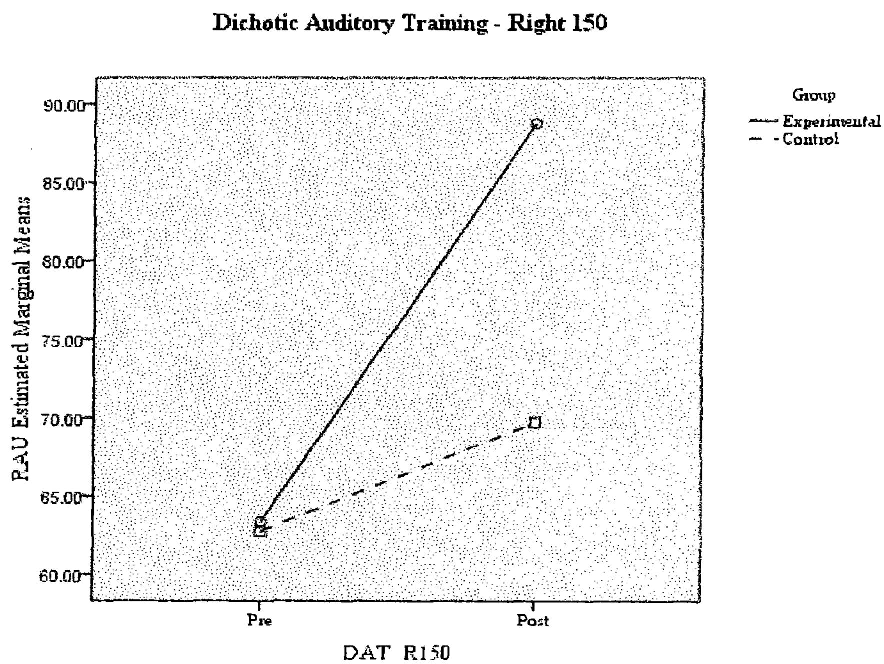


Figure 4. Dichotic Auditory Training: Right 150: Pre- to Post-Testing.

Table 6 presents the means, standard deviations, and confidence intervals for each group on the Dichotic Auditory Training Total: Left 150 (DATL150).

Table 6

Means, Standard Deviations, and Confidence Intervals:
Dichotic Auditory Training: Left 150

Group	Condition	M	SD	95% Confidence Interval Lower	Upper
Experimental					
	Pre	60.472	15.322	43.044	77.900
	Post	75.047	22.633	53.933	96.161
Control	Pre	62.758	22.145	47.664	77.851
	Post	67.679	24.495	49.394	85.96

A repeated measures ANOVA was performed on the DATL150 revealing no significant main effects, [F (1, 13) = 6.155, p = .029, partial η^2 = .112] or interactions [F (1, 13) = 1.509, p = .243, partial η^2 = .339] for the groups when using a Bonferonni correction of .0023 (see Figure 5).

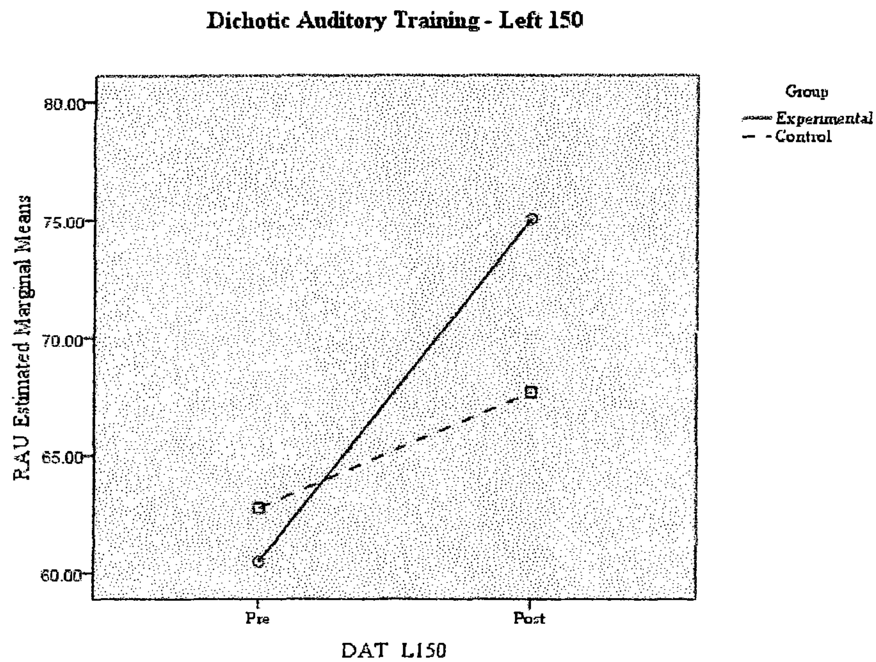


Figure 5. Dichotic Auditory Training: Left 150: Pre- to Post-Testing.

Table 7 presents the means, standard deviations, and confidence intervals for each group on the Dichotic Auditory Training Total: Dichotic (DAT DICHOTIC).

Table 7

Means, Standard Deviations, and Confidence Intervals:
Dichotic Auditory Training: Dichotic

Group	Condition	M	SD	95% Confidence Interval Lower	Upper
Experimental					
	Pre	50.180	22.627	33.487	66.873
	Post	71.633	17.491	56.025	87.241
Control	Pre	51.066	15.428	36.610	65.522
	Post	62.640	17.587	49.123	76.157

A repeated measures ANOVA was performed on the DAT DICHOTIC revealing no significant main effects, [F (1, 13) = 12.011, p = .005, partial η^2 = .500] or interactions [F (1, 13) = 1.075, p = .320, partial η^2 = .082] for the groups when using a Bonferonni correction of .0023 (see Figure 6).

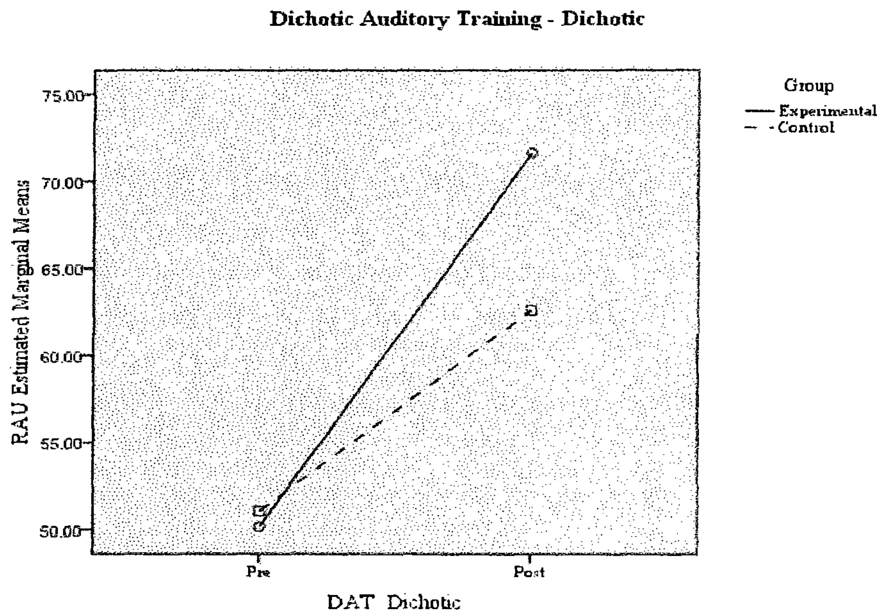


Figure 6. Dichotic Auditory Training: Dichotic: Pre- to Post-Testing.

Table 8 presents a pairwise comparison between the experimental group and control group for the following conditions: DAT-total, R300, L300, R150, L150, and DICHOTIC.

Table 8

MANOVA: Pairwise comparison of the Dichotic Auditory Training variables

	Pre		Post	
Variables	*p*-value	partial η^2	*p*-value	partial η^2
DAT Total	.901	.001	.285	.094
R300	.351	.109	.082	.331
L300	.791	.009	.495	.060
R150	.663	.025	.030*	.466
L150	.839	.005	.181	.211
Dichotic	.784	.010	.111	.287

Note. *$p < 0.05$

All pre-test variables of the DAT revealed no significant difference between the experimental and control group. On post-testing the MANOVA pairwise comparison yielded a significant difference on the R150 condition ($p = .030$). There were no clinical significant group differences on the DAT TOT, however after the experimental treatment the experimental group had a medium effect size compared to the control group. Prior to the experimental treatment, the experimental group had a medium effect size on the R300 when compared to the control group and a large effect size for the experimental group after the experimental treatment. There were no clinical significant group differences on the L300, however after the experimental treatment the experimental group had a medium effect size compared to the control group. Prior to the experimental treatment the experimental group had a small effect size on the R150 and a large effect size for the experimental group after the experimental treatment. There were no clinical significant group differences on the DAT L150, however after the experimental treatment the experimental group had a large effect size compared to the control group. Prior to the experimental treatment, the control group had a small effect size on the DAT Dichotic when compared to the experimental group and a large effect size for the experimental group after the experimental treatment.

Table 9 presents the means, standard deviations, and confidence intervals for each group on the Staggered Spondaic Word Test: Total Errors (SSWTOT).

Table 9

Means, Standard Deviations, and Confidence Intervals: Staggered Spondaic Word Test: Total Errors

Group	Condition	M	SD	95% Confidence Interval	
				Lower	Upper
Experimental					
	Pre	94.410	5.665	86.788	102.032
	Post	100.973	4.575	92.816	109.131
Control	Pre	97.235	10.147	90.634	103.836
	Post	105.109	11.368	98.044	112.173

A repeated measures ANOVA was performed on the SSWTOT revealing significant main effects, [F (1, 13) = 15.617, p = .002, partial η^2 = .565], but no significant interactions [F (1, 13) = .129, p = .726, partial η^2 = .011] for the groups when using a Bonferonni correction of .0023 (see Figure 7).

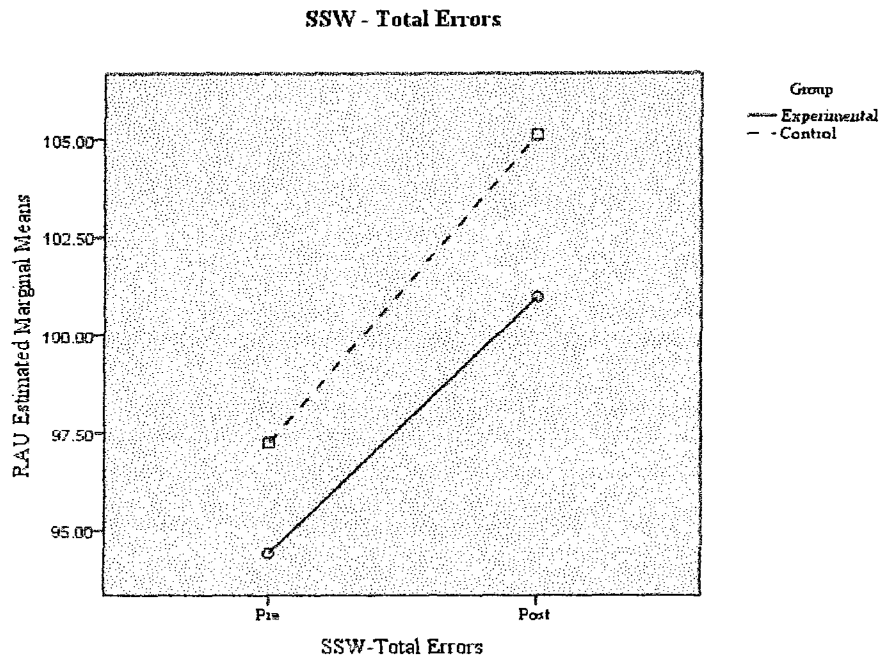


Figure 7. Staggered Spondaic Word Test: Total Errors: Pre- to Post-Testing.

Table 10 presents the means, standard deviations, and confidence intervals for each group on the Staggered Spondaic Word Test: Right Competing (SSWRC).

Table 10

Means, Standard Deviations, and Confidence Intervals: Staggered Spondaic Word Test: Right Competing

Group	Condition	M	SD	95% Confidence Interval	
				Lower	Upper
Experimental					
	Pre	95.255	10.840	83.566	106.944
	Post	98.422	9.387	89.196	107.647
Control	Pre	97.455	14.563	87.332	107.578
	Post	102.429	11.021	94.440	110.418

A repeated measures ANOVA was performed on the SSWRC revealing no significant main effects, [F (1, 13) = 2.172, p = .166, partial η^2 = .153] or interactions [F (1, 13) = .107, p = .749, partial η^2 = .009] for the groups when using a Bonferonni correction of .0023 (see Figure 8).

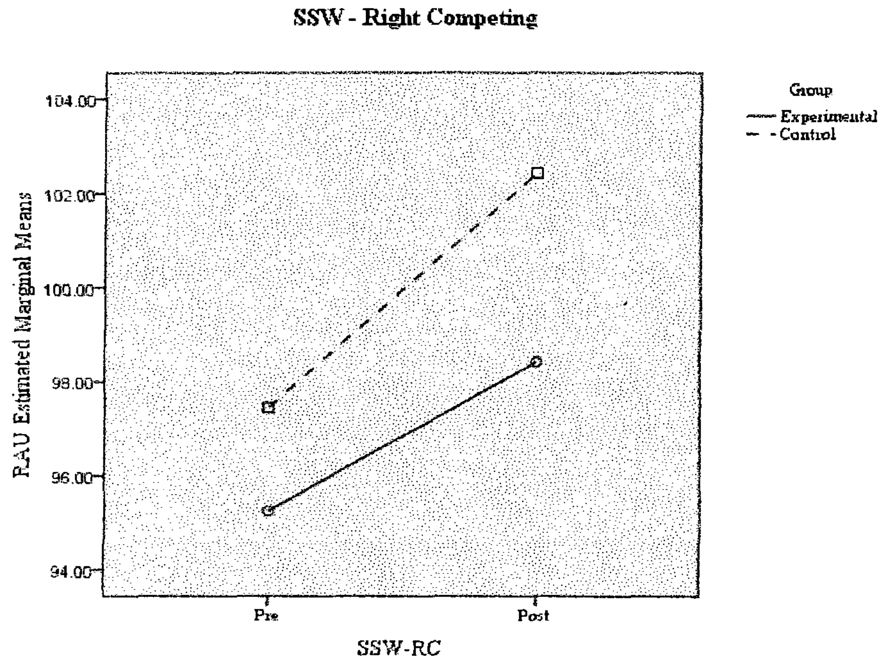


Figure 8. Staggered Spondaic Word Test: Right Competing: Pre- to Post-Testing.

Table 11 presents the means, standard deviations, and confidence intervals for each group on the Staggered Spondaic Word Test: Right Non-Competing (SSWRNC).

Table 11

Means, Standard Deviations, and Confidence Intervals: Staggered Spondaic Word Test: Right Non-Competing

Group	Condition	M	SD	95% Confidence Interval Lower	Upper
Experimental					
	Pre	108.252	9.580	97.775	118.728
	Post	108.810	5.345	103.424	114.196
Control	Pre	107.864	13.124	98.791	116.936
	Post	111.149	6.515	106.484	115.813

A repeated measures ANOVA was performed on the SSWRNC revealing no significant main effects, [F (1, 13) = 0.906, p = .360, partial η^2 = .070] or interactions [F (1, 13) = .456, p = .512, partial η^2 = .037] for the groups when using a Bonferonni correction of .0023 (see Figure 9).

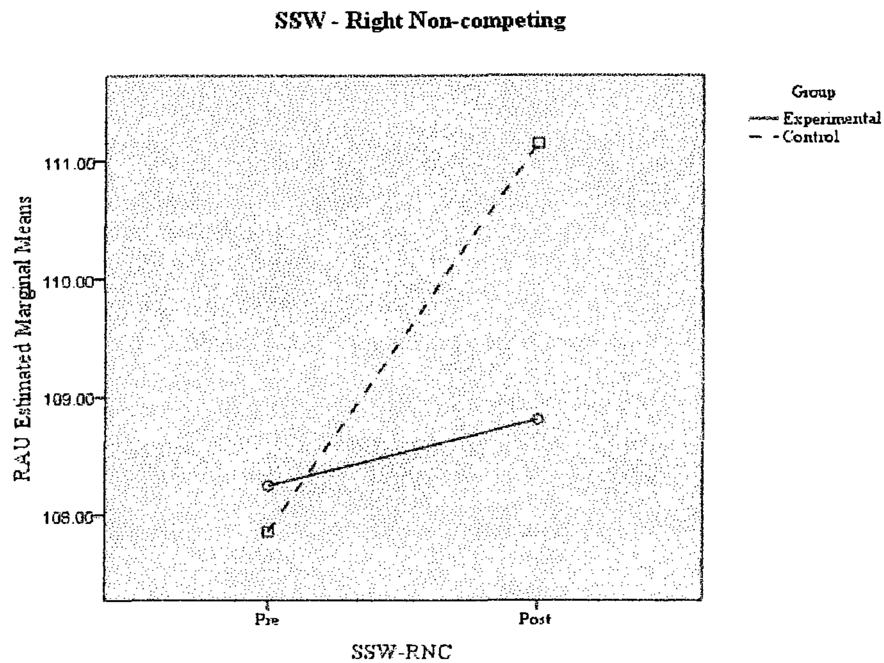


Figure 9. Staggered Spondaic Word Test: Right Non-Competing: Pre- to Post-Testing.

Table 12 presents the means, standard deviations, and confidence intervals for each group on the Staggered Spondaic Word Test: Left Competing (SSWLC).

Table 12

Means, Standard Deviations, and Confidence Intervals: Staggered Spondaic Word Test: Left Competing

Group	Condition	M	SD	95% Confidence Interval Lower	Upper
Experimental					
	Pre	78.150	8.505	69.329	86.971
	Post	88.847	8.242	76.712	100.981
Control	Pre	82.804	10.813	75.165	90.443
	Post	95.283	16.447	84.774	105.791

A repeated measures ANOVA was performed on the SSWLC revealing significant main effects, [F (1, 13) = 15.372, p = .002, partial η^2 = .562], but no interactions [F (1, 13) = 0.091, p = .768, partial η^2 = .008] for the groups when using a Bonferonni correction of .0023 (see Figure 10).

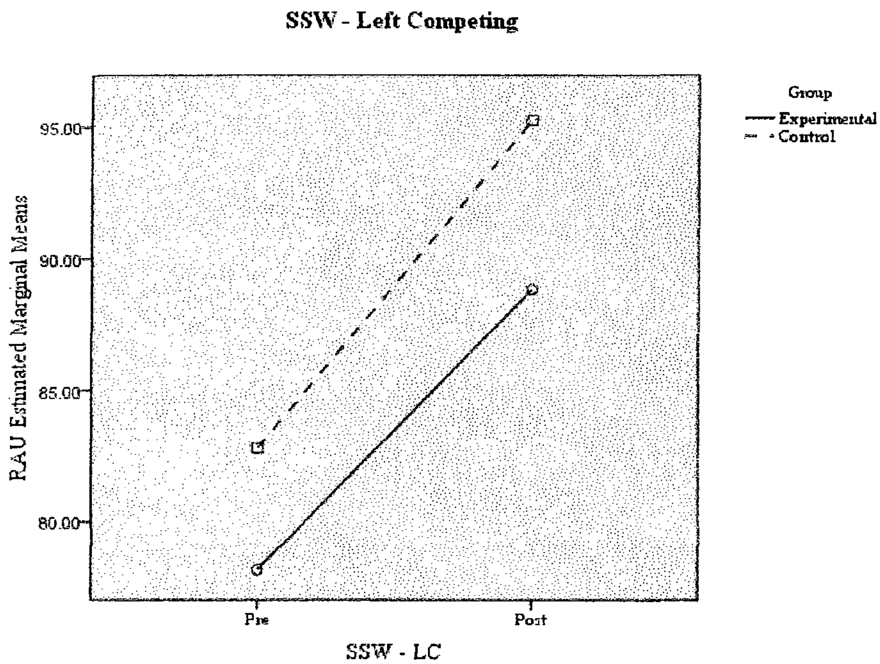


Figure 10. Staggered Spondaic Word Test: Left Competing: Pre- to Post-Testing.

Table 13 presents the means, standard deviations, and confidence intervals for each group on the Staggered Spondaic Word Test: Left Non-Competing (SSWLNC).

Table 13

Means, Standard Deviations, and Confidence Intervals: Staggered Spondaic Word Test: Left Non-Competing

Group	Condition	M	SD	95% Confidence Interval Lower	Upper
Experimental					
	Pre	102.895	7.672	95.220	110.570
	Post	112.260	5.345	105.256	119.264
Control	Pre	106.298	9.251	99.651	112.944
	Post	109.366	9.268	103.300	115.43

A repeated measures ANOVA was performed on the SSWLNC revealing no significant main effects, [F (1, 13) = 4.522, p = .055, partial η^2 = .274] or interactions [F (1, 13) = 1.159, p = .303, partial η^2 = .088] for the groups when using a Bonferonni correction of .0023 (see Figure 11).

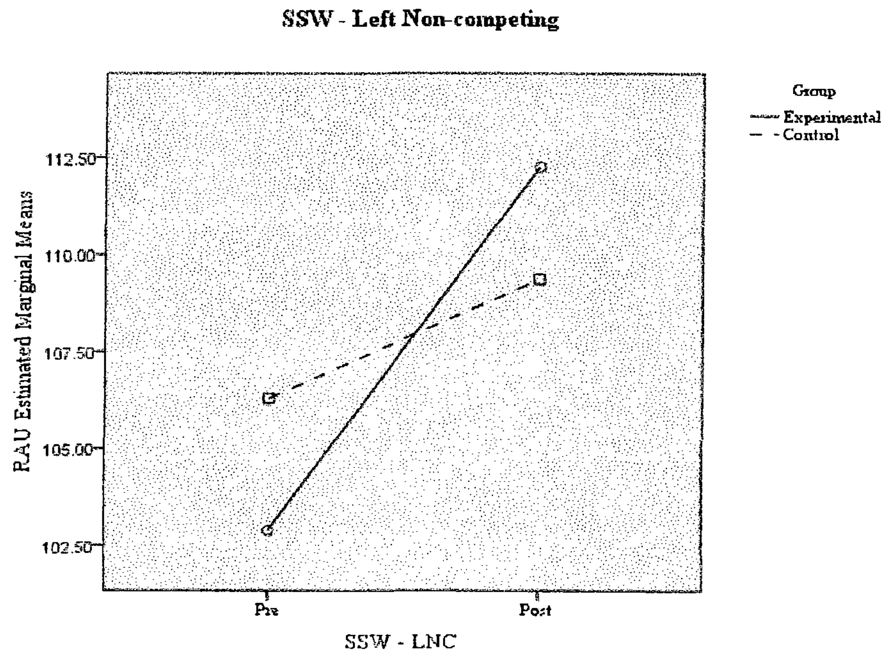


Figure 11. Staggered Spondaic Word Test: Left Non-Competing: Pre- to Post-Testing.

Table 14 presents a pairwise comparison between the experimental group and control group for the following *SSW* conditions: Total Errors, RNC, RC, LNC, and LC.

Table 14

MANOVA: Pairwise comparison of the *SSW* variables

	Pre		Post	
Variables	*p*-value	partial η^2	*p*-value	partial η^2
SSW TOTAL	.553	.030	.420	.055
SSWRNC	.520	.054	.242	.167
SSWRC	.376	.099	.053	.391
SSWLNC	.010*	.583	.691	.021
SSWLC	.050*	.399	.463	.069

*Note.**p< 0.05

On pre-testing the MANOVA pairwise comparison yielded a significant difference on the SSWLNC ($p = .010$) and SSWLC ($p = .050$) conditions for the control group when compared to the experimental group. The remaining pre-test variables of the SSW revealed no significant difference between the experimental and control group. All post-test variables of the SSW revealed no significant difference between the experimental and control group. Prior to the experimental treatment and after the treatment, the control group had a small effect size on the SSW Total. Prior to the experimental treatment, the experimental group had a small effect size on the SSW RNC when compared to the control group and a large effect size for the control group after the experimental treatment. Prior to the experimental treatment, the control group had a medium effect size on the SSW RC when compared to the experimental group and a large effect size for the control group after the experimental treatment. Prior to and after the experimental treatment, the control group had a large effect size on the SSW LNC and SSW LC when compared to the experimental group.

Table 15 presents the means, standard deviations, and confidence intervals for each group on the SCAN: Filtered Words: Right Ear (SCANFWR).

Table 15

Means, Standard Deviations, and Confidence Intervals: SCAN: Filtered Words: Right Ear

Group	Condition	M	SD	95% Confidence Interval Lower	Upper
Experimental					
	Pre	88.855	8.188	80.641	97.069
	Post	93.007	4.023	82.696	103.317
Control	Pre	90.630	9.915	83.516	97.744
	Post	94.371	14.791	85.442	103.301

A repeated measures ANOVA was performed on the SCANFWR revealing no significant main effects, [F (1, 13) = 2.281, p = .157, partial η^2 = .160] or interactions [F (1, 13) = 0.006, p = .939, partial η^2 = .001] for the groups when using a Bonferonni correction of .0023 (see Figure 12).

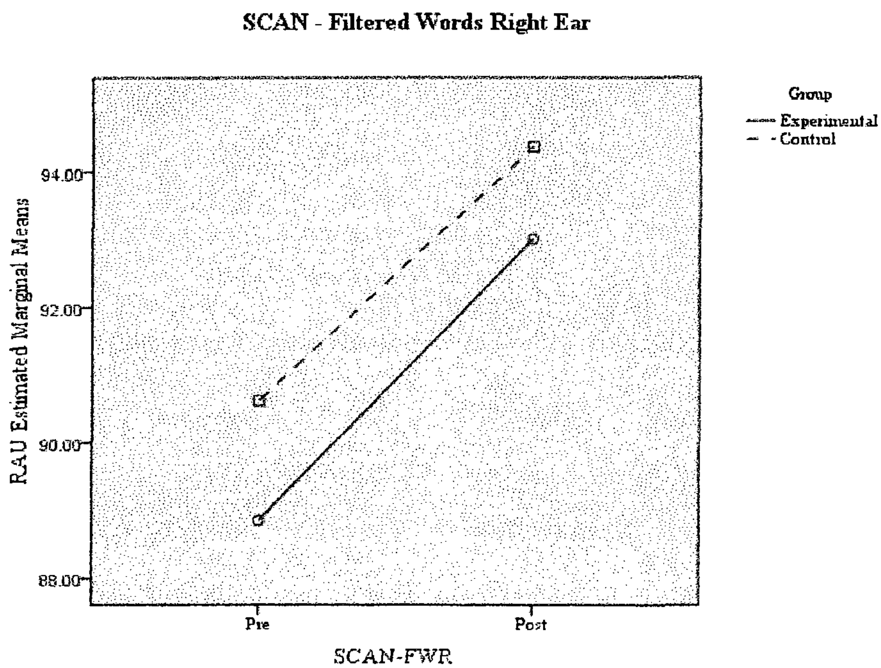


Figure 12. SCAN: Filtered Words: Right Ear: Pre- to Post-Testing.

Table 16 presents the means, standard deviations, and confidence intervals for each group on the SCAN: Filtered Words: Left Ear (SCANFWL).

Table 16

Means, Standard Deviations, and Confidence Intervals: SCAN: Filtered Words: Left Ear

Group	Condition	M	SD	95% Confidence Interval Lower	Upper
Experimental					
	Pre	94.368	10.081	86.895	101.841
	Post	93.237	5.919	82.420	104.053
Control	Pre	89.244	6.957	82.772	95.716
	Post	92.596	15.115	83.229	101.963

A repeated measures ANOVA was performed on the SCANFWL A repeated measures ANOVA was performed on the SSWRNC revealing no significant main effects, [F (1, 13) = 0.099, p = .758, partial η^2 = .008] or interactions [F (1, 13) = 0.405, p = .536, partial η^2 = .033] for the groups when using a Bonferonni correction of .0023 (see *Figure 13*).

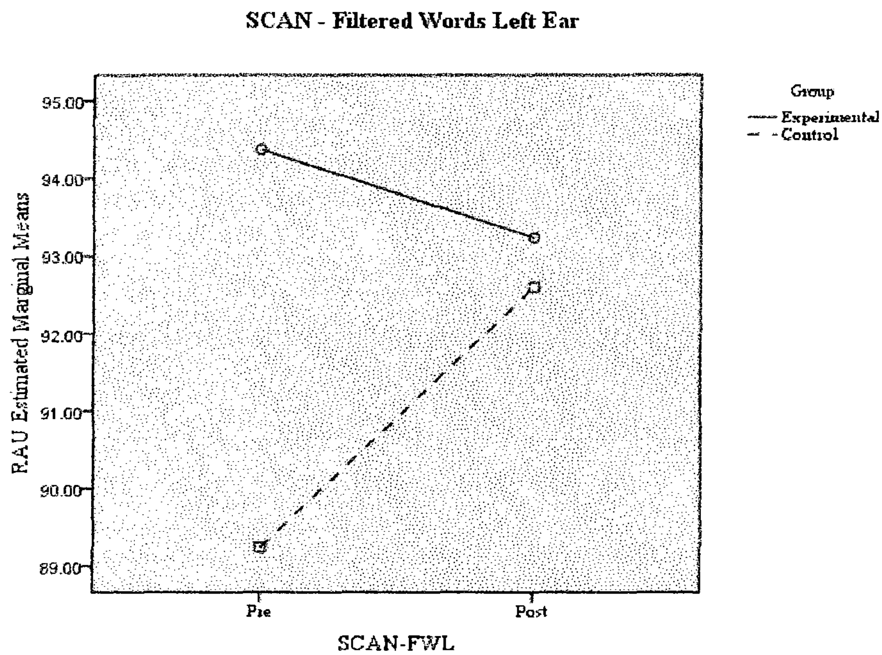


Figure 13. SCAN: Filtered Words: Left Ear: Pre- to Post-Testing.

Table 17 presents the means, standard deviations, and confidence intervals for each group on the SCAN: Auditory Figure Ground: Right Ear (SCANAFGR).

Table 17

Means, Standard Deviations, and Confidence Intervals: SCAN: Auditory Figure Ground: Right Ear

Group	Condition	M	SD	95% Confidence Interval	
				Lower	Upper
Experimental					
	Pre	96.760	16.577	84.530	108.990
	Post	99.810	15.614	86.907	112.713
Control	Pre	90.356	11.304	79.765	100.948
	Post	91.839	13.659	80.664	103.013

A repeated measures ANOVA was performed on the SCANAFGR revealing no significant main effects, [F (1, 13) = 0.728, p = .410, partial η^2 = .057] or interactions [F (1, 13) = 0.087, p = .773, partial η^2 = .007] for the groups when using a Bonferonni correction of .0023 (see Figure 14).

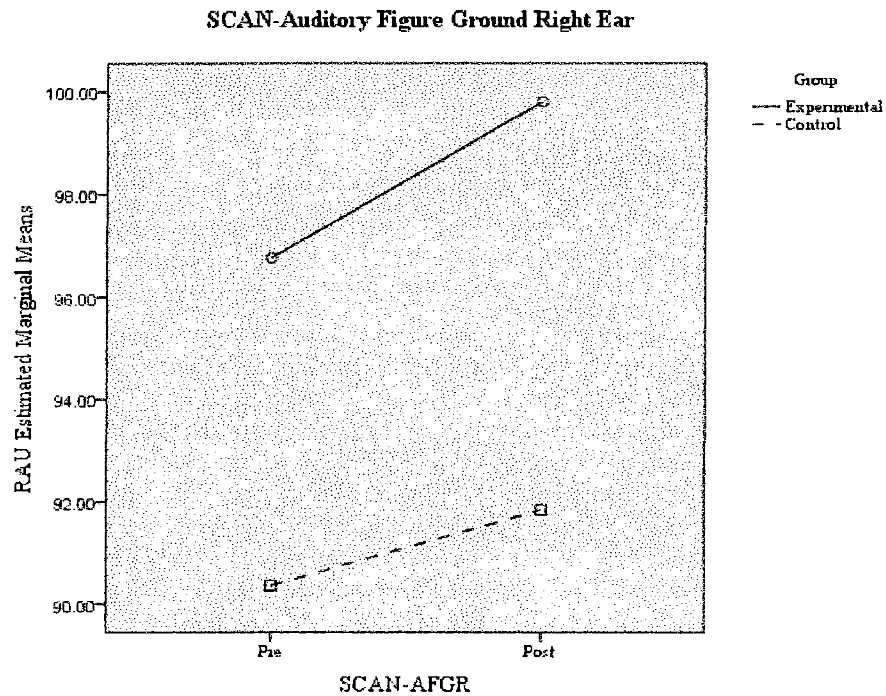


Figure 14. SCAN: Auditory Figure Ground: Right Ear: Pre- to Post-Testing.

Table 18 presents the means, standard deviations, and confidence intervals for each group on the SCAN: Auditory Figure Ground: Left Ear (SCANAFGL).

Table 18

Means, Standard Deviations, and Confidence Intervals: SCAN: Auditory Figure Ground: Left Ear

Group	Condition	M	SD	95% Confidence Interval Lower	Upper
Experimental					
	Pre	75.380	10.039	65.573	85.187
	Post	92.002	10.653	83.974	100.029
Control	Pre	88.754	11.679	80.261	97.247
	Post	91.993	7.653	85.041	98.944

A repeated measures ANOVA was performed on the SCANAFGL revealing no significant main effects, [F (1, 13) = 7.316, p = .019, partial η^2 = .379] or interactions [F (1, 13) = 3.322, p = .093, partial η^2 = .217] for the groups when using a Bonferonni correction of .0023 (see Figure 15).

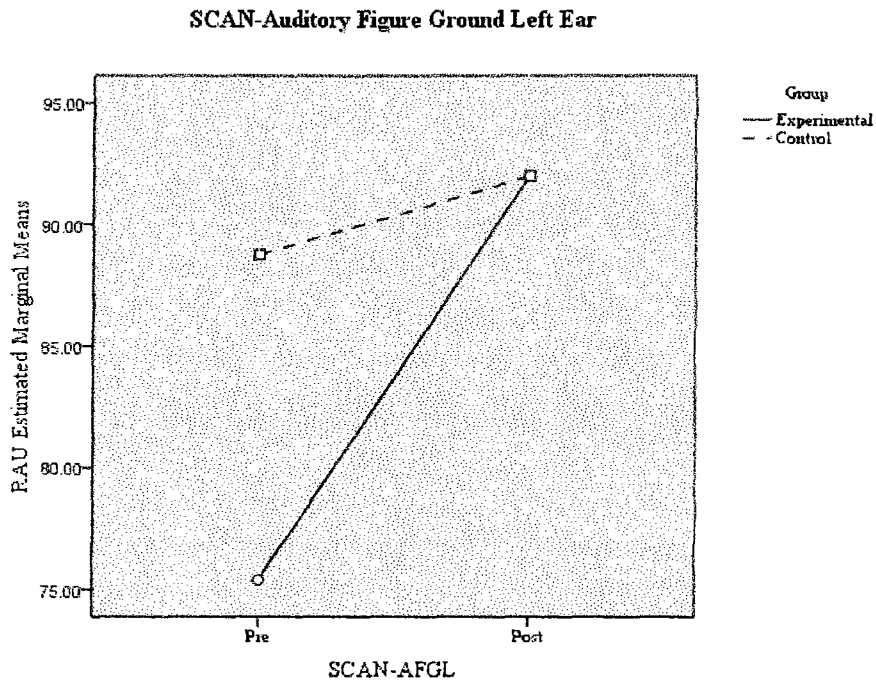


Figure 15. SCAN: Auditory Figure Ground: Left Ear: Pre- to Post-Testing.

Table 19 presents the means, standard deviations, and confidence intervals for each group on the SCAN: Competing Words: Right Ear (SCANCWR).

Table 19

Means, Standard Deviations, and Confidence Intervals: SCAN: Competing Words: Right Ear

Group	Condition	M	SD	95% Confidence Interval Lower	Upper
Experimental					
	Pre	78.413	11.035	64.109	92.717
	Post	87.068	10.565	76.575	97.562
Control	Pre	82.300	18.877	69.912	94.688
	Post	88.773	12.604	79.685	97.860

A repeated measures ANOVA was performed on the SCANCWR revealing no significant main effects, [F (1, 13) = 7.207, p = .020, partial η^2 = .375] or interactions [F (1, 13) = 0.150, p = .705, partial η^2 = .012] for the groups when using a Bonferonni correction of .0023 (see Figure 16).

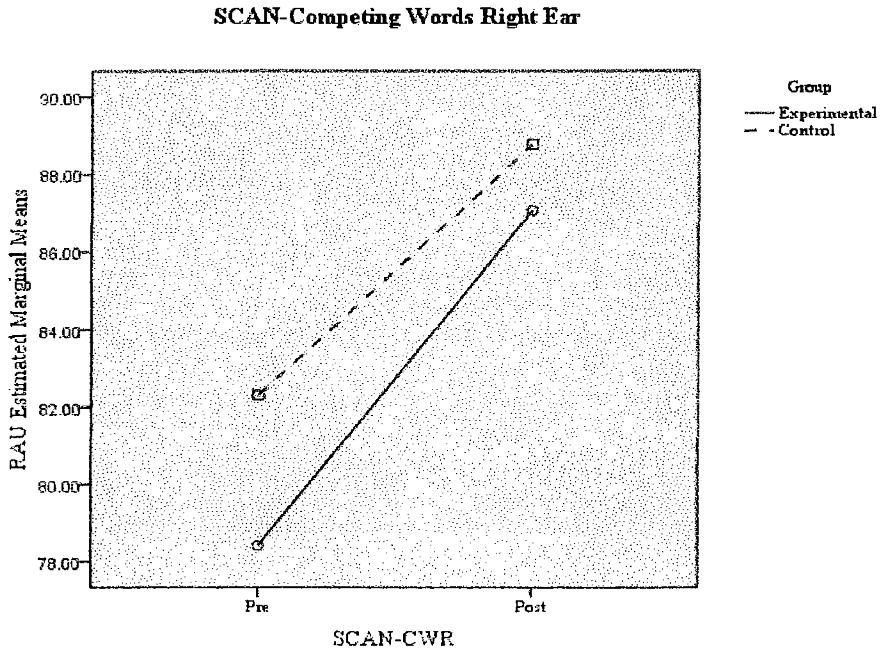


Figure 16. SCAN: Competing Words: Right Ear: Pre- to Post-Testing.

Table 20 presents the means, standard deviations, and confidence intervals for each group on the SCAN: Competing Words: Left Ear (SCANCWL).

Table 20

Means, Standard Deviations, and Confidence Intervals: SCAN: Competing Words: Left Ear

Group	Condition	M	SD	95% Confidence Interval Lower	Upper
Experimental					
	Pre	65.453	8.397	56.653	74.254
	Post	79.080	6.492	70.253	87.907
Control	Pre	75.436	10.837	67.815	83.058
	Post	85.314	11.778	77.669	92.958

A repeated measures ANOVA was performed on the SCANCWL revealing significant main effects, [F (1, 13) = 23.652, p = .000, partial η^2 = .663], but no significant interactions [F (1, 13) = 0.602, p = .453, partial η^2 = .048] for the groups when using a Bonferonni correction of .0023 (see Figure 17).

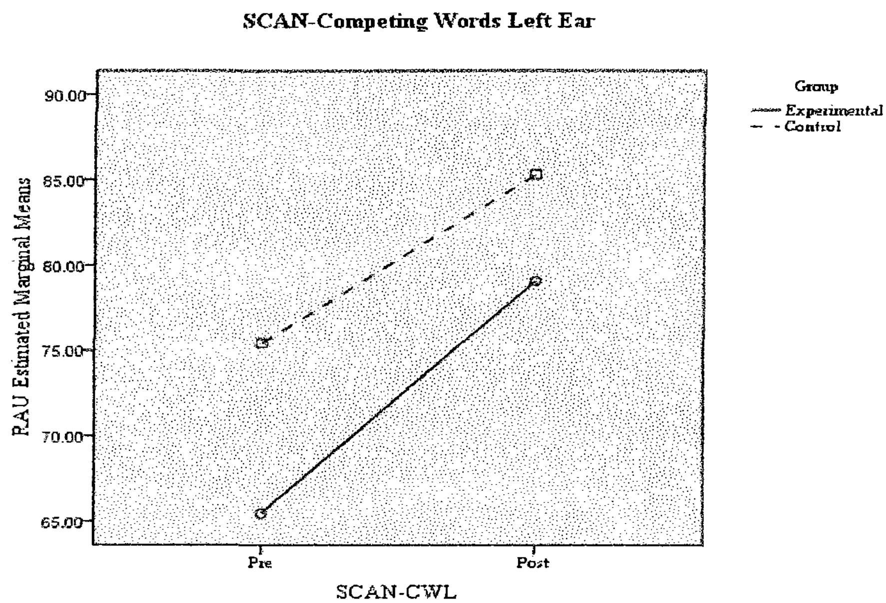


Figure 17. SCAN: Competing Words: Left Ear: Pre- to Post-Testing.

Table 21 presents the means, standard deviations, and confidence intervals for each group on the SCAN: Competing Sentences: Right Ear (SCANCSR).

Table 21

Means, Standard Deviations, and Confidence Intervals: SCAN: Competing Sentences: Right Ear

Group	Condition	M	SD	95% Confidence Interval	
				Lower	Upper
Experimental					
	Pre	88.147	18.511	64.968	111.326
	Post	101.943	10.576	87.419	116.467
Control	Pre	98.050	30.321	77.976	118.124
	Post	95.958	19.421	83.379	108.536

A repeated measures ANOVA was performed on the SCANCSR revealing no significant main effects, [F (1, 13) = 1.746, p = .211, partial η^2 = .127] or interactions [F (1, 13) = 3.219, p = .098, partial η^2 = .211] for the groups when using a Bonferonni correction of .0023 (see Figure 18).

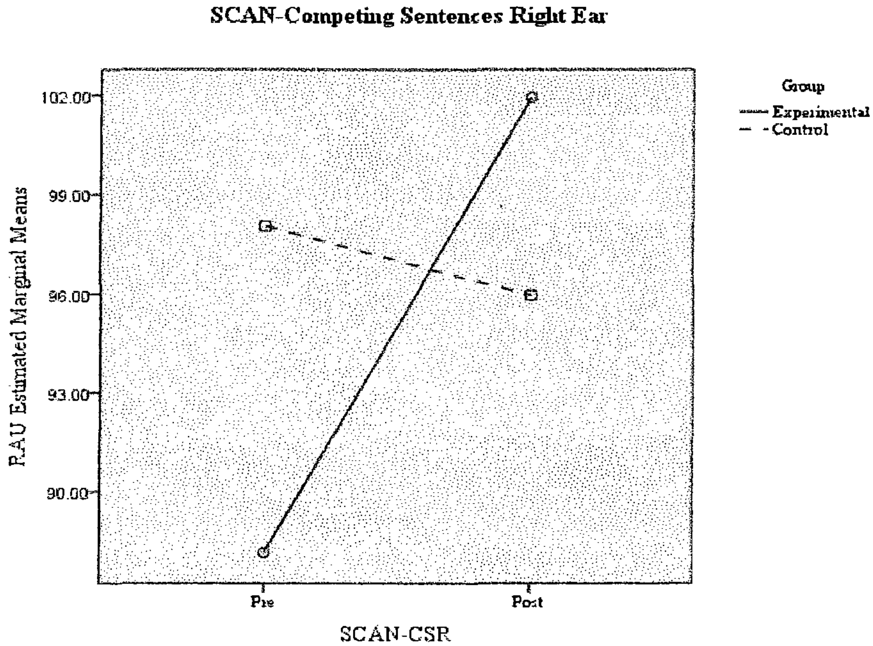


Figure 18. SCAN: Competing Sentences: Right Ear: Pre- to Post-Testing.

Table 22 presents the means, standard deviations, and confidence intervals for each group on the SCAN: Competing Sentences: Left Ear (SCANCSL).

Table 22

Means, Standard Deviations, and Confidence Intervals: SCAN: Competing Sentences: Left Ear

Group	Condition	M	SD	95% Confidence Interval Lower	Upper
Experimental					
	Pre	62.692	24.228	38.820	86.564
	Post	68.683	21.181	43.890	93.477
Control	Pre	62.906	28.556	42.233	83.580
	Post	86.731	31.803	65.259	108.203

A repeated measures ANOVA was performed on the SCANCSL revealing no significant main effects, [F (1, 13) = 9.959, p = .008, partial η^2 = .454] or interactions [F (1, 13) = 3.562, p = .084, partial η^2 = .229] for the groups when using a Bonferonni correction of .0023 (see Figure 19).

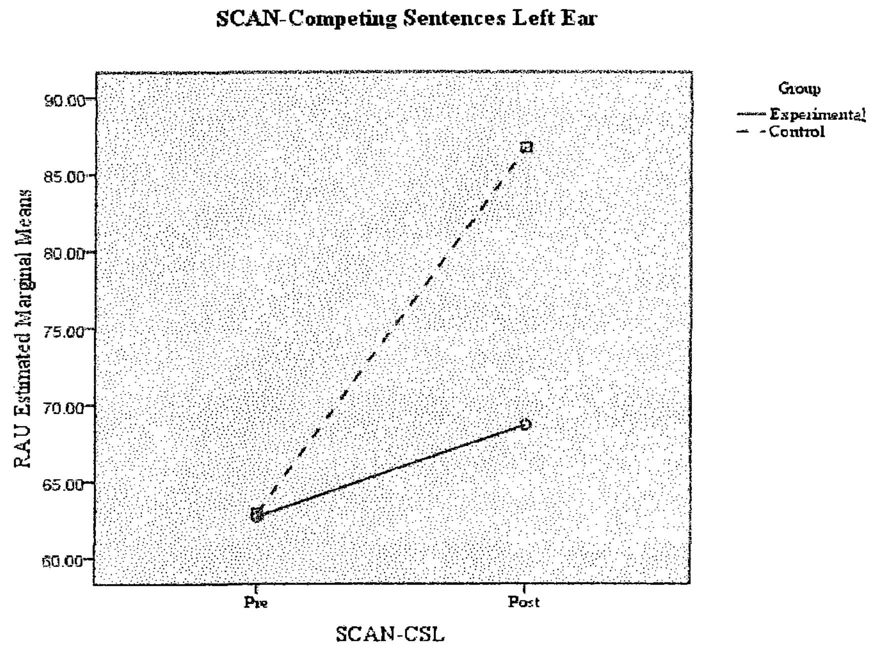


Figure 19. SCAN: Competing Sentences: Left Ear: Pre- to Post-Testing.

Table 23 presents a pairwise comparison between the experimental group and control group for the following *SCAN-C/A* conditions: FWR, FWL, AFGR, AFGL, CWR, CWL, CSR, and CSL.

Table 23

MANOVA: Pairwise comparison of the *SCAN-C/A* variables

	Pre		Post	
Variables	*p*-value	partial η^2	*p*-value	paritial η^2
SCANFWR	.457	.071	.555	.045
SCANFWL	.496	.060	.543	.048
SCANAFGR	.385	.095	.780	.010
SCANAFGL	.064	.365	.049*	.401
SCANCWR	.298	.134	.314	.126
SCANCWL	.013*	.560	.264	.153
SCANCSR	.013*	.560	.141	.250
SCANCSL	.208	.190	.022*	.503

*Note.**p< 0.05

On pre-testing the MANOVA pairwise comparison yielded significant differences on the SCANCWL (p = .013) and SCANCSR (p = .013) conditions for the control group when compared to the experimental group. On post-testing the MANOVA pairwise comparison yielded a significant difference on the SCAN AFGL condition (*p* = .030). Prior to the experimental treatment, the control group had a medium effect size on the SCANFWR when compared to the experimental group and a small effect size for the control group after the experimental treatment. Prior to the experimental treatment, the experimental group had a medium effect size on the SCANFWL and SCANAFGR conditions when compared to the control group and a small effect size in both conditions for the experimental group after the experimental treatment. Prior to the experimental treatment, the control group had a large effect size on the SCANAFGL condition when compared to the experimental group and a large effect size for the experimental group after the treatment. Prior to the experimental treatment and after the treatment, the control group had a medium effect size on the SCANCWR condition when compared to the experimental group. Prior to the experimental treatment, the control group had a large effect size on the SCANCSR condition when compared to the experimental group and a large effect size for the experimental group when compared to the control group. Prior to and after the experimental treatment, the control group had a large effect size for the SCANCSL condition when compared to the experimental group.

Table 24 presents the means, standard deviations, and confidence intervals for each group on the Dichotic Digits: Right Ear (DDR).

Table 24

Means, Standard Deviations, and Confidence Intervals: Dichotic Digits: Right Ear

Group	Condition	M	SD	95% Confidence Interval	
				Lower	Upper
Experimental					
	Pre	99.762	17.048	85.327	114.197
	Post	97.142	10.405	84.803	109.481
Control	Pre	87.798	10.061	73.363	102.233
	Post	95.826	13.343	83.487	108.165

A repeated measures ANOVA was performed on the DDR revealing no significant main effects, [F (1, 13) = .343, p = .574, partial η^2 = .041] or interactions [F (1, 13) = 1.331, p = .282, partial η^2 = .143] for the groups when using a Bonferonni correction of .0023 (see Figure 20).

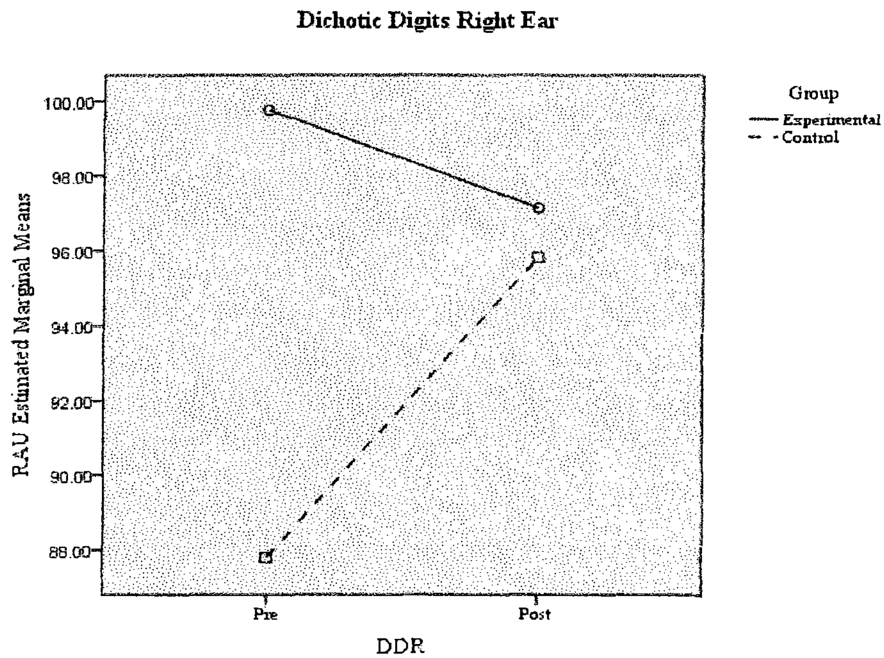


Figure 20. Dichotic Digits: Right Ear: Pre- to Post-Testing.

Table 25 presents the means, standard deviations, and confidence intervals for each group on the Dichotic Digits: Left Ear (DDL).

Table 25

Means, Standard Deviations, and Confidence Intervals: Dichotic Digits: Left Ear

Group	Condition	M	SD	95% Confidence Interval Lower	Upper
Experimental					
	Pre	96.134	15.183	84.798	107.470
	Post	98.634	14.220	86.551	110.717
Control	Pre	89.706	3.339	78.370	101.042
	Post	92.110	8.505	80.027	104.193

A repeated measures ANOVA was performed on the DDL revealing no significant main effects, [F (1, 13) = 1.375, p = .275, partial η^2 = .147] or interactions [F (1, 13) = 001, p = .982, partial η^2 = .000] for the groups when using a Bonferonni correction of .0023 (see Figure 21).

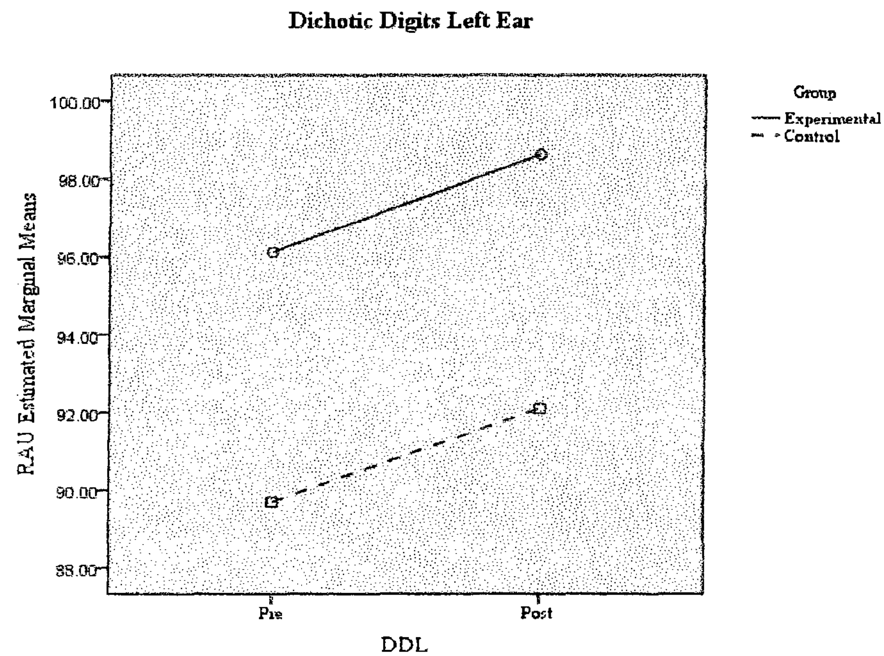


Figure 21. Dichotic Digits: Left Ear: Pre- to Post-Testing.

Table 26 presents a pairwise comparison between the experimental group and control group for the following *Dichotic Digit* conditions: DDL and DDR.

Table 26

MANOVA: Pairwise comparison of the *Dichotic Digits* variables

	Pre		Post	
Variable	*p*-value	partial η^2	*p*-value	partial η^2
DDL	.382	.097	.404	.088
DDR	.214	.186	.866	.004

Note. *$p < 0.05$

All pre- and post-test variables of the DD revealed no significant difference between the experimental and control group. Prior to the experimental treatment and after the treatment, the experimental group had a medium effect size on the DDL condition when compared to the control group. Prior to the experimental treatment, the experimental group had a large effect size on the DDR condition when compared to the control group and there were no clinical significant group differences after the experimental treatment.

CHAPTER V

DISCUSSION

There has been much research focused on assessing (C)APDs, however only a limited number of therapy programs have been developed that are used clinically to help those individuals who have been identified as having a (C)APD. Therefore, the purpose of this study was to determine if participants with normal auditory processing skills would improve after receiving the DAT when compared to a group of normal participants who only received pre- and post-testing. The investigator hypothesized that the experimental group would improve on the post-DAT test when compared to the pre-DAT testing due to the experimental group receiving the treatment. Especially since the DAT pre- and post-screening tool used the same type of stimuli as the DAT therapy. The investigator did not expect to see significant findings for the experimental group when compared to the control group on the pre- to post standardized test measures (i.e., *SSW*, *SCAN-C/A*, and *Dichotic Digits*). Any significant findings on the standardized tests would suggest that the treatment improved dichotic performances for the experimental group because these standardized tests did not contain the same stimuli as the DAT therapy.

During the review of the results, it was speculated that the two groups were not symmetrical in reference to their mean age. The mean age (11years, 8 months) for the control group far exceeded the mean age (8 years, 4 months) for the experimental group. Based on the literature discussed in Chapter II, the maturation of the auditory system, particularly the corpus callosum matures at approximately 12 years of age. Therefore, it is assumed that the control group's maturation level was more advanced than the experimental group. Based on this information, the investigator expected to see significant differences between the two groups on pre-test results with the control group scoring higher. Even though the two groups were different in age, the pre- and post-test scores were analyzed based on whether or not the immature group (experimental) improved in relation to the mature (control) group.

The repeated measures ANOVA found statistically significant main effect differences existed on the pre-test scores between the experimental and control group for 4 of the 22 testing conditions when using a Bonferroni correction of $p = 0.0023$ ($p = .05/22$). Also, when comparing pre- to post-test scores, 7 of the 22 conditions were found statistically significant on the MANOVA. The clinical significance of the pre- to post-test scores were determined by analyzing the effect size (i.e., large effect [=/> 0.138], medium effect [0.059 – 0.137], small effect [0.01 – 0.058]) of the partial η^2 for the pre- and post-test scores reported by the MANOVA (Nolan & Heinzen, 2007). An effect size indicates that, while not statistically significant, there were improvements between the pre- and post-test scores.

Based on the results of this study, the DAT shows great strides in becoming a therapy program that could provide benefit for those individuals with (C)APD. Pre- and post-test measures (DAT, *SCAN-C/A*, *SSW*, and *Dichotic Digits*) were observed for statistically significant improvements, and any significant results were thought to be the evidence of the plastic changes desired.

DAT

On the DAT, the right ear leading by 150 milliseconds (ms) (R150) for the experimental group was observed to be statistical significant for the main effect (p = .001), suggesting there were differences among the two groups prior to administering the therapy. The experimental group had statistically significant post-test scores on the R150 (p = .030) when compared to the control group, suggesting that the experimental group scored better than the control group and that this was a result of plastic changes in the auditory system. There was a small effect size on the pre-R150 condition ($\eta^2 = .025$) and a large effect size on the post-R150 condition ($\eta^2 = .466$) for the experimental group when compared to the control group, suggesting that the right ear had not yet reached its fullest potential until after receiving the therapy. It also suggests that the therapy may help even a normal system reach its fullest potential faster than the normal maturation process.

Although there were no statistically significant results for the remainder of the DAT conditions (i.e. right ear leading by 300 ms [R300], left ear leading by 150 ms [L150], left ear leading by 300 ms [L300], and overall total [DATTOTAL] there were effect sizes present ranging from none to medium for the experimental group on the pre-testing conditions and medium to large for the experimental group on the post-testing conditions. The DAT Dichotic condition revealed a small effect size for the control group on the pre-testing scores and a large effect size for the experimental group on the post-testing scores. These results suggest that the control group and experimental group were almost the same on pre-testing conditions, but much improvement was seen for the experimental group on post-testing conditions. It can be concluded from these results, the DAT did not seem to be affected by the mean age differences between the groups and improved the dichotic listening skills of the participants who underwent the training and that these improvements were due to plastic changes within the central auditory system. The DAT screening tool may prove to be a useful testing tool for assessing a (C)APD.

Staggered Spondaic Word (SSW) Test

Prior to treatment, the two groups revealed statistically significant differences for the Total Errors (TOTAL) and Left Competing (LC) conditions. As mentioned previously, this difference between the two groups was expected and is presumably due to the difference in mean ages between the two groups. Also, there were statistically significant differences on pre-testing scores between the two groups for the LNC and LC conditions, suggesting that the control group scored higher than the experimental group on these conditions. However, after the treatment was administered, the post-test scores did not reveal any significant difference between the two groups for these two conditions, indicating that the scores between the two groups on the post-test were more alike. These results suggest that the experimental group has matured to the level of the control group.

When comparing the effect size of the pre- to post-testing scores, the differences between the two groups tend to decrease for the LNC and LC conditions, suggesting that the experimental group is maturing to the level of the control group after receiving the treatment. Despite the mean age difference between the two groups, the experimental group showed surprising improvements. This difference from pre- to post-testing scores is a result of plasticity taking place in the central auditory system specifically with binaural integration abilities.

SCAN-C/A

The conditions found on the *SCAN-C/A* to be statistically significant were the Competing Words for the Left Ear (CWL), Competing Sentences for the Right Ear (CSR), Competing Sentences for the Left Ear, and Auditory Figure Ground for the Left Ear (AFGL). On the *SCAN-C/A*, two conditions were significantly different for the experimental group compared to the control group (i.e., CWL, CSR). That is, the experimental group performed significantly different than the control group, presumably due to the age differences between the two groups. However, after the experimental DAT treatment, the experimental group was no longer significantly different on these two variables. There was statistical significance for the control group on the post-Competing Sentences for the Left Ear (CSL) ($p = .022$) when compared to the experimental group. However, when comparing the post-CSL to the pre-CSL, there seemed to be an indication of a learning effect taking place. There was statistical significance for the post-AFGL ($p = .049$) for the experimental group when compared to the control group, suggesting that the left ear improved after the therapy. The effect size on the post-AFGL (partial $\eta^2 = .401$) for the experimental group compared to the effect size on the pre-AFGL (partial $\eta^2 = .365$) for the control group also supported this finding. This was an unexpected finding, especially since the AFG subtest on the *SCAN-C/A* contains stimuli that are given in the presence of background noise and the DAT therapy did not contain material focused with this type of stimulus. This finding suggests that the DAT therapy may improve deficits in background noise.

Although not statistically significant, the Filtered Words for the Right Ear (FWR) revealed that the control group scored better than the experimental group when comparing the pre-test scores. However, when examining the post-test scores the experimental group and control group were more alike than they were for the pre-test. Therefore, the experimental group improved after receiving the DAT therapy on the FWR condition, which was not expected because filtered words was not apart of the DAT therapy.

On the pre-test scores, the control group scored better than the experimental group for the CSR and CWL subtests. After the experimental group completed the DAT therapy, their post-test scores were in closer proximity to the post-test scores of the control group. This is a direct result of plastic changes taking place in the auditory system. The CSL subtest revealed a statistically significant difference between the two groups on post-testing when compared to pre-testing for the control group. The control group's pre-test scores were a lot smaller in relation to the post-test scores, which were a lot bigger. This increase in scores from pre- to post-test is suggestive of a possible learning effect for this condition.

Dichotic Digits

The Dichotic Digits for the left and right ear did not reveal statistically significant differences for the main effect nor for the interaction, suggesting there were no differences between the two groups prior to and after the treatment. A medium effect size was observed for the experimental group on the pre- and post-Dichotic Digits Left ear (partial $\eta^2 = .097$; partial $\eta^2 = .088$) condition when compared to the control group. A large effect size was observed for the experimental group on the pre- and post-Dichotic

Digits Right ear (partial $\eta^2 = .186$; partial $\eta^2 = .004$) condition when compared to the control group.

In summary, there were significant differences between the two groups for the DAT, *SCAN-C/A*, and *SSW*. The right ear as well as the left ear showed improvement after receiving the DAT. It was also observed that the DAT improved the experimental group's listening abilities when the stimuli was distorted (i.e. FW) or in the presence of back ground noise (i.e. AFG). These two listening situations are major complaints of a person with a (C)APD. The changes observed in the experimental group are a direct result of the plastic changes occurring in the central auditory system due to the experimental treatment. The significant results observed for some of the conditions on the standardized tests were surprising and not expected, especially since the therapy was not focused on material with those stimuli in mind. To be able to obtain significant results on standardized test reveals that the DAT has great potential in becoming a useful screening tool and therapy program for those individuals with a (C)APD.

Limitations

Some of the limitations to this study are the small sample size and significant difference in the mean age of the participants between the two groups. As mentioned previously, there's a great possibility that if the mean ages where more approximate to each other, the experimental group's scores would have appeared better than predicted. Therefore, these results should be viewed cautiously and generalization limited.

Future Studies

Future studies should include longitudinal studies, in order to determine the stability or continued improvement/maturation in the auditory system. This can be accomplished by testing the participants every six months for two years to determine if the participant has increased, stayed the same or has digressed in their dichotic listening abilities since receiving the DAT. Since significant improvements were seen in the presence of background noise and filtered words, an expansion of the material including progressive filtering, adding background noise, and additional interaural timing differences on DAT (e.g., 200, 400, and 500 msec) may also improve auditory functioning. Also, keep in mind starting a therapy program with an easy task and increasing it to a more difficult task will give encouragement to the participant.

Many of the articles discussed in Chapter II revealed a support for electrophysiological testing in assessing the affects that auditory training has on the cortical levels of the brain. Therefore, incorporating electrophysiological testing into the testing protocol will add additional support and assess the effects of DAT at the cortical level. Also, the length of training and additional exercises directed toward the left ear should be investigated as well.

Also, it may prove to be beneficial to include some type of questionnaire that assess the classroom and academic performance prior to and after the study to determine if these changes that were observed during the treatment can be generalized to "real-world" situations. Also, by including parental and teacher ratings of children's performance could attest to functional changes.

While the results of this study are promising, much research is still needed to investigate the effects of directly stimulating the auditory system. The impact of (C)APD can be devastating and developing therapeutic tools to strengthen weak auditory systems could alter the academic, social, and emotional ramifications of this disorder.

APPENDIX A

AUDITORY PROCESSING CASE HISTORY

LOUISIANA TECH UNIVERSITY
SPEECH AND HEARING CENTER

P.O. BOX 3165 T.S.
306 ROBINSON HALL
RUSTON, LA 71272
Phone: (318) 257-4766
Fax: (318) 257-4492

Auditory Processing Case History

Date: ____________________

We are pleased that you have chosen to have your child evaluated at the Louisiana Tech University Speech and Hearing Center. In order to give us a comprehensive overview of your child we request that you fill out this questionnaire and return it to us as soon as possible. If there is insufficient time before your appointment, please bring it with you. If you have additional test results, school papers, personal observations that you wish to share with us, please enclose them with this questionnaire.

GENERAL HISTORY:

Child's Name: ____________________________ Age: ________ D.O.B. _________

Address: ____________________________________ Phone: ______________

City: __________________________ State: ___________ Zip Code: _________

Name of person answering questionnaire: ________________________________
Relationship to child: ___________________
Has your child been seen in this department before: ____________
If yes, when? ____
Father's Name: _________________________________ Age: _____________
Occupation: ___________________________________ Education: ____________
Mother's Name: _________________________________ Age: _____________
Occupation: ___________________________________ Education: ____________
Other Children in the Family:

NAME	AGE	SEX	ANY PROBLEMS?

List other adults in the home:

____

What is the primary language spoken in your home? ____________________________
Other? ___________________________

STATEMENT OF THE PROBLEM

Completely describe your child's Speech/Language/Auditory problem:

____

____

____

____

When was the problem first noticed?

____

____

What has been done about it?

____

____

What specific questions would you liked answered about your child's problem?

____

____

BIRTH AND DEVELOPMENTAL INFORMATION

Age of parents at child's birth: Mother: _______________
Father: _________________
Is this an adopted child? ______________________
Child's age at adoption: _____________________
Mother's health during pregnancy: Normal? _____________________________________
Amount of weight: Gain: ___________________ Loss: _______________ Diet: __________
Medications taken during pregnancy: ____
Any unusual conditions during pregnancy?

__________ Chicken Pox	__________ Asthma	__________ Flu
__________ German Measles	__________ Pneumonia	__________ Mumps
__________ Urinary Infections	__________ Sinusitis	__________ Toxemia
__________ High Blood Pressure	__________ Bronchitis	__________ Anemia

Other: ____
Full term child? ____________________ Birth Weight: __________
Labor and delivery: _____ Spontaneous ______Induced ______ Length of Labor ______

Check as many of the following as pertain to your child as a newborn:

________	Alert	_________	Oxygen	___________	Slow to breathe
________	Bruised	_________	Poor sucking	___________	Slow weight gain
________	Jaundiced	_________	Swallow		

Other:

____

Were there any feeding problems or formula changes?

____

Is there a Rh factor in your family? ___________
Other blood incompatibilities: ___________________________

Health of baby during first few months:

____

Describe your child's personality as an infant:

____

____

Indicate the age your child completed the following: (approximate ages are fine)

Turned from stomach to back: _______________________
Sit alone: _______________________
Crawl: _______________________
Walked alone: _______________________
Dress self: _______________________
Tie shoes: _______________________
Cut with scissors: _______________________
Skip: _______________________
Ride a bike: _______________________
Established hand preference: _______________________
Bowel trained: _______________________
Bladder trained: _______________________

What leisure activities does your child like to engage in alone?

____

____

What activities does your child like to do with his parent(s) or others?

____

____

At what age did your child begin to play organize sports? Which sports?

____

____

What is your child's reaction to organized sports?

____

____

____

Was normal development interrupted by anything?

____

____

____

MEDICAL HISTORY

Is your child generally healthy? ____

Which of the following medical conditions has your child experienced?

	Age/Severity		Age/Severity
Tonsillitis	____________	Head injuries	____________
Pneumonia	____________	Frequent Colds	____________
Earaches	____________	Allergies	____________
Tonsillectomy	____________	Adenoidectomy	____________
Ear Surgery (tubes)	____________	Seizures	____________
Measles	____________	Mumps	____________
Chicken pox	____________	Digestive upsets	____________

Other: ____

Does anyone in the family (parents, siblings, uncles, grandparents, etc.) have a similar problem?

____

____

Has your child ever been tested for allergies? When? ___________________________

____

PERSONALITY TRAITS/PHYSICAL CHARACTERISTICS

Which of the following descriptors best identify your child? Select as many as are appropriate:

hyperactive	self-sufficient	tires
circles under eyes	puffiness around eyes	nasal voice
bed wetting	joint aches	easy to anger
dependent	independent	aggressive
underactive	distractible	impulsive
short attention span	calm	too happy
itchy rashes	doesn't try	too controlled
difficulty sleeping	has few friends	depressed
easily frustrated	frequently nauseated	irritable
cries easily	bruises easily	helps others
lacks confidence	temper tantrums	sulks
fast worker	dawdles	hard to love
fearful	disorganized	takes turns
follows directions	responsible	good memory
good social skills	poor social skills	competitive

Would your child rather be a leader or a follower? ______________________________

Does your child have any unnatural fears? ___________________________________

What additional information would you like to tell us about your child's behavior?

____

____

SPEECH AND HEARING HISTORY

When did your child speak his/her first word? __________________________________

When did your child begin to use two word sentences? ___________________________

Does your child use speech: Frequently __________Occasionally________ Never______

Does your child prefer to use speech or gesture? (Give examples)

____

____

Which does your child prefer to use:
Complete sentences: ________________
Phrases: ____________________
One or two words ____________ Sounds __________________________
How well can your child be understood by: Parents ______________ Stranger ________
Brothers and sisters ________________________
Friends and playmates ______________________
Describe your child's auditory behavior:

____

____

____

Is noise a factor in your child's ability to understand information? Please describe:

____

____

____

READING HISTORY

How does your child feel about reading?

____

____

What comments do you get from the school about your child's reading ability?

____

____

____

At what age did your child begin to recognize letters by sight? ____________________

At what age did your child begin to identify the sound of letters? __________________

Does your child like to read to himself? ______________________________________

How do you rate your child's problem? Mild, Moderate, or Severe

________________________ Does not know letters and sounds

________________________ Can not decode words (sound out word)

________________________ Poor comprehension of what he reads

________________________ Inattentive to instruction

________________________ Inadequate reading vocabulary

Has your child changed schools recently? What was the effect on his reading instruction?

____

____

____

How often do you read to your child?

_________________ frequently _______________ often

_________________ occasionally _______________ seldom

Does your child reverse numbers or letters when reading or writing? _______________

Does your child learn best by : seeing ________ hearing __________ doing __________

EDUCATIONAL INFORMATION

School (Pre-School) ____

Address: ____

Principal's Name: ____

Teacher's Name: ____

Grade: ______________

Has he/she ever failed a grade? ________________
Which grade(s) ____________________________
Does he/she excel in any subjects? ______________________________________
Does he/she have any serious difficulty in any subjects: ________________________
How does he/she feel about school and his/her teachers? _______________________

Has he/she ever had any psychological tests? _____________________
When? _______________________
Where? _______________________
By Whom? ______________________________
Were the results interpreted to you? ________________________
Teacher or Parent Name: _____________________________________
Child's Name: ____

Read each item carefully and describe how much you think this child is bothered by these problems. Put your check in the box that is true of this child at the present time.

	Not at ALL	Just a Little	Pretty Much	Very Much
1. Restless in the "squirmy" sense.	______	______	______	______
2. Demands must be met immediately.	______	______	______	______
3. Temper outbursts/unpredictable behavior.	______	______	______	______
4. Distractibility or attention spans a problem.	______	______	______	______
5. Disturbs other children.	______	______	______	______
6. Pouts and sulks.	______	______	______	______
7. Mood changes quickly and drastically	______	______	______	______
8. Restless; always on the go.	______	______	______	______
9. Excitable, impulsive.	______	______	______	______
10. Fails to finish things that he starts.	______	______	______	______

<u>OPTIONAL</u>

How much of a problem do you think this child has at the present time (compared to age mates)?

NONE ________ MINOR________ MODERATE __________ SEVERE__________

APPENDIX B

RELEASE OF INFORMATION

Release of Information

I hereby give my permission to allow Dr. Sheryl S. Shoemaker/Chasity McCrum to review my child's record and make contact with me regarding inclusion in the study "Dichotic Auditory Training."

____

Child's Name

____

Parent or Guardian Date

____________________________________ Day Time Phone Number

____________________________________ Evening Phone Number

APPENDIX C

HUMANS SUBJECT CONSENT FORM GROUP A

HUMAN SUBJECTS CONSENT FORM

Experimental Group Group A

The following is a brief summary of the project in which you have been asked to participate. Please read this information before signing below:

TITLE: Dichotic Auditory Training

PURPOSE OF STUDY/PROJECT: The purpose of this project is to develop a new therapeutic tool for the treatment of children identified as having a central auditory processing disorder.

PROCEDURE: Prior to inclusion in this study, each child will receive a standard audiometric battery (otoscopic examination, tympanometry, acoustic reflexes, pure tone testing, speech reception threshold, word recognition testing), the *Staggered Spondaic Word* test, *SCAN-C: Test for Auditory Processing Disorders in Children-Revised (or SCAN-A)*, *Dichotic Digits (Single/Double)*, and a baseline DAT. Each child will receive multiple lists of monosyllabic words that are presented dichotically with varying degrees of overlap ranging from 300 msec to 100% overlap. All words will be presented at comfortable presentation levels. The child will be required to repeat the words heard. Each child will be required to spend a minimum of 30 minutes two times a week performing the exercises for a period of 4 weeks. At the end of the trial period, each child will receive a standard audiometric battery (otoscopic examination, tympanometry, acoustic reflexes, pure tone testing, speech reception threshold, word recognition testing), the *Staggered Spondaic Word* test, *SCAN-C: Test for Auditory Processing Disorders in Children-Revised (or SCAN-A)*, *Dichotic Digits (Single/Double)*, and a post-treatment DAT.

INSTRUMENTS: The subject's identity will not be used in any form in the analysis or representation of the data. Only numerical data such as percent correct will be used in the presentation of the results.

RISKS/ALTERNATIVE TREATMENTS: There are no known risks to subjects. These procedures do not vary from routine audiometric measures. The experimental aspect of this study is in the variation of time intervals of words presented dichotically. Participation is voluntary with parental consent.

BENEFITS/COMPENSATION: None.

I,________________________________, attest with my signature that I have read and understood the following description of the study, "Dichotic auditory training", and its purposes and methods. I understand that my and my child's participation in this research is strictly voluntary and my participation or refusal to participate in this study will not affect my relationship with Louisiana Tech University or the Louisiana Tech Speech and Hearing Center. I am aware that once the experimental treatment is completed, my child will receive traditional therapeutic procedures for the remainder of the Quarter, if applicable. This procedure will not substitute for any speech and language services currently being received. Further, I understand that I may withdraw my child at any time or refuse to answer any questions without penalty. Upon completion of the study, I understand that the results will be freely available to me upon request. I understand that the results will be confidential, accessible only to the project director, principal experimenters, myself, or a legally appointed representative. I have not been requested to waive nor do I waive any of my rights related to participating in this study.

I hereby give my permission for my child, ______________________________, to participate in the above mentioned study.

____ ________________________________

Signature of Participant or Guardian Date

CONTACT INFORMATION: The principal experimenter listed below may be reached to answer questions about the research, subject's rights, or related matters.

Sheryl S. Shoemaker, Au.D. Department of Speech (318) 257-4764

Members of the Human Use Committee of Louisiana Tech University may also be contacted if a problem cannot be discussed with the experimenters:
Dr. Les Guice (257-3056); Dr. Mary Livingston (257-2292 or 257-4315)

APPENDIX D

HUMANS SUBJECT CONSENT FORM GROUP B

HUMAN SUBJECTS CONSENT FORM

Control Group B

The following is a brief summary of the project in which you have been asked to participate. Please read this information before signing below:

TITLE: Dichotic Auditory Training

PURPOSE OF STUDY/PROJECT: The purpose of this project is to develop a new therapeutic tool for the treatment of children identified as having a central auditory processing disorder.

PROCEDURE: Prior to inclusion in this study, each child will receive a standard audiometric battery (otoscopic examination, tympanometry, acoustic reflexes, pure tone testing, speech reception threshold, word recognition testing), the *Staggered Spondaic Word* test, *SCAN-C: Test for Auditory Processing Disorders in Children-Revised (or SCAN-A), Dichotic Digits (Single/Double)*, and a baseline DAT. Each child will be required to return within 6 weeks to receive a standard audiometric battery (otoscopic examination, tympanometry, acoustic reflexes, pure tone testing, speech reception threshold, word recognition testing), the *Staggered Spondaic Word* test, *SCAN-C: Test for Auditory Processing Disorders in Children-Revised (or SCAN-A), Dichotic Digits (Single/Double)*, and a post-DAT.

INSTRUMENTS: The subject's identity will not be used in any form in the analysis or representation of the data. Only numerical data such as percent correct will be used in the presentation of the results.

RISKS/ALTERNATIVE TREATMENTS: There are no known risks to subjects. These procedures do not vary from routine audiometric measures. The experimental aspect of this study is in the variation of time intervals of words presented dichotically. Participation is voluntary with parental consent.

BENEFITS/COMPENSATION: None.

I,____________________________________, attest with my signature that I have read and understood the following description of the study, "Dichotic auditory training", and its purposes and methods. I understand that my and my child's participation in this research is strictly voluntary and my participation or refusal to participate in this study will not affect my relationship with Louisiana Tech University and the Louisiana Tech Speech and Hearing Center. Further, I understand that I may withdraw my child at any time or refuse to answer any questions without penalty. Upon completion of the study, I understand that the results will be freely available to me upon request. I understand that the results will be confidential, accessible only to the project director, principal experimenters, myself, or a legally appointed representative. I have not been requested to waive nor do I waive any of my rights related to participating in this study.

I hereby give my permission for my child, ____________________________, to participate in the above mentioned study.

______________________________________ ______________________________

Signature of Participant or Guardian Date

CONTACT INFORMATION: The principal experimenter listed below may be reached to answer questions about the research, subject's rights, or related matters.

Sheryl S. Shoemaker, Au.D. Department of Speech (318) 257-4764

Members of the Human Use Committee of Louisiana Tech University may also be contacted if a problem cannot be discussed with the experimenters:
Dr. Les Guice (257-3056)
Dr. Mary Livingston (257-2292 or 257-4315)

APPENDIX E

BASELINE DAT

Baseline DAT

Name:______________________________ Date:_______________________

EAR		CONDITION				
RIGHT	**LEFT**	**R300**	**L300**	**R150**	**L150**	**100%**
1. Perch	Bath					
2. Juice	Numb					
3. Pick	Nice					
4. Mess	Base					
5. Door	Raise					
6. Neat	Tire					
7. Rain	Wag					
8. Walk	Good					
9. South	White					
10. Dime	Reach					
11. Loaf	Dab					
12. Pearl	Date					
13. Keg	Ton					
14. Wife	Fit					
15. King	Fat					
16. Said	Fail					
17. Mop	Cause					
18. Back	Bone					
19. Merge	Chief					
20. Met	Hurl					
21. Shirt	Wash					
22. Young	Soap					
23. Pain	Youth					
24. Keep	Dead					
25. Third	Which					
26. Sour	Dog					
27. Ton	Keg					
28. Ring	Talk					
29. Thought	Pad					
30. Death	Jar					
31. Calm	Tool					
32. Doll	Pass					
33. Team	Germ					
34. Gaze	Voice					
35. Goose	Limb					
36. Make	Mob					
37. Turn	Bought					
38. Pole	Lid					
39. Chair	Lore					
40. Whip	Week					

41. Bite	Match					
42. Mill	Pike					
43. Shall	Road					
44. Rose	Kill					
45. Yes	Chalk					
46. Near	Lease					
47. Read	Shack					
48. Gun	Beg					
49. Live	Book					
50. Jail	Vine					

APPENDIX F

POST DAT

Post-DAT

Name:______________________________ Date:______________________

EAR		CONDITION				
RIGHT	**LEFT**	**R300**	**L300**	**R150**	**L150**	**100 %**
1. Perch	Bath					
2. Juice	Numb					
3. Pick	Nice					
4. Mess	Base					
5. Door	Raise					
6. Neat	Tire					
7. Rain	Wag					
8. Walk	Good					
9. South	White					
10. Dime	Reach					
11. Loaf	Dab					
12. Pearl	Date					
13. Keg	Ton					
14. Wife	Fit					
15. King	Fat					
16. Said	Fail					
17. Mop	Cause					
18. Back	Bone					
19. Merge	Chief					
20. Met	Hurl					
21. Shirt	Wash					
22. Young	Soap					
23. Pain	Youth					
24. Keep	Dead					
25. Third	Which					
26. Sour	Dog					
27. Ton	Keg					
28. Ring	Talk					
29. Thought	Pad					
30. Death	Jar					
31. Calm	Tool					
32. Doll	Pass					
33. Team	Germ					
34. Gaze	Voice					
35. Goose	Limb					
36. Make	Mob					
37. Turn	Bought					
38. Pole	Lid					
39. Chair	Lore					

40. Whip	Week					
41. Bite	Match					
42. Mill	Pike					
43. Shall	Road					
44. Rose	Kill					
45. Yes	Chalk					
46. Near	Lease					
47. Read	Shack					
48. Gun	Beg					
49. Live	Book					
50. Jail	Vine					

APPENDIX G

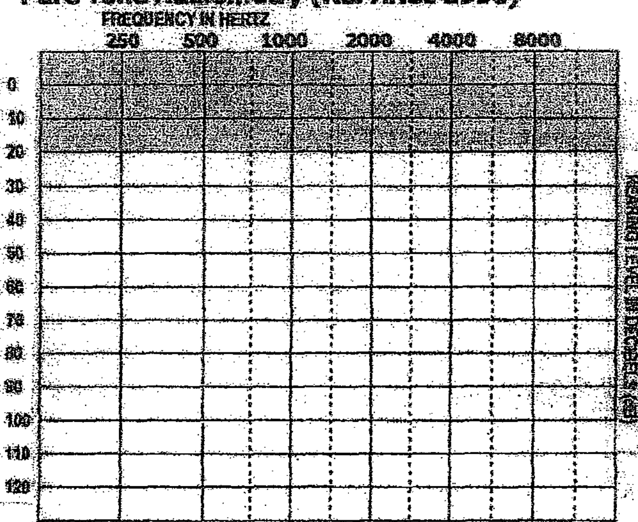
AUDIOLOGICAL EVALUATION

LOUISIANA TECH UNIVERSITY
SPEECH AND HEARING CENTER
RUSTON, LOUISIANA
P.O. Box 3165, Ruston, LA 71272 Phone: (318) 257-4764 Fax: (318) 257-4492

Name: ______________________ DOB: ____________ Gender: ___ Date: ________

Center File #: ______________________ Audiometer: ________ Reliability: ____________

Pure Tone Audiometry (Re: ANSI 1996)



MASKING

	R	L	R	L	R	L	R	L	R	L	R	L	
AC													AC
BC													BC

Acoustic Reflex Thresholds

Probe	Stim	500	1000	2000	4000
R	R				
R	L				
L	L				
L	R				
Reflex	Decay	500	1000		
R	L				
L	R				

Tympanometry

	R	L
Tymp Type		
Peak Pressure		
Gradient		
Static Compl		
Base Volume		

Otoacoustic Emissions (OAEs)

EMISSION TYPE USED	TEST TYPE PERFORMED
Transient	OAE Diagnostic
Distortion Product	OAE Screen
OAE RESULTS SHOWED THE	FOLLOWING:
Right Ear	
Left Ear	

Speech Audiometry

	Speech material	RIGHT	LEFT	BIN	AIDED	UNAID
SRT						
SDT						
PTA__						
MCL						
UCL						
Masking						
dB__	Speech material	RIGHT	LEFT	BIN	AID	UNAID
		%	%	%	%	%
		%	%	%	%	%
		%	%	%	%	%
Masking						

KEY

L	STIMULUS	R
X	AC	O
⊏	AC Mask	Δ
>	BC	<
]	BC Mask	[
↓	No Resp	↓
L	Aided SF	R
	SF	S

TEST TYPE	TRANSDUCER
Standard	Insert
Play	[illegible]
COR/VRA	Sound Field
BOA	

Hearing Aid Information

Right Ear ______________________

Left Ear ______________________

Otoscopy ______________________

Comments ______________________

____

____

____

Student Clinician ______________________

Clinical Educator ______________________

APPENDIX H

DAT EXERCISES

Exercise 1 (150L)
Name: ____________________; Examiner:________________
Date: _______________________ Lesson:____________________

Left		Right	
1. Pick	________	1. Nice	__________
2. Said	_________	2. Fail	__________
3. South	________	3. White	__________
4. Keep	_________	4. Dead	__________
5. Loaf	________	5. Dab	__________
6. Numb	________	6. Juice	__________
7. Chief	_________	7. Merge	_________
8. Wag	________	8. Rain	__________
9. Soap	_________	9. Young	__________
10. Ton	________	10. Keg	__________
11. Calm	_________	11. Tool	__________
12. Pike	_________	12. Mill	__________
13. Shack	_________	13. Read	__________
14. Rot	_________	14. Hate	__________
15. Live	_________	15. Book	__________
16. Voice	_________	16. Gaze	__________
17. Pad	_________	17. Thought	________
18.Bought	_________	18.Turn	__________
19. Chair	_________	19. Lore	__________
20. Bite	_________	20. Match	__________

Exercise 1 (150R)
Name: ____________________; Examiner: ________________
Date: _______________________ Lesson: ____________________

Right	Left
1. Base ________	1. Bath __________
2. Cause _________	2. Bone__________
3. Good_________	3. Hit__________
4. Youth _________	4. Wash__________
5. Date ________	5. Tire __________
6. Search________	6. Mob__________
7. Talk ________	7. Pass ________
8. Germ ________	8. Dog__________
9. Lid _________	9. Time _________
10. Road ________	10. Lease__________
11. Late _________	11. Kill __________
12. Beg _________	12. Food __________
13. Jug _________	13. Should __________
14. Five _________	14. Kick__________
15. Rat _________	15. Tape__________
16. Wire_________	16. Lean __________
17. Name _________	17. Sail _______
18. Tell ________	18. Wheat__________
19. Mouse________	19. Mood __________
20. Hit_________	20. Such__________

Exercise 1 (300L)
Name: ____________________; Examiner:________________
Date: ______________________ Lesson:____________________

Left	Right
1. Rat ________	1. Doll__________
2. Bar _________	2. Mouse__________
3. Talk ________	3. Hire__________
4. Search _________	4. Luck__________
5. Cab ________	5. Brush ________
6. Five________	6. Team__________
7. Pearl_________	7. Soup_________
8. Half ________	8. Chat __________
9. Road _________	9. Pole__________
10. Phone ________	10. Life __________
11. Pain _________	11. Base __________
12. Mop _________	12. Mess __________
13. Germ_________	13. Thin _________
14. Name _________	14. Ditch __________
15. Tell _________	15. Cool_________
16. Seize _________	16. Dodge __________
17. Youth ________	17. Hit ________
18. Late _________	18. Jug__________
19. Wire _________	19. Walk__________
20. Date _________	20. Win __________

Exercise 1 (300R)
Name: ____________________; Examiner: ________________
Date: _______________________ Lesson: ____________________

Right	Left
1. Pass ________	1. Doll ________
2. Back ________	2. Red ________
3. Wash ________	3. Sour ________
4. Bone ________	4. Get ________
5. Thumb ________	5. Sail ________
6. Yearn ________	6. Wife ________
7. Such ________	7. Neat ________
8. Peg ________	8. Mob ________
9. Gas ________	9. Check ________
10. Joint ________	10. Lease ________
11. Long ________	11. Chain ________
12. Kill ________	12. Hole ________
13. Lean ________	13. Tape ________
14. Tire ________	14. Dip ________
15. Rose ________	15. Came ________
16. Fit ________	16. Make ________
17. Vote ________	17. Judge ________
18. Food ________	18. Ripe ________
19. Have ________	19. Rough ________
20. Kick ________	20. Lose ________

Exercise 1 (Dichotic)
Name: ____________________; Examiner:________________
Date: ______________________ Lesson:____________________

Right	Left
1. Voice __________	1. Live _________
2. Learn __________	2. Ton ___________
3. Chair _________	3. Match ___________
4. Pike __________	4. Deep ___________
5. Read _________	5. Room ___________
6. Book _________	6. Calm ___________
7. Loaf __________	7. Dab _________
8. Shack _________	8. Goal ___________
9. Which __________	9. Far __________
10. Pick_________	10. Rot ___________
11. Said __________	11. Fail ___________
12. Haze__________	12. Wag ___________
13. Hush __________	13. White ___________
14. Pad __________	14. Dead ___________
15. Merge __________	15. Mill ___________
16. Keg __________	16. Juice ___________
17. Nice __________	17. Gin __________
18. Chief _________	18. Numb __________
19. Young _________	19. Gaze ___________
20. Tool __________	20. Keep ___________

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