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Effects of dichotic auditory training on children with central auditory processing disorder

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EFFECTS OF DICHOTIC AUDITORY TRAINING ON CHILDREN WITH CENTRAL AUDITORY PROCESSING DISORDER

by

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ABSTRACT

(Central) auditory processing disorder (CAPD) is a condition in which individuals with normal hearing present with difficulties often associated with hearing loss. While there are currently many tests available for the CAPD assessment, there are very few therapies for the remediation of a CAPD. A new therapy program, called Dichotic Auditory Training (DAT), aimed at improving the performance of those individuals with CAPD, was the focus of this study. Eight children between the ages of seven and twelve went through the four week training. The *Staggered Spondaic Word (SSW)* test, the *SCAN-C/A*, and a test designed after the DAT were given prior to and immediately following training. The results from these tests were analyzed for statistically significant differences between pre- and post-testing. Statistically significant results were yielded for six of the nineteen different testing conditions. All conditions that yielded statistically significant were those associated with the dichotic presentation of words. These results are thought to be reflective of plastic changes occurring within the central auditory systems, and a direct result of the training the subjects underwent. The results from this study offer much promise for the future of the remediation of CAPD.

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DEDICATION

This Dissertation is dedicated to my wife, Julie, who is a constant source of strength and inspiration in my life. And to my children, Tatum and Cooper, who blessed our lives in so many ways. Thank you for supporting me and understanding throughout this whole process.

I love and cherish you all.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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CHAPTER I: REVIEW OF THE LITERATURE

Introduction

The most recent definition of a (central) auditory processing disorder [(C)APD] was provided by the ASHA Working Group on Auditory Processing Disorders (2005), which states that a (C)APD can manifest as difficulties in one or more of the following areas: sound localization and lateralization; auditory discrimination; auditory pattern recognition; temporal aspects of audition; auditory performance in competing acoustic signals, i.e. dichotic listening; and auditory performance with degraded acoustic signals. Essentially, a (C)APD is a disorder that manifests as a hearing related problem that is not caused by a hearing loss. In children, (C)APD is typically attributed to neurological disorganization, damage to the brain, or lack of auditory maturation. (Central) auditory processing disorders can have a negative impact on academic performance, as well as in the home. After a review of available literature on (C)APD, it has become apparent that, while much research has been done regarding the definition and assessment, very little has been devoted to the remediation of this disorder.

There are different types of training and remediation techniques currently being used on individuals diagnosed with a (C)APD. These techniques include Earobics, Fast ForWord, and Auditory Integration Training (AIT). However, very little research has been done in regards to developing training exercises to remediate the dichotic listening skills of those with (C)APD. It is, therefore, the intention of this investigator to attempt to design a training regimen for those with (C)APD, specifically for those who show decreased dichotic performance. This decreased dichotic ability manifests itself in the inability, or decreased ability, to comprehend information in the presence of multiple sound sources. This can be especially destructive to a child in an academic setting where environmental sounds may interfere with what the teacher is saying. It is imperative that remediation of this type be developed to help children with (C)APD and prevent them from falling behind their peers academically.

Review of the Literature

Anatomy and Physiology

The auditory system is divided into two sections: peripheral and central. The peripheral auditory pathway is further divided into the outer, middle, and inner ear, while the central auditory pathway encompasses the auditory nerve, brainstem nuclei, and auditory cortices. Each part of the auditory system has a role in the perception of sound, and a problem or deficit in any one area has the potential of disrupting the detection and interpretation of an auditory signal. Therefore, when discussing (C)APD, it is important to understand the integral part each component of the auditory system plays in the process of hearing.

The Peripheral Auditory System

The peripheral system begins at the outer ear. The outer ear consists of the pinna and the external auditory meatus, or ear canal. Acoustical energy is collected and funneled by the pinna (i.e. the cartilaginous outer portion of the ear) to the ear canal, which carries the signal to the tympanic membrane, or ear drum.

The tympanic membrane is the beginning of the next part of the peripheral auditory system, the middle ear. The tympanic membrane has a conical shape and consists of connective tissue and a mucous membrane. Connected to the tympanic membrane are the ossicles, which are the three bones of the middle ear. The ossicles consist of the malleus, the incus, and the stapes. The footplate of the stapes is connected to the inner ear. The ossicles are arranged in a manner between the tympanic membrane and inner ear to function as a lever, moving with a pivotal motion. As long as the ossicles are functioning properly, any movement of the tympanic membrane sets the ossicles into motion, focusing the energy into the inner ear.

In addition to the ossicles, the middle ear has two muscles: the tensor tympani and stapedius muscle. These muscles serve as protection to the inner ear from potentially harmful noises and to decrease the intensity of sounds generated within the body.

The Eustachian tube is also a part of the middle ear and serves to maintain pressure within the middle ear to preserve maximum mobility of the tympanic membrane. This maximum mobility is reached when the pressure is equal on both sides of the tympanic membrane.

The function of the middle ear serves as an impedance matching device, that is, converts acoustical energy into mechanical energy. The overall purpose of the impedance matching device is to overcome the differences of impedance from an airborne sound to the fluid filled inner ear. The airborne acoustical energy strikes the tympanic membrane setting it into motion. The overall surface area and conical shape of the tympanic membrane helps to collect the sound and focus that energy into a much smaller area (i.e., the oval window). Once the tympanic membrane is vibrating, the lever action of the ossicles directs the energy into the oval window. The conical shape of the tympanic membrane serves to gather and focus the acoustic energy more efficiently. However, the largest contributor to the impedance matching device is called the areal advantage. The surface area of the tympanic membrane is 20 times that of the stapes footplate and accounts for approximately 27 dB of the total 30 dB of gain contributed by the impedance matching device. The force that moves the tympanic membrane is equal to the force that reaches the oval window; however, the pressure that reaches the oval window is 23 times greater. The lever action of the ossicles, which makes up the other 3 dB of gain, allows the increased force to be distributed to the oval window without losing any of the energy or damaging any portion of the hearing mechanism (Webster, 1999).

To summarize the middle ear and how sound travels through it, acoustic vibrations reach the tympanic membrane setting the ossicles into motion. The malleus is embedded in the fibrous layer of the tympanic membrane, so that as the vibrations move the tympanic membrane, the malleus is set into motion as well. The head of the malleus is attached to the incus, which is attached to the head of the stapes. Due to the shape and lever configuration, the ossicles are able to rock back and forth in a pivoting motion, transforming the acoustic energy received from the outer ear into mechanical energy. As the ossicles pivot, the mechanical energy of the middle ear is transferred to the oval window, which is the beginning of the inner ear, via the footplate of the stapes (Clark & Martin, 2002).

The inner ear consists of the cochlea (i.e., the portion for hearing) and a vestibular portion (i.e., the balance system). The cochlea is filled with extracellular fluids called perilymph and endolymph. Endolymph has a high concentration of potassium and a low concentration of sodium. Perilymph also has potassium and sodium, but in concentrations opposite to that of perilymph. This high concentration of potassium within the endolymph is vital to the function of the inner ear, as it is what causes the hair cells of the cochlea to be excited.

The cochlea is divided into three channels: the scala vestibuli, scala tympani, and the scala media. The scala vestibuli and scala tympani both contain perilypmh; the scala media contains endolymph and is separated from the other two channels by Reissner's membrane and the basilar membrane. The basilar membrane runs the length of the cochlea and is tonotopically organized; the higher frequencies are located at the stiffer basal end while the lower frequencies are located at the apical end.

Housed within the scala media and located on the basilar membrane is the organ of Corti. The organ of corti is a structure that contains numerous hair cells and supporting structures. There is a single row of 3,000 inner hair cells and three to four rows of outer hair cells numbering between 12,000 and 15,000. On top of each hair cell are stereocilia, which are arranged from shortest to tallest. The stereocilia are structures which detect and respond to the fluid motion through the cochlea. Inhibition or excitation of each cell is greatly dependent on the direction the stereocilia are deflected. Depolarization (i.e., the deflection of stereocilia from shortest to tallest) of a hair cell results in an influx of potassium ions from the endolymph into the root of the hair cell. This in turn causes the release neurotransmitters, creating an action potential, or electrical impulse, at the auditory nerve, resulting in its excitation. If stereocilia are deflected towards the shortest, the cell is hyperpolarized, or inhibited. No innervation occurs when the hair cell is hyperpolarized because the ion channels are effectively cut off by the deflection of the stereocilia from tallest to shortest.

The tectorial membrane is a gelatinous flap fixed in place on both its outer and inner edge of the scala media. Embedded in the undersurface of the tectorial membrane are the stereocilia. Also located within the scala media are numerous supporting cells and structures which provide rigidity to the organ of corti. Among these supportive structures are the inner and outer pillar cells, Deiters' cells, Hensens' cells, and Claudius' cells.

In summary, the footplate of the stapes transfers the mechanical energy of the middle ear to the inner ear, via the oval window, where the mechanical energy is transformed into hydraulic energy. The vibrations transmitted to the oval window cause the fluid of the cochlea to be displaced. The vibrations also displace the fluid within the cochlear duct, or scala media, causing the basilar membrane to move, shearing the hair cells and stereocilia. When the stereocilia of the inner hair cells bend from shortest to tallest, depolarization occurs, resulting in an influx of potassium ions entering the hair cell. This stimulates the release of neurotransmitters at the base of the hair cell. The neurotransmitter then generates an action potential of the auditory nerve.

The Central Auditory System

Exiting from the cochlea, the auditory nerve is a bundle of nerve fibers which innervate the outer and inner hair cells. The majority of these auditory nerve fibers are called Type I and comprise 95% of the fibers. They are myelinated and connect to the inner hair cells. Type II fibers are unmyelinated fibers and connect to the outer hair cells. The auditory nerve innervates the cochlear nucleus at the level of the pons in the brainstem.

The cochlear nucleus is located where the pons, medulla, and cerebellum meet, an area termed the cerebellopontine angle. Receiving ipsilateral input, the cochlear nucleus is divided into the anterior ventral cochlear nucleus, the posterior ventral cochlear nucleus, and the dorsal cochlear nucleus, and is made up of several different cell types, "including pyramidal, fusiform, octopus, stellate, and spherical cells" (Chermak & Musiek, 1997, p.28). There are three tracts that connect the cochlear nucleus to the higher levels of the central auditory nervous system; the dorsal acoustic stria, intermediate acoustic stria, and the ventral acoustic stria. While these three tracts transmit information both ipsilaterally and contralaterally, the majority of the fibers project contralaterally to the superior olivary complex. The dorsal acoustic stria fibers project to higher brainstem nucei: the lateral lemniscus and inferior colliculus. The ventral acoustic stria and intermediate acoustic stria relay information to both the ipsilateral and contralateral superior olivary complex.

The primary function of the superior olivary complex is to analyze sound between the ears, aiding in localization. It is comprised of several groups of nuclei, including the lateral superior olivary nucleus (LSO), medial superior olivary nucleus (MSO), the medial nucleus of the trapezoid body (MNTB), and the medial and lateral preolivary nuclei. The MNTB's main purpose is to transmit signals to the contralateral LSO, while the MSO and the LSO function to localize sound. This is accomplished through interaural timing differences and interaural intensity differences (Chermak & Musiek, 1997).

Interaural timing differences provide localization cues for the lower frequencies, or frequencies below 1500 Hz, and occur at the level of the MSO. Lower frequencies have longer wavelengths than the path around the head, thus diffracting the signal around the head. The difference in time between when the signal reaches the near ear compared to the far ear results in an interaural timing difference. Higher frequencies have smaller wavelengths and therefore reach the far ear with a reduced intensity. This reduction in intensity between the two ears is the interaural intensity difference, and the processing of this information occurs at the LSO. Once the signal is processed at the level of the superior olivary complex, it then travels on to the lateral lemniscus.

The lateral lemniscus is the largest fiber tract in the auditory brainstem. It is actually a conglomeration of six separate cell groups, but is still considered one tract because each cell group is "both structurally and functionally parallel" (Webster, 1999, p. 273). The fiber tracts that make up the lateral lemniscus are projections from the AVCN, PVCN, DCN, MSO, LSO, and VCN. The main function of the lateral lemniscus is to transmit signals to the inferior colliculus.

The inferior colliculus is the largest auditory center in the midbrain, as well the center which receives all auditory input. The main area of the inferior colliculus that receives auditory information is the central nucleus of the inferior colliculus (CNIC). The commisure of probst connects both central nuclei, allowing for the analysis of intensity information as well as the localization of sound. Some of the fibers of the central nuclei cross over the commisure of probst to the contralateral CNIC, while other "cell axons form the brachium of the ipsilateral inferior colliculus" (Webster, 1999, p.276). The fibers of the brachium transmit information to the medial geniculate body (MGB), located in the thalamus.

The MGB is the main auditory portion of the forebrain. It consists of a ventral, dorsal, and medial division. While the dorsal and medial divisions do receive input from the inferior colliculus, their main functions are thought to be more for arousal and auditory attention. The majority of specific auditory information is received and processed by the ventral division, and then transmitted to the primary auditory cortices, namely Heschl's gyri.

Heschl's gyri are the primary auditory cortices of the brain, and are also known as Brodmann's areas 41 and 42. The number of Heschl's gyri varies from one to three among individuals, as well as from hemisphere to hemisphere. Wernicke's area, also known as Brodmann's area 22, is located in the left temporal lobe, and receives input from Heschl's gyri from both hemispheres. Wernicke's area is the receptive language center that receives information from Heschl's gyri in the left hemisphere and also from Heschl's gyri in the right hemisphere via the corpus callosum. Also located in the left hemisphere is Broca's area (Brodmann's 44 and 45), the area of the brain that is responsible for the motoric aspects of speech. Information is passed from Wernicke's area to Broca's area via the arcuate fasciculus, which is composed of axons from both Wernicke's area as well as from other areas within the left temporal lobe.

Allowing for interhemispheric communication, the corpus callosum (CC) is a network of fibers connecting the two cerebral hemispheres. According to Chermak and Musiek, "the corpus callosum is composed of long, heavily myelinated axons" and is the "main connection between the left and right hemisphere" (1997, pp. 48-49). The corpus callosum communicates many types of sensory information, including visual, olfactory (smell), and auditory. The majority of the auditory fibers projecting from the temporal lobe are located in the sulcus of the CC, which is the thinnest portion of the trunk of the CC. The pathway auditory information takes from hemisphere to hemisphere is known as the transcallosal auditory pathway (TCAP). Starting from the auditory cortex, the TCAP "courses posteriorly, and runs superiorly around the lateral ventricles, crosses a periventricular area known as the trigone, and courses medially and inferiorly into the CC proper", and "any lesion of the TCAP can result in degraded interhemispheric transfer" (Chermak & Musiek, 1997, p. 49). While the brainstem reaches auditory maturity around eighteen months of age, the CC does not reach auditory maturity until eleven or twelve years of age. Therefore, the transfer of auditory information between the two hemispheres may not be as efficient until adolescence.

In summary, the hearing mechanism is divided into two sections. First is the peripheral system, where the acoustic signal is transformed into different forms of energy until it reaches the auditory nerve, where it finally becomes an electrical impulse. The auditory nerve is the beginning of the second system, known as the central auditory system. A disruption or abnormal functioning of auditory processing of an auditory signal, which cannot be attributed to a peripheral abnormality or loss, is thought to be the basis of CAPD. However, the human central nervous system has the ability to rewire itself, if stimulated efficiently. This ability of the central nervous system to change in response to stimulation is known as plasticity.

Plasticity

Musiek and Berge (1998) define plasticity as "the alteration of nerve cells to better conform to immediate environmental changes, with this alteration often connected to a behavioral change" (p. 18). In other words, plasticity is the ability of the central nervous system to change in response to stimulation, resulting in a behavioral change to that stimulus. The 1996 ASHA Task Force described plasticity as being "characteristic of the central auditory system, while stability is more characteristic of the peripheral auditory system" (p. 44). There are many terms associated with plasticity, including maturation, auditory stimulation, auditory deprivation, myelination, and long term potentiation.

Maturation, regarding the central nervous system, refers to the development of the neural pathways. The process of "maturation of neural pathways, especially association fibers, takes place over many years" (Keith, 1997, p. 102). In terms of maturation of the auditory system, maturation is closely related to auditory experience. As Chermak (2000) stated, "early experience shapes auditory behavior" (p. 13). If deprivation of auditory experience occurs at a young age, the effects can be detrimental to auditory development.

When there is improper auditory stimulation, the systems within the body that require stimulation change neurally, often resulting in loss of function or loss of efficiency within the neural pathways of that system (Chermak & Musiek, 1997; Musiek & Berge, 1998). The adage "if you don't use it, you lose it" is an accurate assessment regarding the consequences of a lack of auditory stimulation during childhood, particularly early childhood when there is a tremendous amount of development and learning occurring.

Myelination of the neural networks also greatly influences maturation, and therefore, plasticity. Myelin is the white matter in the CNS that covers the axons of nerve fibers, as well as insulates them. The amount of myelin covering an axon is related to how quickly the axon conducts impulses. The more myelin an axon has, the quicker it can conduct those impulses, and vice versa. While some areas of the CNS reach maximum myelination at or around the age of two, other areas, such as the corpus callosum, can take as long as twenty years to reach adult myelination. The relationship between maturity and myelination is a direct one. The more myelinated a structure is, the more mature it is. Structures that are lightly myelinated often cannot carry out their functions, or at least not as efficiently. This is thought to be evident in the varying performances among (C)APD test scores among children of the same age. The decreased performance on (C)APD tests of some children may be directly related to the amount of myelination covering the axons of the structures required to perform those tasks, and therefore, the maturation level of those structures (Chermak & Musiek, 1997).

Chermak and Musiek (1997) also investigated the relationship between plasticity and auditory stimulation. They described how the plasticity of the central nervous system is related to the maturity of that system. Essentially what they found was that the younger the system, the more plastic it is. This finding holds great promise for auditory training. Although a child may have been deprived of the auditory stimulation needed to fully develop the auditory centers of the brain, it may be possible that repeated exposure to auditory stimulation may allow a child, in essence, to "catch up". According to several sources (Chermak, 2000; Chermak & Musiek, 1997; Musiek & Berge, 1998), auditory stimulation is necessary to invoke plastic changes within the CNS. Further evidence of this was discussed by Keith and Jerger (1991) whose research involved auditory training of both children and adults with known lesions of the brain. They concluded from these studies that "the immature brain is capable of functional reorganization that tends to normalize perceptual function" (Keith & Jerger, 1991, p. 241). This plastic change of the neural structures, which result in the increased function of those structures, is known as long term potentiation.

Long term potentiation (LTP) is defined as "the condition when the strength of transmission at many synapses increases with repetitive use", and that these changes "can be demonstrated months after the initial stimulation regime" (Chermak & Musiek, 1997, p.70). According to Musiek and Berge (1998), in order to be classified as LTP, the effect (i.e., strengthened neural transmission) has to last for more than minutes. They also stated that these changes, which were occurring in the CNS neurons, were a result of repetitive use. The changes taking place indicate a strengthening in neural transmission, and, theoretically, increased myelination (Chermak, 2000). Again, this is evidence of the plastic capabilities of the CNS.

There are three different types of plasticity: developmental, compensatory, and learning related. Developmental plasticity occurs naturally, as long as auditory stimulation is sufficient. Plasticity which occurs after some type of damage is incurred by the CANS is known as compensatory. This is often seen in individuals who have suffered head trauma (e.g., car accidents, blunt force trauma, etc.). Performance on tests that assess the status of their CNS show results much better than would be expected based on the extent of the damage. However, due to compensatory plasticity, other structures take over the functions of the affected areas (Musiek & Berge, 1998).

Learning related plasticity, a third type, essentially means that with exposure to new experiences (i.e., stimulation), the CNS is able to change and integrate the processing of new information. Auditory stimulation, as has been previously discussed, is essential to the plastic changes observed in the CANS. Musiek and Berge (1998) postulated that if one could control and manipulate experiences (e.g., a stimulus), essentially creating a treatment, one could possibly predict the resultant behaviors of those receiving the treatment. For example, in the case of a child with identifiable auditory deficits, auditory experiences (therapy/treatments) can be created to target those deficits. In doing so, it may be possible to predict an improvement in those identified areas. Utilizing the model provided by Musiek and Berge (1998), the therapy would serve as the stimulus; while the changes observed between pre- and post-testing would be the result of plastic changes occurring within the neurons of the CANS.

Auditory training is known to alter the neural activity of the CANS, as noted by Tremblay and Kraus in 2002. In their study, electrophysiologic measures were used to measure neural changes that occurred as a result of auditory training. The results of their study indicated that there were changes in performance after training. Another study, conducted by Hayes, Warrier, Nicol, Zecker, and Kraus (2003) also sought to establish if performance was increased in children following auditory training. These researchers found that auditory training did alter the processing skills and cortical representation of speech in quiet and in noise in children with learning impairments.

It is imperative that clinicians capitalize on the fact that the younger a person is the more plastic their CANS may be. If children are identified early and auditory training provided, the devastating effects of a (C)APD on development and academic progress may be minimized or eliminated altogether.

Definitions and Characteristics

The definition of a (C)APD is a controversial issue with many opposing views. Due to the discrepancies among the many definitions of (C)APD, it is important to consider each one to fully understand the subtleties of the disorder.

One of the more recent definitions of (C)APD was proposed by the American Speech-Language-Hearing Association (ASHA) Working Group on Auditory Processing Disorders (2005), which supports the ASHA Task Force on Central Auditory Processing Consensus Development (1996) definition. According to both groups, (C)APD can manifest as difficulties in one or more of the following areas: sound localization and lateralization; auditory discrimination; auditory pattern recognition; temporal aspects of audition; auditory performance in competing acoustic signals (i.e., dichotic listening); and auditory performance with degraded acoustic signals. The ASHA Task Force (1996) also reported that "these mechanisms and processes are presumed to apply to nonverbal as well as verbal signals and can affect many areas of speech and language" (p.41).

Therefore, the ASHA Working Group (2005) and ASHA Task Force (1996) define a (C)APD as an inability to comprehend a signal in one or more of the above mentioned domains. In addition, the Task Force stated that some believe a (C)APD "may stem from a more general dysfunction, such as an attention deficit or neural timing deficit, which affects performance across modalities" (1996, p. 2). The 2005 Working Group also states that:

> Although abilities such as phonological awareness, attention to and memory for auditory information, auditory synthesis, comprehension and interpretation of auditorily presented information, and similar skills may be reliant on or associated with intact central auditory function, they are considered higher order cognitive-communicative and/or language related functions and, thus, are not included in the definition of CAPD. (p. 2)

While (C)APD may lead to or be associated with difficulties in higher order skills, the 2005 Working Group stated that (C)APD is specifically a "deficit in neural processing of auditory stimuli that cannot be attributed to these higher order skills" (p. 2). The working group also reported that (C)APD may coexist with other disorders; however, "it is not the result of these disorders" (p. 2).

Many of the behaviors exhibited by children with (C)APD are similar to those behaviors exhibited by children with hearing loss. Jerger and Musiek (2000) describe (C)APD in much the same way as the ASHA groups, however in their definition a

(C)APD can exist in the presence of normal peripheral hearing or with a hearing loss. Therefore, both authors felt that a more appropriate term for the disorder would be auditory processing disorder, due to the possibility of interactions between both central and peripheral sites. They believed that an auditory processing disorder was indicative of a deficit of the auditory modality only, or "as a deficit in the processing of auditory input" (p. 468).

In 1999, Keith discussed the 1996 definition of (C)APD proposed by the ASHA Task Force. Keith (1999) stated this definition was "inclusive, recognizing the contribution of neurocognitive, attentional, and auditory factors" (p.340). Keith also compared the 1996 ASHA definition to the definition proposed by Cacace and McFarland (1998). While the task force suggested that a (C)APD can coexist with other disabilities, Cacace and McFarland felt that this was too broad and that (C)APD should be viewed as modality specific. The term modality specific, which had been defined earlier by Cacace and McFarland in 1995 suggested that "the deficit in question critically depends on the use of information presented to a specific sensory system", and that, "in the case of (C)APD, the deficit should occur primarily when the subject deals with acoustic information and not when similar information is presented in other sensory modalities (e.g., visual, tactile, or olfactory)" (p.237).

In both their 1995 and 1998 articles, Cacace and McFarland postulated that the primary deficit associated with (C)APD should manifest itself in tasks requiring the processing of acoustic information exclusively. When an individual presents difficulty processing information auditorily and difficulty with other sensory modalities, the problem should not be assumed to be a (C)APD. However, if other sensory modalities are functioning normally in the presence of auditory dysfunction, a (C)APD is more likely. Cacace and McFarland's definition therefore contrasts the definition proposed by the 2005 ASHA Working Group and 1996 ASHA Task Force, who consider (C)APD to be a disorder which may coexist with, or be a cause or symptom of other disorders.

Keith proposed a definition in 1997 similar to that of the two ASHA groups. Keith defined (C)APD as a "dysfunction of one or more of the basic processes involved in understanding spoken language, which may manifest itself in an imperfect ability to listen" (p.101). More specifically, Keith defined (C)APD as:

> The inability or impaired ability to attend to, discriminate, remember, recognize, or comprehend information presented auditorily even though the person has normal hearing sensitivity, and that these difficulties are more pronounced when listening to low-redundancy (distorted) speech, when there are competing sounds, or in poor acoustic environments. (p.101)

While there may be some discrepancy regarding the definition of (C)APD, one aspect remains constant. A (C)APD is characterized by an inability to process auditory information when there is any degradation or competition with the signal. There are numerous other characteristics seen in the literature that depicts the symptoms of children with (C)APD. These characteristics can be divided into three different groups: hearing related, academic, and behavioral. These characteristics have been compiled from a number of different resources including Keith, 1997; Keith, 1999; Schminky & Baran, 1999; Keith, 2000a; Chermak, Tucker, & Seikel, 2002; Ciocci, 2002; and Bellis, 2004.

Many of the hearing related symptoms or characteristics are not as overtly recognizable unless in a testing situation. According to Keith (1997), many children with (C)APD have trouble with localization of sound and request repetition constantly. Auditory discrimination deficits and difficulty understanding speech in the presence of background noise are also often found in children with (C)APD. Other hearing related characteristics include inconsistent responses to auditory stimuli, lack of attention to auditory stimuli, and difficulty understanding rapid or distorted speech. In addition, the case history often reveals a history of otitis media.

Regarding academic characteristics, Schminky and Baran (1999) listed difficulty taking notes, reading, and/or spelling as manifestations of CAPD. Keith (1999) also mentioned a deficit in remembering phonemes and being able to manipulate them, which could possibly be the underlying cause of the difficulty with spelling and reading. In addition to phoneme awareness and their manipulation, Keith stated that carrying out multi-step directions can also be difficult for children with (C)APD, which is indicative of a short term memory deficit.

Memory deficits, as well as fatigue when participating in school lessons, were also mentioned by Keith in 1999. Children with (C)APD often fatigue easily due to the constant attention and effort that they have to exert in order to follow the lessons. This fatigue often exacerbates the difficulties they already have, eventually leading to falling behind their peers academically.

Distractibility and restlessness are two common behavioral characteristics associated with CAPD. Due to distractibility, following conversations can also prove to be a difficult task for a child with (C)APD. While the two can be seen as behavioral characteristics in other disorders, Bellis (2004) estimated that possibly half of the children diagnosed with learning disability may exhibit characteristics of a (C)APD. To accurately diagnose a (C)APD, Jerger and Musiek (2000) suggested that the diagnosis should be made only through the use of a thorough test battery administered by a certified professional, as well as through collaboration with other professionals, parents, and teachers.

Test Battery

As we have seen in the definition of (C)APD, it is a disorder which may, in fact, coexist with other disorders. Due to this possibility of interaction, Keith (1991) suggested that any test used to determine the presence of a (C)APD:

> Must be (1) sufficiently easy in terms of linguistic-cognitive demands and mode of responding to be insensitive to developmental differences in cognitive skills but (2) sufficiently difficult in terms of auditory perceptual demands to be sensitive to the presence of central auditory deficits. (p. 243)

In order to achieve this, measures used in the assessment of (C)APD require sensitized material, or material that has been altered.

Sensitized material may include speech that has been degraded, commonly known as low redundancy speech. Degradation of the speech signal can be accomplished through filtering, time-alteration, intensity-alteration, and through the addition of competing noise or speech. According to Keith (2000a), individuals with normal hearing and auditory processing skills should be able to comprehend sensitized materials.

However, a person whose central auditory processing abilities are compromised will have difficulty with the distorted material, and therefore perform poorly on the test.

The premise underlying sensitized speech is the reduction of extrinsic redundancy, allowing for the assessment of the CANS (i.e., intrinsic redundancy). Extrinsic redundancy refers to the information related to phonological, syntactical, and semantic content and rules of language. Due to extrinsic redundancy, an individual with normal processing abilities is able to comprehend a signal, even when the signal is degraded, due to the wealth of information provided by language. Intrinsic redundancy is the anatomical, physiological, and biochemical overlap within the CANS. Essentially, due to intrinsic redundancy, if a neurological disorder is present, other parts of the CANS can take over the functions of the damaged or impaired regions. If a person does poorly on a behavioral (C)APD test, those results indicate poor intrinsic redundancy within the CANS of that individual, and therefore, a (C)APD is assumed to exist.

There are several sources, (ASHA Task Force, 1996; Keith, 1997; Jerger & Musiek 2000; ASHA Working Group, 2005; ASHA Preferred Practices 2006), which discuss minimum requirements for a (C)APD test battery, targeting specific auditory processes. First, these sources recommend a thorough case history offering the clinician the opportunity to discuss with the parent or guardian the problems a child may be experiencing. The case history also functions to guide the clinician in individualization of the assessment.

A second recommendation made is that a basic audiological evaluation (i.e., pure tones and speech) be included to rule out peripheral hearing loss. According to Keith

(1997), a person with a (C)APD has "an inability or impaired ability to attend to, discriminate, remember, recognize, or comprehend information presented auditorily even though the person has normal hearing sensitivity" (p.101). Therefore, a complete hearing evaluation (i.e. pure-tone threshold, speech reception threshold, word recognition) is a necessary part of any (C)APD battery.

In addition, electrophysiologic, electroacoustic, and neuroimaging tests are considered by many researchers as beneficial to a (C)APD test battery. Jerger and Musiek (2000) stated that these measures can be time consuming as well as expensive, while the behavioral measures, conversely, are easily accessible and inexpensive to administer. Because of this, electrophysiologic and electroacoustic measures, as well as neuroimaging procedures, are often not included in the test battery. When available, however, these methods of testing are recommended.

A final recommendation of experts in the area of (C)APD includes behavioral measures. These measures require the patient to respond to a stimulus, either verbally or motorically (e.g., raising their hand) when they hear a tone. Behavioral measures require the patient to be an active participant in the testing.

One behavioral measure recommended by researchers is the assessment of temporal processing. Tests targeting temporal processing may utilize sensitized speech, but could also include click or tonal stimuli. According to ASHA (1996), temporal processing includes: temporal resolution, temporal masking, temporal integration, and temporal ordering. Keith (2000a) describes temporal processing as dependent on our ability to perceive frequency transitions in speech and lend to our ability to discriminate auditorily. According to ASHA (2005), common tests of temporal processing include pattern recognition, gap detection, and fusion discrimination.

Other common behavioral assessment paradigms suggested in the literature include monotic, diotic, and dichotic stimuli. Monotic tests consist of stimuli presented to one ear at a time. The premise behind monotic testing is that in a normal functioning auditory system sufficient comprehension of a degraded signal should occur due to the "richness of the neural pathways in our auditory system" (Schminky & Baran, 1999, p. 4). One example of monotic testing is filtered speech, which reduces acoustical energy in mid and high frequencies. Through filtering we are able to assess auditory closure abilities, or the ability to fill in the blanks caused by the filtering. Jerger and Musiek (2000) also stated that monotic testing is performed in order to detect asymmetries between the ears, which may indicate a problem specific to one hemisphere of the brain (p. 471).

Diotic testing, also known as binaural interaction, refers to testing that involves the presentation of the same stimulus to both ears simultaneously. These tests assess an individual's ability to process signals that are dependent on intensity and/or timing differences. ASHA (2005) reported that difficulty with diotic testing may indicate a breakdown in processing between the ears, most often at the level of the brainstem.

Dichotic testing, which is of particular importance to this study, is also often included in the (C)APD test battery. Dichotic testing consists of presenting different stimuli to each ear and asking the person to recall one or both stimuli. In 2000, Keith described two types of tasks used in dichotic testing: free recall and directed ear. When an individual is asked to repeat the information presented, regardless of the order of presentation, the term free recall is used. For a directed ear task, the stimuli are presented simultaneously and the person recalls the stimuli in the designated order.

Dichotic testing assesses a person's ability to integrate and separate auditory information. Auditory integration, also known as divided attention, is evaluated through requiring the individual to recall both stimuli. Dichotic testing involving recall of only one stimulus assesses auditory separation. Schminky and Baran (1999) also call this directed attention and requires an individual to focus on and successfully process information presented to one ear while ignoring the stimulus presented to the other ear.

The concepts related to dichotic testing (i.e., directed ear, free recall, auditory separation, and auditory integration) are essential in the evaluation of the CANS. According to Keith (2000a), abnormal dichotic test results are indicative of auditory maturation delays, which may be associated with neurological disorganization and possibly damage to the auditory pathways.

In addition, the dichotic paradigm is sensitive to ear advantages (i.e., when performance in one ear is better than the performance in the other ear). In the normal developing auditory system, stimuli directed to the right ear has direct access to the language centers of the brain located in the left hemisphere. This leads to the typical finding of a right ear advantage until a child reaches 11 to 12 years of age. It is around this age when the final portion of the corpus callosum reaches "adult-like" maturation and the left ear will perform similarly.

During free recall tasks, the information presented to the right ear is most often the first to be recalled. When a right ear advantage is reported it is not usually seen as a concern. However, if an abnormally large right ear advantage is found it can be indicative of an immature auditory system. A left ear advantage is typically associated with possible damage of the auditory reception areas of the left hemisphere or right hemisphere dominance for language.

Three dichotic tests considered to be useful in the assessment of (C)APD are the *SCAN-C: A Test for Auditory Processing Disorders in Children* (*SCAN-C*), the *SCAN-A: A Test for Auditory Processing Disorders in Adults (SCAN-A)*, and the *Staggered Spondaic Word* (*SSW*) test. The purpose of the *SCAN-C* is to test an individual's performance on four sensitized speech measures. The *SCAN-C* has been normed on children ages 5 years, 0 months to 11 years, 11 months. Anyone over the age of 12 years is evaluated using the *SCAN-A*. Total time of testing from administration to scoring is typically no longer than 30 minutes. While the *SCAN-C/A* are very efficient and useful, they are a screening tool and should be used in conjunction with other tests of auditory processing ability for diagnostic purposes.

The *SCAN-C/A* has been used for a number of different purposes. According to the *SCAN-C/A* manual, it has served as a means to study auditory processing, language, and learning problems in children, adolescents, and adults. The *SCAN-C/A* has also been used to study the auditory processing abilities of children with academic difficulties and attention deficit disorders (Keith, 2000b). While it has been used as a screening tool for determining the possible presence of a (C)APD in both children and adults, Domitz and

Schow (2000) also noted that it could also be used for diagnostic purposes, though not by itself.

The *SCAN-C/A* consists of four subtests: Filtered Words, Auditory Figure Ground, Competing Words, and Competing Sentences. The Filtered Words subtest consists of the monotic presentation of words which are filtered with a 1000 HZ low pass filter or 750 Hz for *SCAN-A*. Filtering reduces the information contained in those frequencies above 1000 (750) Hz, making it harder for the subject to perceive the stimulus. While also being presented monotically, the Auditory Figure Ground subtest uses words presented in the presence of background noise (i.e., cafeteria noise). By presenting speech to one ear while simultaneously presenting the cafeteria noise (+8 dB signal to noise ratio for *SCAN-C*, +4 dB signal to noise ratio for *SCAN-A*) below the level of the speech to the same ear, it is possible to assess the individual's ability to perceive speech in the presence of a competing signal.

The Competing Words and Competing Sentences subtests are both presented in the dichotic paradigm. The Competing Words subtest, which is an auditory integration task, consists of two words being presented (i.e., one to each ear simultaneously). The words overlap each other and for the first fifteen words the person is asked to recall the word presented to the right ear first and for the second set of fifteen words the person is asked to repeat the left ear first.

The Competing Sentences subtest, an auditory separation task, requires the individual to repeat a sentence in the designated ear while ignoring a sentence being presented to the other ear. Both of these subtests assess the CANS using a competing signal, as did the Auditory Figure Ground subtest; however, these tests also assess the individual's ability to separate and integrate auditory information.

The *Staggered Spondaic Word (SSW)* test is a dichotically presented, directed ear task which assesses auditory integration. According to Katz (1998) the *SSW* test is considered a highly reliable and sensitive test of central auditory functioning. It is a relatively easy test to administer and score, typically taking no longer than 20 minutes to complete. This makes the *SSW* test a highly efficient test to include in the (C)APD test battery, and according to Chermak, Silva, Nye, Hasbrouck, and Musiek (2007), is today one of the six most frequently used tests in the assessment of (C)APD.

In 1962, Katz discussed the finding that basic audiometry did not reveal what was called "cortical hearing" impairments. In order to diagnose the presence of this type of impairment, the patient needed to be tested utilizing more difficult material. This was the basis for the development of the SSW. In 1963, Katz, Basil, and Smith found that the *SSW* was of great value in that it, unlike many other tests of that time, was successful in localizing cortical hearing impairments, and that the difficulty to cope with difficult test material resides primarily in the ear contralateral to the affected hemisphere.

The *SSW* test consists of four conditions: right competing (RC), right non-competing (RNC), left competing (LC), and left non-competing (LNC). The stimuli are spondaic words (i.e., two syllable words with equal emphasis on each syllable) presented at 50 dB SL. Presentations alternate between right ear first and left ear first tasks. This design allows the clinician to analyze the results for "cortical hearing" impairments, which Keith (1983) also found to be beneficial in localizing the problem to either the left or right hemisphere. Specifically, the affected hemisphere would be the one contralateral to the poorer performing ear.

Keith (1983) stated that poor performance on the *SSW* does not necessarily indicate a lesion, but possibly an indication of auditory maturation delay, which should typically conclude around twelve years of age. This, Keith reported, was the most prevalent abnormal finding.

Katz and his colleagues (1963) thought of the *SSW* as more of a site of lesion test, while Keith (1983) felt that it would be more appropriate to use the *SSW* as a means of establishing auditory maturation. In addition to auditory maturation delays, Keith found the *SSW* to be sensitive to difficulties in directing attention from ear to ear and short-term memory deficits. By utilizing the *SSW* to assess individuals for these problems, Keith felt that it would offer a basis for management planning.

There are four categories of dysfunctions a person with (C)APD may exhibit as identified by the *SSW*: Decoding, Tolerance-Fading Memory, Integration, and Organization. A person with Decoding problems may have difficulty processing speech and may exhibit poor phonics skills, spelling difficulties, and receptive language and oral comprehension difficulty. Individuals who fall under the Tolerance-Fading Memory category have difficulty comprehending speech in the presence of background noise, as well as a lack of short-term auditory memory.

Individuals identified as having Integration difficulties have trouble assimilating oral and visual information presented simultaneously and may present with extreme learning disorders. There are two sub-categories under Integration: Type I and Type II. A person classified as a Type I may also have decoding problems, while a person classified as a Type II may also have Tolerance-Fading Memory problems. Due to the severity of the problems associated with Integration, poor academic performance is often encountered in these individuals (Katz, 1998).

Individuals identified under the Organization category have difficulty organizing and sequencing information presented orally. There may also be some organizational problems not associated with verbal information. While this may seem like a relatively minor problem, organizational deficits can exacerbate other auditory and/or academic problems (Katz, 1998).

Therapeutic Programs

While only a few diagnostic tests were discussed, there are numerous tests available that assess different aspects of the central auditory system. One area lacking research is the treatment of (C)APD. In addition, there are currently no programs which concentrate primarily on auditory integration and separation. As discussed earlier, these two aspects of auditory performance are critical. The abilities to integrate and separate information presented auditorily are important when one considers the typical classroom environment.

In a typical classroom, there are many signals that may interfere with the teacher's voice (i.e., air conditioner, other students, etc.). Therefore, a child who cannot separate or integrate information presented simultaneously, i.e. the teacher's voice and background noise, may have difficulty comprehending what the teacher is saying. For this reason, training to resolve this problem is necessary. This is not to say that training in other areas is not equally important, but training that increases everyday function is vital to a child diagnosed with (C)APD. Computerized therapy programs currently available for individuals with (C)APD include the Fast ForWord program and Earobics.

Fast ForWord

The Fast ForWord program is a computer-based program which addresses problems with receptive language skills with the primary target being decoding. A person with a decoding deficit has difficulty discriminating among the numerous sounds, which decreases an individual's processing rate. Difficulty with decoding is often seen in individuals with a (C)APD and therefore Fast ForWord is often utilized as a therapeutic intervention strategy (Cinnoti, 1998).

Fast ForWord consists of animated games in which children are asked to identify what is heard. The instructions are first given at a rate manipulated to be slower than average speed. As the child masters each presentation level, the computer automatically increases the rate at which instructions are given, while also increasing the difficulty of the task. By slowly increasing the presentation and difficulty, each child is able to progress through the program at his or her own speed while being continually challenged, as well as encouraged, as each success is rewarded with an animation. The goal of Fast ForWord is that once the child has completed the program he or she will have learned to perceive sounds at a processing rate equal to that of average listeners (Yencer, 1998).

Fast ForWord is based on two theoretical assumptions. One assumption is that (C)APD is caused by a decreased ability to process temporal information. This means that the individual with (C)APD has difficulty comprehending rapidly presented visual and auditory information. While multiple etiologies may cause this, a temporal processing deficit has the potential to influence neurological development, resulting in a delay in language development.

The second theoretical assumption on which Fast ForWord is based is brain plasticity. As previously discussed, when the brain experiences new stimuli repeatedly, new neural groups within the brain have the potential to form and strengthen over time. The application of this theory in Fast ForWord can be seen in the progression of the training, which involves increasingly difficult, and continual, temporal processing requirements. It was also reasoned that not only does this have the potential to improve a child's temporal processing deficit; it also has the potential to improve a child's language learning ability (Gillam, 1999).

A recent study conducted by Battin, Young, and Burns (2000) evaluated the Fast ForWord program and its effectiveness in treating (C)APD. Their study involved 15 children between the ages of 5 and 11 who had been identified as having (C)APD using the *SCAN-C*. In addition, parts of the *Test of Language Development* (*TOLD*) were given to individuals who required language testing. Post-test scores revealed improvements in the Filtered Words and Competing Words subtests of the *SCAN-C*, as well as improvements in the overall standard score on the *SCAN-C*. Post-test scores on the *TOLD* showed improvements in the Oral Vocabulary, Grammatical Understanding, and Sentence Imitation subtests, as well as standard scores. Battin and his colleagues (2000) concluded from this study that an intensive computer program, such as Fast ForWord, benefits children with central auditory processing deficits as well as children with language deficits.

Earobics

Earobics is another computer-based program used in the treatment of (C)APD. As with Fast ForWord, the purpose of Earobics is to teach auditory and phonemic awareness to children (Wasowicz, 1997). This awareness is taught through six computer games addressing auditory attention, auditory figure-ground discrimination, auditory discrimination, auditory sequential memory, phoneme and syllable synthesis, auditory phoneme and syllable segmentation, auditory and phoneme identification, sound-symbol correspondence, and rhyming and phonological awareness (Wasowicz, 1997). Each game includes tasks designed to enhance a child's performance in one or more of the above mentioned areas, and each game becomes progressively more taxing as the child becomes more proficient in that area.

Experimental Research

There are several studies which reflect a correlation between auditory training and plastic changes within the CANS. An earlier study by Katz, Chertoff, and Sawusch (1984) revealed improved dichotic listening ability following auditory training. They used low-pass filtered digits presented at varying time offsets as their training stimuli, and subjects were required to attend training for a total of 8 weeks. The test devised for pre- and post-testing purposes was called the *Staggered Dichotic Digits* (SDD) and was similar to the *SSW* in design, only digits were used as stimuli instead of words. Post-testing *SDD* results revealed that the experimental group subjects showed a considerable improvement when compared to their control counterparts. However, *SSW* results did not yield any significant findings. The authors suggested that this may be due to the short length of time in training, the complexity of the *SSW* in comparison to the *SDD*, and that pre-test performance on the *SDD* was better than the pre-*SSW*, so more time in training may be required before a significant improvement on the *SSW* could be expected. Though results for the *SSW* did not show any improvement, it is important to recognize that the *SDD*, which contained essentially the same material being trained (i.e., dichotic digits), did show improvement.

Auditory Integration Training (AIT) utilizes frequency altered music as a stimulus for training purposes. Frequency altered music is theorized to improve the processing of auditory stimuli and may be beneficial in the treatment (C)APD. Yencer (1998), however, found no support for this theory. Her study consisted of 39 subjects between 7 and 9 years of age who went through the 10 week AIT program. Testing procedures included measures of auditory processing, electrophysiological tests, a parental questionnaire, and basic audiometric procedures. Yencer found that differences between pre- and post-testing did not yield any statistically significant findings.

In 2002, Tremblay and Kraus studied the effects of auditory training utilizing different voice onset times. The N1-P2 complex was evaluated before and after training to determine any changes in neural activity. This N1-P2 complex represents the "pre-attentive processing of the sound in the human auditory cortex" (p. 565). They found that components of the N1-P2 complex were altered following training, and that these modifications were a result of the training. Specifically, the ability to distinguish different voice onset times showed significant improvement. Their findings suggest that neural changes due to training can be recorded using evoked potential testing.

A similar study conducted by Hayes, Warrier, Nicol, Zecker, and Kraus (2003) found similar results. Plastic changes invoked through computerized therapy, Earobics, was the interests of their study. Children between the ages of 8 and 12 years of age with learning impairments were recruited for the study, as well as children with normal learning abilities to function as the control group. The auditory neurophysiology of each subject was evaluated before and after undergoing Earobics training. They found that sound blending and auditory processing abilities were improved following training. In addition, "auditory processing skills and cortical representations of speech in quiet and noise" is altered after brief exposure to auditory training (Hayes, 2003, p.680). The difference in plastic capability of the various components of the central auditory pathway was also thought to be evident in the difference between brainstem and cortical responses. This difference may also "reflect intrinsic properties and/or developmental limitations in the plasticity of subcortical pathways (e.g. changes in timing of the brainstem response may only occur in younger children)" (Hayes, 2003, p.682). These results are consistent with results from previous studies

Other than Yencer's study on AIT, the literature indicates that through auditory training, plastic changes within the CANS (i.e., improved auditory processing abilities) can be achieved. Katz, Chertoff, and Sawusch (1984) found that a training program of 15 one-hour sessions, one session per week, was sufficient to show improvement between pre-testing and post-testing scores. However, according to Cinnoti (1998), the time required for each session of the Fast ForWord is one hour and forty minutes. Therefore, based on the research by Katz and his colleagues (1984), it seems possible that children may receive equal or better results from a treatment design that requires less time to be spent in training, while still taxing the central auditory system a sufficient amount to evoke plastic changes within that system.

It was the intention of this investigator to devise a dichotic training regimen that improved dichotic listening performance. Performance, both before and after the training period, was assessed in order to determine if any differences between performances found were statistically significant. The hypothesis of this study was that a significant improvement in the dichotic performance would be measured following training.

CHAPTER II: RESEARCH DESIGN

Purpose

The purpose of this study was to:

a) To determine if statistically significant differences exist between pre- and post-Dichotic Auditory Training scores;

b) To determine if statistically significant differences exist between pre- and post-*SSW* scores; and,

c) To determine if statistically significant differences exist between pre- and post-*SCAN-C/A* scores.

Based on the premise of plasticity, the hypothesis of is that through repeated exposure to the dichotic auditory stimuli provided by the Dichotic Auditory Training (DAT) exercises, the dichotic performance of those with auditory processing disorders will improve over the four week period of training required to complete the DAT.

Subjects

Eight children between the ages of 7 and 12 years who had normal peripheral hearing, and had been identified as having (C)APD received four weeks of training designed to improve dichotic listening ability. Normal peripheral hearing was verified through tympanometry, speech testing, and pure tone testing (0-25 dBHL at 500-4,000 Hz) utilizing the modified Hughson-Westlake method. Children with peripheral hearing loss were excluded from the study due to the confounding effects of peripheral hearing loss on auditory processing test outcomes. Children whose first language was not English, children with low cognitive function, and children diagnosed with other disorders (i.e. attention deficit disorder, language impairment, autism) were excluded from the experimental group. These exclusionary factors were evaluated through a portion of the case history which was completed by the caregiver at the initial evaluation. When necessary, information was obtained by consent (Appendix B) of the caregiver in order to verify a diagnosis.

The *Staggered Spondaic Word* test (*SSW*), *Test for Auditory Processing Disorder for Children* (*SCAN-C*), and the *Test for Auditory Processing Disorder for Adults* (*SCAN-A*) were used to determine the presence of a ©APD at the initial diagnostic evaluation. Table 1 lists each subject and their respective data.

Table 1: Subject Data

Subject	A	B	C	D	E	F	G	H
Treatment	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
APD	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Age	11	12	8	10	7	9	12	10
Gender	Female	Male	Male	Male	Male	Female	Male	Male
Pre-Test Date	8/10/2005	6/14/2005	7/18/2005	3/21/2005	3/22/2005	1/10/2006	1/12/2006	1/10/2006
Post-Test Date	9/13/2005	7/14/2005	8/26/2005	5/4/2005	5/10/2005	3/27/2006	2/23/2006	3/13/2006
Oto	WNL	WNL	WNL	WNL	WNL	WNL	WNL	WNL
Tymps	A	A	A	A	A	B*	A	A
Hearing	WNL	WNL	WNL	WNL	WNL	WNL	WNL	WNL

* Subject had patent PE tubes with large ear canal volumes

Most of the children in the experimental group were recruited by contacting the parents of children who had previously been evaluated at the Louisiana Tech University Speech and Hearing Center. These children had been identified as having (C)APD and the caregivers of these children were contacted via telephone. Additionally, fliers were placed within the Louisiana Tech University Speech and Hearing Center to recruit subjects.

Methods and Procedures

The parent(s) of each subject signed the Human Subjects Consent Form (Appendix D) prior to the initial/baseline testing, as well as a release of information (Appendix B). The parents of each subject also completed a case history (Appendix A) prior to testing. All children recruited for the study were given an audiometric evaluation (i.e., otoscopy, tympanometry, acoustic reflexes, speech reception threshold, word recognition, and pure tone audiometry) to ensure normal peripheral hearing sensitivity Central auditory processing testing was conducted using the *SSW* and the *SCAN-C/A* to determine the status of their central auditory processing skills.

Instrumentation

Audiological Evaluation

Otoscopy was performed utilizing a Welch Allen otoscope. Acoustic reflex testing and tympanometry were performed using a Grason-Stadler TympStar Version 2 Middle-Ear Analyzer, calibrated to ANSI standards S3.6-1969 and S3.39-1987. Pure tone and speech audiometry testing was performed through insert earphones (EARTone 3A) on each subject from 250-8000 Hz utilizing a Grason-Stadler Model 16 audiometer, calibrated to ANSI standard S3.6-1996. All results from the audiological evaluation were recorded on an audiogram (Appendix E). The Northwestern University Test #6 words were presented via live voice for word recognition testing. Daily biological checks ensured proper functioning of audiological equipment throughout the duration of the study.

Pre-Dichotic Auditory Training Test

In addition to the *SSW* and the *SCAN-C/A,* each subject was given a pre-test called the Baseline DAT (Appendix F). The purpose of this test was to determine the subject's baseline ability to distinguish between words presented at different interaural time differences. The timing differences on the Pre-DAT were randomly distributed but include: 10 sets of words beginning in the right ear with a timing difference of 300 milliseconds, 10 sets of words beginning in the left ear with a timing difference of 300 milliseconds, 10 sets of words beginning in the right ear with a timing difference of 150 milliseconds, 10 sets of words beginning in the left ear with a timing difference of 150 milliseconds, and 10 sets of words with no timing difference.

Professionally recorded Northwestern University Test #6 words from Auditec of St. Louis were manipulated using Sound Forge Version 7.0. This was accomplished by copying the words from the NU-6 compact discs purchased from Auditec of St. Louis onto the Sound Forge program. First, each carrier phrase "say the word" was removed. Next, the words were randomized and copied onto blank tracks on the Sound Forge software. After copying a total of twenty words for each exercise needed, the words were manipulated for the timing differences stated above. The Pre-DAT was presented through a Dell OPTIPLEX GX270 computer coupled to Koss Headphones.

Staggered Spondaic Words Test

The *Staggered Spondaic Word (SSW)* test is designed to evaluate central auditory function, and was administered to each subject before and after completing the experimental treatment. The *SSW* was presented through the Grason-Stadler Model 16 audiometer coupled to a Yamaha KX-930 audio cassette player. The EARTone 3A insert earphones were also used for presentation of this test.

The *SSW* is a dichotic listening test comprised of forty spondee words presented to each ear simultaneously at 40 or 50 dB SL (re: speech reception threshold). The test and instructions were presented via an audio cassette recording from Precision Acoustics. The individual being tested was required to repeat all words in the order presented. This test has four conditions: right competing (RC), right non-competing (RNC), left competing (LC), and left non-competing (LNC). Each subject's performance on the *SSW* was recorded using the Standard *SSW* Test-List EC and scored using the Number of Error (NOE) Analysis. Cardinal numbers for all four conditions and the total number of errors, as well as reversals and any qualifiers, were compared to normative data provided in the testing manual. Scores which were no more than two standard deviations below the mean were considered normal.

SCAN-C(A)

The *SCAN-C: A Test for Auditory Processing Disorders in Children* or *SCAN-A: A Test for Auditory Processing Disorders in Adults* was administered to each subject, depending on age. The *SCAN-C* is for subjects 11 years, 11 months of age or younger and the *SCAN-A* is for subjects older than 12 years of age. This test was presented through the Grason-Stadler Model 16 audiometer coupled to a Tascam CD-160 CD player. The EARTone 3A insert earphones were also used for presentation of this test.

The *SCAN-C(A)* has four subtests: Filtered Words, Auditory Figure Ground, Competing Words, and Competing Sentences. The Filtered Words subtest measures the ability to understand a distorted speech signal by presenting monosyllabic words with a 1000 Hz (750 Hz for *SCAN*-A) low pass filter. The Auditory Figure Ground subtest measures the ability to comprehend speech in background noise by presenting monosyllabic words in the presence of multitalker babble with a +8 dB (+4 dB for *SCAN-A*) signal-to-noise ratio. The Competing Words subtest measures the ability to recognize a word when two speech signals are presented to both ears. The Competing Sentences subtest measures the ability to repeat sentences presented to one ear while ignoring the sentence in the other ear. All subtests and instructions were presented via recorded audio cassette at 40 dB SL (re: speech reception threshold). Subject performance for all subtests was recorded and scored on the form provided and compared to age appropriate norms provided in the testing manual. A standard score of 7 (no more than one standard deviation below the mean) was considered normal.

<u>Dichotic Auditory Training</u>

Each subject completed the audiological evaluation, Pre-DAT, *SSW*, and *SCAN-C(A)* during the first appointment. Once all pre-testing was completed, two 45 minute training sessions per week for four weeks were scheduled. Each session consisted of 12 exercises. Each exercise contained twenty dichotic presentations of NU-6 words, manipulated and pre-recorded in the same manner as the Pre-DAT, presented at different interaural timing differences. The exercises were presented through a Dell OPTIPLEX GX270 computer coupled to Koss Headphones.

The DAT schedule was designed as follows:

	Exercise	Timing Difference	Beginning Ear
Day 1	1-6	300 ms	Right
	7-12	300 ms	Left
Day 2	1-6	300 ms	Right
	7-12	300 ms	Left
Day 3	1-3	300 ms	Right
	4-6	300 ms	Left
	7-9	150 ms	Right
	10-12	150 ms	Left
Day 4	1-6	150 ms	Right
	7-12	150 ms	Left
Day 5	1-6	150 ms	Right
	7-12	150 ms	Left
Day 6	1-12	0 ms	Dichotic
Day 7	1-12	0 ms	Dichotic
Day 8	1-12	0 ms	Dichotic

(See Appendix G for examples of each exercise)

To reduce subject fatigue, a five minute break was taken between every fourth exercise. No more than two days of training (24 exercises) occurred within one week. In the case of missed appointments, a make-up session was scheduled for the same week if possible. If a make-up session could not be scheduled for that week, training resumed the following week beginning with the missed lesson and an extra appointment was added to the training schedule to ensure completion of all exercises.

Post-Testing

Once all exercises in the DAT were complete, an appointment was made for post-testing. The post-testing consisted of an audiological evaluation (otoscopy, tympanometry, acoustic reflex testing, speech reception threshold, word recognition, pure tone (audiometry), central auditory processing testing (*SSW* and *SCAN-C(A)*), and Post-DAT (Appendix H). All standards for what was considered normal in pre-testing applied to the post-testing. Post-testing scores from each test were compared to scores from the pre-testing to determine if any statistically significant improvements existed between them.

CHAPTER III: RESULTS

The purpose of this study was to determine if statistically significant differences existed between pre- and post-test results on the *SSW*, the *SCAN-C/*A, and the DAT, as well as to determine if the DAT exercises caused any improvements in dichotic listening ability. Each subject (mean age of 9.8) was given the DAT test, the *SSW* test, and the *SCAN-C/A* prior to and immediately following their 4 week training sessions. Each of these tests was separated into different conditions, or variables, for statistical analysis. These conditions are listed below in Table 2.

Table 2: Conditions

Test	Condition
DAT	Right 300 Right 150 Left 300 Left 150 Dichotic Overall
SSW	Right Non-Competing Right Competing Left Non-Competing Left Competing Total Errors
SCAN-C/A	Filtered Words (Right and Left Ear) Auditory Figure Ground (Right and Left Ear) Competing Words (Right and Left Ear) Competing Sentences (Right and Left Ear)

Separate repeated measures analysis of variances (ANOVAs) were conducted for each of the 19 different testing conditions. These tests were carried out utilizing the Bonferroni corrected alpha of .0026 to determine if the differences between pre- and post-testing scores were significant for the Dichotic Auditory Training test, the *SSW*, and the *SCAN-C/A*.

Dichotic Auditory Training

A repeated measures ANOVA was used to observe possible differences between the pre- and post-DAT with dichotic listening ability as the dependent variable. The bonferroni corrected results indicated statistically significant differences for the overall scores ($F(1,7) = 34.62$, $p = .001$, partial $\eta 2 = .832$), the right ear leading by 300 ms (R300) ($F(1,7) = 43.75$, $p = .000$, partial $\eta 2 = .862$), the right ear leading by 150 ms (R150) ($F(1,7) = 108.57$, $p = .000$, partial $\eta 2 = .939$, and the dichotic condition ($F(1,7) = 23.09$, $p = .002$, partial $\eta 2 = .767$. These results are thought to reflect plastic changes that have occurred within the CANS of the subjects as a result of the dichotic training they received. Table 3 lists the means and standard deviations of the DAT.

Table 3: DAT Means and Standard Deviations

Test	Condition	M	SD
DAT	Pre-DAT	75.25	11.54
	Post-DAT	90.25	7.15
	R300-Pre	60.00	19.27
	R300-Post	85.00	11.95
	L300-Pre	61.25	24.16
	L300-Post	82.50	15.18
	R150-Pre	56.25	17.68
	R150-Post	90.00	10.69
	L150-Pre	57.50	23.15
	L150-Post	71.25	15.53
	Dich-Pre	52.50	23.15
	Dich-Post	88.75	9.91

The repeated measures ANOVAs did not yield statistically significant results, however, for the left ear leading by 300 ms condition (L300) ($F(1,7) = 17.00$, $p = .004$, partial $\eta 2 = .708$) or the left ear leading by 150 ms condition (L150) ($F(1,7) = 5.33$, $p = .054$, partial $\eta 2 = .432$). These results may be due to insufficient time in training for the left ear, or not enough exercises directed towards the left ear.

Staggered Spondaic Words Test

Repeated measures ANOVAs utilizing the bonferroni corrected alpha with dichotic listening ability as the dependent variable yielded statistically significant differences between pre- and post-testing for both the total number of errors (*SSW*TE) ($F(1,7) = 36.14$, $p = .001$, partial $\eta 2 = .838$) and the left-competing condition (LC) ($F(1,7) = 35.36$, $p = .001$, partial $\eta 2 = .835$) of the SSW. As with the DAT, these results are evidence that plastic changes were occurring in the subjects that can be attributed to the training. Table 4 lists the means and standard deviations of the *SSW*.

Table 4: *SSW* Means and Standard Deviations

Test	Condition	M	SD
SSW	Total Error-Pre	27.00	12.68
	Total Error- Post	14.13	10.76
	RNC-Pre	4.50	2.98
	RNC-Post	1.88	3.00
	RC-Pre	6.63	3.58
	RC-Post	3.00	1.60
	LNC-Pre	4.00	2.33
	LNC-Post	2.25	1.98
	LC-Pre	11.88	5.64
	LC-Post	7.25	5.39

No significant differences were found for the right non-competing condition (RNC) ($F(1,7) = 8.80$, $p = .021$, partial $\eta 2 = .557$), the left non-competing condition (LNC) ($F(1,7) = 5.81$, $p = .047$, partial $\eta 2 = .454$), or the left competing condition (LC) ($F(1,7) = 12.29$, $p = .010$, partial $\eta 2 = .637$). While the results for the left ear may indicate a need for more training directed towards that ear, the results for the RNC condition may reveal an already mature right ear. If the right ear has reached maturity then no significant improvement would be expected.

<u>*SCAN-C/A*</u>

Table 5 lists the means and standard deviations of the *SCAN-C/A*.

Table 5: *SCAN-C/A* Means and Standard Deviations

Test	Condition	M	SD
SCAN-C/A	FWR-Pre	18.00	2.07
	FWR-Post	18.62	1.77
	FWL-Pre	17.50	2.00
	FWL-Post	18.50	1.77
	AFGR-Pre	16.63	3.38
	AFGR-Post	17.25	1.75
	AFGL-Pre	16.00	1.85
	AFGL-Post	17.75	.71
	CWR-Pre	22.86	2.85
	CWR-Post	24.63	3.25
	CWL-Pre	16.88	7.27
	CWL-Post	20.63	3.34
	CSR-Pre	7.88	2.64
	CSR-Post	8.88	.99
	CSL-Pre	4.38	3.20
	CSL-Post	6.13	2.10

Repeated measures ANOVAs did not yield statistically significant results for any condition of the *SCAN-C/A* (p range = .047-.521). These results can be viewed in Table 6.

Table 6: *SCAN-C/A* Repeated Measures ANOVAs

Condition	F	Df	P	Partial $\eta 2$
FWR	.46	1,7	.521	.061
FWL	2.80	1,7	.138	.286
AFGR	.79	1,7	.405	.101
AFGL	12.70	1,7	.009	.645
CWR	1.41	1,7	.274	.168
CWL	5.81	1,7	.047	.454
CSR	1.56	1,7	.252	.182
CSL	2.05	1,7	.195	.227

These non-significant scores were expected for the Filtered Words, Auditory Figure Ground, and Competing Words subtests. No improvements were expected because the training that each subject underwent did not involve any filtering, addition of background noise, or use competing sentences as stimuli. Significant results were expected for the Competing Words subtest. As discussed with the DAT and the *SSW*, the results for the left ear may be an indication that more training for the left ear is needed. While it is possible that more training may be needed for the right ear, it is more likely that the insignificant results for the right ear may be a sign of a right ear that is performing at maturity. More training for the right ear is not thought to be needed because no effect size was found for this condition. An effect size indicates that, while no significant results were found, some improvement was occurring. The effect sizes for the Competing Words subtest are .454 for the left ear, which is considered to be moderate, and .168 for the right ear, which reveals no effect size.

CHAPTER IV: DISCUSSION

There is a general lack of therapies available for the remediation of (C)APD, as well as a general lack of research in creating new therapies. Therefore the goal of this study was to develop a training program for individuals with (C)APD that would improve their dichotic listening skills. Plastic changes are known to occur in the CANS with repeat exposure to auditory stimulation. Based on plasticity, it was thought that a training program consisting of dichotic exercises that get progressively more difficult may invoke plastic changes in the CANS of those who underwent the training. Pre- and post-test measures (*SSW*, *SCAN-C/A*, and the DAT) were observed for statistically significant improvements, and any significant results were thought to be evidence of the plastic changes desired. It was found that statistically significant differences existed between pre- and post-test scores for 6 of the 19 testing conditions.

Dichotic Auditory Training

The conditions found to be significant for the DAT were the right ear leading by 300 ms (R300) condition, the right ear leading by 150 ms (R150) condition, the dichotic condition, and the overall DAT. Based on these results, it appears that Dichotic Auditory Training did improve the dichotic listening skills, for the above listed conditions, of the subjects who underwent the training. It can be concluded from these results that the improvements were due to plastic changes within the central auditory system. Essentially, through repeat exposure to the auditory stimulus, long term potentiation was achieved, and the central auditory systems of those undergoing training were able to mature to a level sufficient to perform these dichotic listening tasks successfully.

The left ear leading by 300 ms (L300) and the left ear leading by 150 ms (L150) conditions did not yield statistically significant differences. However, a large effect size was found for the L300 ($\eta2$= .708) condition and a moderate effect size was found for the L150 condition ($\eta2$= .432). An effect size indicates that, while not statistically significant, there were improvements between the pre- and post-test scores.

Staggered Spondaic Word Test

The conditions found to be significant for the *SSW* were the total errors and the left competing (LC) condition. As with the DAT, these results are thought to reflect plastic changes occurring within the central auditory system. The right non-competing (RNC), right competing (RC), and left non-competing (LNC) did not yield statistically significant results but did show an effect size. The LNC condition yielded a moderate effect size ($\eta2$= .454), and a moderate, but larger, effect size was found for the RNC condition ($\eta2$= .557) and the LC condition ($\eta2$= .637). Again, this indicates that more training focused on these conditions may aid the central auditory system in the maturation process.

SCAN-C/A

The Filtered Words subtest yielded no significant differences between pre- and post-testing and no significant effect size was found. This is to be expected as there was no manipulation of the signal with regards to filtering. The Auditory Figure Ground subtest for the right ear yielded no statistically significant results; however, the left ear showed a moderate effect size ($\eta 2 = .645$). Because DAT does involve competing stimuli, this result was considered to be an indirect result of the training. This result could also indicate the right ear had reached maturity, and the left ear received enough benefit from the training to improve performance for this condition.

Given the nature of the training, an improvement in the Competing Words subtest is the goal and would be expected if the training were indeed effective. A moderate effect size was found for the left ear in this condition ($\eta 2 = .454$), which shows promise. As with the other tests, a moderate effect size is evidence that a change is occurring, and more focus on those particular conditions may be needed before a significant change can be made and considered to be long term potentiation. There was no significant difference or effect size found for the right ear. However, Figure 1 shows that only two subjects showed no improvement in post-test performance, while the other subjects improved or maintained the same score, which may indicate that the right ear may have already reached maturity, and therefore no improvement would be expected.

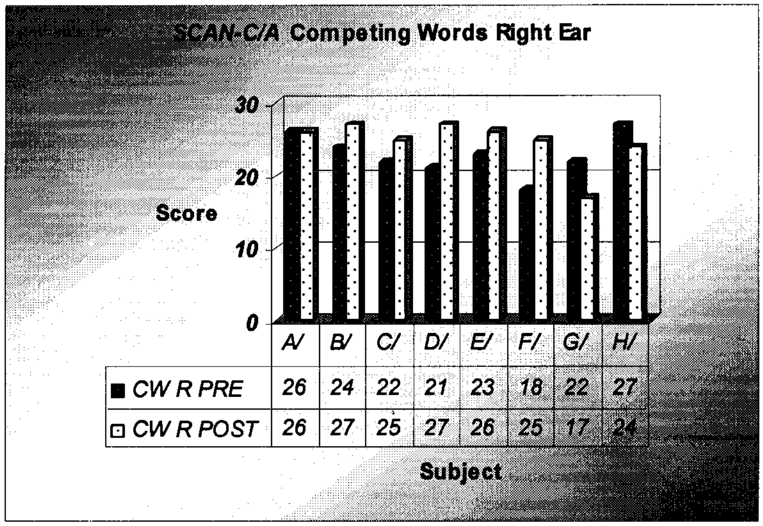

Figure 1: *SCAN-C/A* Competing Words Right Ear

The Competing Sentences subtest was not significant and yielded no effect size. This result is to be expected as there was no training involving sentences as the stimulus. Sentences are a much more complex stimulus and assess a person's binaural separation abilities, whereas DAT is an assessment of binaural integration.

In addition to test results, it should be noted that anecdotal reports from the parents of nearly all subjects also indicate improvement in performance. Many parents reported improvements in academic performance, mainly in the areas of mathematical skills and reading comprehension. Some parents also reported comments from teachers of increased attention and motivation in the classroom setting. These reports are important because, as mentioned in chapter one, many children who have a CAPD often perform poorly in the classroom setting.

Limitations

A learning or practice effect is not suspected in this study. While there were several statistically significant differences between pre- and post-testing, if a practice effect had occurred it is assumed that many more tests would have shown significant differences. In addition, with the exception of the Auditory Figure Ground subtest, no significant differences were found to exist when the material was manipulated in other domains (i.e. filtering, background noise, sentences). The only significant results found were those that were directly related to the dichotic training the subjects underwent.

The sample size for this study was small; however, the area in which this study was conducted is a relatively small community. Therefore, the number of children who are diagnosed as having CAPD is limited. Another limitation of this study was the number of pre- and post-test measures. While the *SCAN-C/A* is a useful test which includes materials manipulated in four different domains (i.e., filtering, background noise, competing words, and competing sentences), it is used as a screener for CAPD rather than a diagnostic tool.

Clinically Significant Results

While a large number of testing conditions did yield statistically significant differences between pre- and post-test performance, there was also a large number that did not. However, 7 of the 19 conditions did yield a moderate to large effect size. Again, an effect size indicates that, while not statistically significant, pre- and post-test scores did reveal improvement. This indicates that the DAT does have clinical relevance. As mentioned previously, there are a limited number of therapies being used in the remediation of CAPD. This study shows that training the auditory system in the manner in which it is tested (i.e., dichotic presentations) can be beneficial to those with a CAPD, and that through more studies focusing on different aspects of this type of training, an extremely useful therapy tool may be made available.

Future Studies

Based on these results, it appears that the Dichotic Auditory Training exercises do strengthen the neural pathways from the ears to brain. Exactly what areas are being strengthened are unknown. To this end, future research regarding the DAT could include pre- and post- functional magnetic resonance imaging (MRI). By doing a functional MRI before and after the training, it may be possible to pinpoint the area, or areas, that are improving. This type of testing could also be beneficial in site of lesion identification for other CAPD tests utilizing dichotic materials.

Future studies need to include other pre- and post-test measures in order to verify any improvement that may or may not be accomplished through training. The inclusion of other measures may also eliminate the possibility of improvement due to normal maturation processes. These tests should include the use of tests which utilize tonal stimuli, such as the *Dichotic Digits: Single* or *Double Pairs*, to determine if improvements are made only with verbal stimuli, or if subject response to tones also improves. Other tests could include the *Pitch Pattern Sequence*, *Duration Pattern Sequence*, *Random Gap Detection Test*, *Low Pass Filtered Words*, and *Competing Sentences*.

Is this improvement in dichotic listening performance permanent, or does it diminish over time? If four weeks is not sufficient to cause a permanent change, how long does training need to last in order to make the improvement permanent? These are both questions which could also be addressed in future studies.

In this study, we can see where improvements could be made in this training paradigm. The results indicate that in some subjects, the right ear may have been mature, while the left ear appears to be lagging. The training could be tailored to the individual needs of each patient. For those who need more training for the left ear and less for the right, sessions could be geared more towards the left ear. The four week post-testing could be an assessment point, at which the progress of each patient could be considered. Post-testing scores could be used as a means to indicate which areas need more training and which appear to have improved to a satisfactory level. Assessment could occur every four weeks until the desired results are achieved

Other areas that could be addressed in future research could focus on longer periods of training and longer time intervals between stimulus presentations. Manipulation of the signal could include the filtering of words, the addition of background noise, and the use of sentences instead of words. There are so many areas to be researched regarding the remediation of CAPD. This study is just a small, but important, piece of the puzzle.

APPENDICES

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 health? ____

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 sounds 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: ______________________
Where the results interpreted to you? ________________
Teacher or Parent Name: __________________________
Child's Name: ___________________________________

Read each item carefully and decide 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.	________	________	________	______

OPTIONAL

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/ Kiley E. Stephenson 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

RECRUITING FLYER

Research Subjects Needed!!!!!

Subjects: Children between the ages of 6 and 11 years

Requirements: Children will receive a free hearing evaluation and central auditory processing evaluation and then have it repeated in 6 weeks.

Some children will also be asked to attend sessions for 4 weeks (2 times a week for 30 minutes).

Contact Dr. Sheryl S. Shoemaker at
257-4764
for additional information.

APPENDIX D

HUMAN SUBJECTS CONSENT FORM

HUMAN SUBJECTS CONSENT FORM

Experimental Group/Control 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*, 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*, 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. 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 (257-4647); Dr. Mary Livingston (257-2292); Nancy Fuller (257-5075)

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

DAT EXERCISES

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 (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 (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 (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 (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 __________

APPENDIX G

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 H

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)

FREQUENCY IN HERTZ

	250	500	1000	2000	4000	8000
0						
10						
20						
30						
40						
50						
60						
70						
80						
90						
100						
110						
120						

HEARING LEVEL IN DECIBELS (dB)

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 / TEST TYPE / TRANSDUCER

L	STIMULUS	R	TEST TYPE	TRANSDUCER
X	AC	O	Standard	Insert
□	AC Mask	Δ	Play	Circumaural
>	BC	<	COR/VRA	Sound Field
]	BC Mask	[	BOA	
↓	No Resp	↓		
L	Aided SF	R		
	SF	S		

Hearing Aid Information

Right Ear ______________________

Left Ear ______________________

Otoscopy ______________________

Comments ______________________

____

____

____

Student Clinician ______________________

Clinical Educator ______________________

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