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Subjective versus objective hearing screening results of rural elementary school-aged children

Meagan Chatelain McClure
Louisiana Tech University

SUBJECTIVE VERSUS OBJECTIVE HEARING SCREENING RESULTS OF RURAL ELEMENTARY SCHOOL-AGED CHILDREN

by

Meagan Chatelain McClure, B.A.

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Supervisor of Dissertation Research

Head of Department

Speech

Department

Recommendation concurred in:

Advisory Committee

Approved:

Director of Graduate Studies

Dean of the College

Approved:

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ABSTRACT

The present study compared the pass/refer results of traditional ASHA recommended hearing screenings to transient evoked otoacoustic emissions (TEOAEs), distortion product otoacoustic emissions (DPOAEs), and screening tympanometry among young students at a rural, medically underserved population at an elementary school. Sixty-seven students (31 boys and 36 girls) from kindergarten to 3rd grade participated in this study. Ten were Hispanic and had English as a second language. Each child had his/her hearing screened at 500 Hz and by the ASHA recommended method for pure tone screenings and by TEOAEs and DPOAEs. Tympanometry was also performed on 53 students. The results revealed that of the 67 children screened: 9% passed the ASHA recommend pure tone screening with the addition of 500 Hz, 58% passed the ASHA recommended pure tone audiometry, 53% passed tympanometry, 78% passed the TEOAE, and 87% passed the DPOAE screenings. Early identification of hearing impairment is crucial for academic success; therefore, the screening process must be increased sensitivity and specificity. As shown by this study, the inclusion of objective measures increased the sensitivity and specificity, and decreased the evaluation time per child. These results should encourage audiologists and school personnel to examine the substitution of objective screening tools for subjective screening tools in the future, or at the very least incorporate them into the screening protocol.

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CHAPTER I

INTRODUCTION

The damaging and deleterious effects of hearing loss on communication has been widely examined and reported. Hearing loss, either transient or permanent results in missed information and compromised communication. For listeners in the academic environment, hearing loss presents significant barriers to learning as well as decreased communication ability. For very young students, the results of hearing loss in the classroom can result in academic difficulties which can negatively impact their entire academic career (Northern & Downs, 2002).

The importance of identifying hearing loss in children is not undisputed. In 1997, the American Speech-Language Hearing Association (ASHA) updated their screening guidelines to identify hearing loss in the school setting. The recommended ASHA hearing screening consists of testing 1000, 2000, and 4000 Hz at 20 dB HL for the left and right ears independently. Responses to pure tone stimuli are recorded by observing the student raising his/her hand in response to the pure tone, or by pressing a response switch. The subjective nature of the screening presents inherent problems when testing young students. The examiner must possess a unique demeanor and have keen observation skills in determining the accuracy and repeatability of a student's responses to pure tone screening. If there is a communication or language barrier, such as with a

student who possesses English as a second language, this may produce an additional problem.

Perhaps of more concern is the reliability of lower frequency information during hearing screenings. Otitis media is typically manifested by increased thresholds at the lower frequencies. Although 500 Hz is not a recommended screening frequency by ASHA, some examiners do include it in their routine audiological screenings. Outside of the test booth, low frequency information can be very difficult to obtain. It is not uncommon for screening administrators to either raise the acceptable response level (e.g., 25 or 30 dB HL) for 500 Hz, or delete its presentation. Either action significantly decreases the effectiveness of the hearing screening to differentiate normal from non-normal hearing. Also not recommended by ASHA is the use of objective measures such as screening otoacoustic emissions (OAEs) and screening tympanometry. These two measures could eliminate the problems mentioned previously and accurately identify the most common form of transient hearing loss in young, school-aged children which is otitis media.

The purpose of the present study was to compare the results of the traditional ASHA recommended hearing screenings to distortion product (DP) OAEs, transient evoked (TE) OAEs, and screening tympanometry among young students at a rural, medically underserved elementary school. The comparisons of interest were the pass/refer rate between test protocols and between native and non-native English speaking student. Additionally, the identification of decreased middle ear compliance in children who passed the pure tone screening was another interest comparison.

CHAPTER II

REVIEW OF LITERATURE

Hearing Loss

Hearing loss can affect the quality of life of a hearing impaired individual. It is generally accepted that hearing loss, permanent or transient, results in reduced learning, the degree to which will vary depending on the onset, type, duration, and treatment/intervention of the hearing loss. Martin and Clark (2006) described three types of hearing loss: conductive or transient, sensorineural, and mixed hearing. A conductive hearing loss is caused by a physical abnormality in either the outer or middle ear. A sensorineural hearing loss is caused by an abnormality in the inner ear or central auditory pathway. The combination of a conductive and sensorineural hearing loss produces a mixed hearing loss.

Diagnosis of hearing impairments are made through extensive audiological evaluations that include both subjective and objective tests. Subjective tests included in the pediatric evaluation process can be challenging when examining young children and infants; and reliable, accurate measurements are difficult to obtain. Because of this, objective tests of auditory function are crucial in determining a young patient's hearing status.

Diagnostic Testing

Objective measures or instrumentations are those that do not require patient participation in the form of behavioral responses. The only behavioral requirement of the patient is to remain still and quiet. Objective audiological measures assess physiological responses and not the psychological event that is defined as hearing. However, the information that objective measures provide is used in concert with traditional subjective measures, such as the pure tone audiogram, to confirm hearing acuity. Objective measures routinely used in the audiological evaluation are tympanometry, acoustic reflexes, otoacoustic emissions, and to the lesser extent auditory brainstem responses.

Each of the previously mentioned objective tests has a screening version. As opposed to objectives tests that can be used to diagnose, screeners are used to determine individuals who are at risk for hearing impairment, or identify individuals with less than normal hearing. Screening measures conclude with a result of either "pass", "refer" or "fail." Any result other than pass indicates the need for further audiological testing. Tympanometry is an appropriate beginning objective measure for observing auditory function. Only in the presence of normal middle ear function can the other objective results be viewed with any certainty.

Tympanometry is used clinically in determining the condition of the middle ear system. Fowler and Shanks (2002) defines tympanometry as "the measure of acoustic admittance that are taken at various pressure points" (p. 175). The recording of tympanometry is traditionally performed by obtaining a hermetic seal in the ear canal and recording the change in admittance of the middle ear system in response to the positive and pressure changes. Conventional tympanometry, commonly used in the standard

audiological assessment, involves presenting a 226 Hz tone to the middle ear system. This low frequency stimulus is sensitive in detecting disorders that affect the stiffness of the middle ear system which reduce admittance. The quantitative results of tympanometry are recorded separately for each ear and plotted graphically as a tympanogram. The configuration of the tympanogram determines whether the middle ear system is functioning properly or if there is an abnormality.

Common abnormalities of the tympanic membrane include perforations and limited mobility. According to Fowler and Shanks (2002) middle ear effusion (fluid) is the most common pathology that affects the stiffness of the middle ear system. Stiffness disorders are the most common pathology of the middle ear system. Tympanometry is also used to determine the condition of pressure equalizing tubes as well as detecting the presence or absence of middle ear fluid, otosclerosis, ossicular disarticulation, and the various stages of otitis media.

Although not as common, disorders that involve a mass component can also be present in the middle ear system. To observe the middle ear systems mass characteristics, multifrequency probe tones are used as opposed to the 226 Hz tone. Specifically, multifrequency probe tones (e.g., 660 Hz and 1000 Hz tones) provide information about the mass characteristics of the tympanic membrane and ossicular chain (Fowler & Shanks, 2002). Multifrequency tympanometry differs from conventional tympanometry in that 1) tympanograms of multifrequency tympanometry record susceptance and conductance separately (e.g., printing out two tympanograms) and 2) multifrequency tympanometry uses a higher frequency stimulus than conventional tympanometry. Harris, Hutchinson, and Moravec (2005) suggested using a stimulus with a frequency of

678 Hz or 1000 Hz. Multifrequency tympanometry is commonly used in testing infants, below the age of six months, due to the higher-frequency pure tone is not as susceptible to the more compliant ear canal of infants which can erroneously indicate a normal middle ear system when using a 226 Hz tone.

Multifrequency and conventional tympanograms are classified using different classification systems which are the Vanhuyse system and Jerger system. The Vanhuyse system is commonly used with multifrequency tympanometry. According to Fowler and Shanks (2002), the difference in classifications is that multifrequency tympanometry includes two additional tympanogram patterns to the conventional Type A, B, and C readings. These additional tympanograms patterns provide information on tympanic membrane mobility, scarring, and ossicular discontinuity that the 226 Hz tone does not. In conventional typanometry these conditions, depending on their severity, might be classified as a Type A.

The Jerger classification system is used when interpreting tympanograms with the low-frequency 226 Hz stimulus in conventional tympanometry. The Jerger system includes labeling the tympanograms according to the overall shape including peak pressure and static compliance. The types included in the Jerger system are as follows: Type A, Type A_s, Type A_d, Type C, and Type B. The Type A tympanogram indicates normal middle ear function with peak pressure ranges from + 100 da Pa to – 100 da Pa, and compliance ranges from .30 – 1.6 ml (Fowler & Shanks, 2002). The Type A tympanogram includes two subtypes: shallow (A_s - low in admittance) or deep (A_d - high in admittance). The Type C tympanogram indicates negative middle ear pressure or possible Eustachian tube malfunction. The peak pressure of a Type C tympanogram falls

outside the normal limit (greater than – 100 da Pa) but with normal admittance. There is not a peak pressure with the Type B tympanogram. The overall appearance of the Type B tympanogram is a relatively flat line indicating either a perforation of the tympanic membrane, a blockage or obstruction of the ear canal, or a mass or fluid behind the tympanic membrane that does not allow for mobility of the tympanic membrane.

Following tympanometric measurements, acoustic reflexes are routinely recorded. Gelfand (2002) stated that the "acoustic reflex is the involuntary contraction of the stapedius muscle that occurs in response to an intense stimulus" (p. 205). The stapedius muscle contraction occurs bilaterally in a healthy auditory system and examines the peripheral auditory system to the level of the contraction of the stapedius muscle. The acoustic reflex threshold is measured by presenting a pure tone (e.g., 1000 Hz) and decrease the intensity of the tone to softest level where a contraction of the stapedius muscle can be measured. The acoustic reflex threshold is measured ipsilaterally (i.e., stimulus is presented and measured in the same ear) and contralaterally (i.e., stimulus in presented to one ear and measured in the other). Normal acoustic reflex thresholds occur at 70 to 100 dB sensation level (Gelfand, 2002). An elevated, reduced, or absent acoustic reflex threshold along with behavioral testing can infer the site-of-lesion for hearing loss and specifically, the site-of-lesion for hearing loss that is beyond the cochlea. According to Gelfand (2002), this reflex is considered absent when a stapedius contraction cannot be elicited.

In the presence of a sensorineural hearing loss the acoustic reflex threshold can be elevated, absent, or reduced depending on the degree of hearing loss. A mild sensorineural hearing loss (e.g., 30 dB HL to 40 dB HL) may not have a significant affect

on the reflex, but greater losses can produce elevated or absent thresholds. The acoustic reflex threshold may be elevated or absent in the presence of a conductive hearing loss as well. For both types of hearing losses, the evaluation or absence of the threshold is due to a lack of cochlea stimulation. In the case of a sensorineural hearing loss, the lack stimulation is due to damaged hair cells in the cochlear or decreased neural function of the auditory nerve. For conductive hearing losses, the lack of stimulation is due to the decreased ability of the middle ear system to transmit the acoustic signal to the cochlea.

Another objective auditory assessment measurement technique that examines peripheral but more importantly retrocochlear function is the auditory brainstem response (ABR). Although not part of the routine audiological assessment, an ABR is used if a retrocochlear problem is suspected. It is also used to screen hearings, especially for new born hearing screenings. Auditory brainstem response recordings are used clinically to objectively assess the integrity of the eighth cranial nerve and lower brainstem. Auditory brainstem responses are elicited by presenting an auditory stimulus (e.g., a click) and are recorded by surface electrodes placed on the forehead and mastoid or ear lobe to record the neural responses. The neural responses are averaged and appear in a single waveform. The waveform is plotted by using microvolts as a function of time. The waveform's peaks are labeled with Roman numeral numbers I through V. Each peak is generated from different anatomical structures along the ascending auditory pathway.

There are three types of ABR recordings: diagnostic, threshold, and automated. Diagnostic ABRs are used in assessing the integrity of the auditory system. Acoustic tumors and auditory neuropathy can be detected with diagnostic ABRs. Diagnostic

ABRs are primarily used with the adult population. However, the diagnostic ABR can be used to assess other population that may be at risk for such abnormalities.

Unlike the diagnostic ABR, the threshold ABR assesses the ability of the auditory system to respond to a sound up to the level of the brainstem. The examiner decreases the intensity of the stimulus until Wave V can no longer be detected and documents the lowest level at which this occurs. This level is typically within 10 dB of the true auditory threshold. Threshold ABRs are primarily used with the pediatric population and other populations (e.g., mentally impaired) where behavioral thresholds cannot or are difficult to obtain.

The automated ABR, commonly referred to as a screening ABR, is quicker in establishing hearing sensitivity when compared to the threshold ABR. According to Hall (2007), a screening ABR can be administered in 5 to 6 minutes, whereas a threshold ABR can take approximately 60 minutes. The screening ABR automatically decreases the stimulus intensity until Wave V is no longer present. Screening or automated ABRs provide an in-depth observation of auditory function and can be preformed and interpreted by medical professionals other than audiologists and is widely used in newborn hearing screening programs. The screening ABR and otoacoustic emissions (OAEs) can be used collectively to identify infants with hearing loss and provide very specific information as to the site-of-lesion (Hall, 2007).

Otoacoustic emissions are an objective measure that provides information about the functioning of the outer hair cells of the cochlea. Otoacoustic emissions are measured through a probe tone which contains one or two signal generators (depending on the type of OAE to be measured) and a microphone. These devices measure outer hair cell

cochlear emissions which Glattke and Kujawa (1991) has described as "a low intensity phenomena that can be elicited by low- and moderate intensity stimuli" (p. 29). Otoacoustic emissions can be evoked by presenting a stimulus to the ear or measured spontaneously with no stimulus.

Spontaneous otoacoustic emissions (SOAEs) are emissions produced by the outer hair cells of the cochlea in the absence of a stimulus. Spontaneous otoacoustic emissions typically have a frequency range between 1000 to 2000 Hz in adults and 2000 to 5000 Hz in children (Prieve & Fitzgerald, 2002). The higher frequency in children is due to their smaller ear canals, resulting in a higher resonant frequency within the external auditory canal. According Bright and Glattke (1986), spontaneous otoacoustic emissions are absent if an individual has a hearing loss greater than 30 dB HL. Prieve and Fitzgerald (2002) report SOAEs are more prevalent in women than men. Additionally, SOAEs have been reported in only 40% of the population (Glattke and Kujawa, 1991). Due to these factors listed above, SOAEs are not utilized clinically.

Evoked emissions are produced by the cochlear outer hair cells in response to a stimulus. There are two types of evoked emissions, transient evoked otoacoustic emissions (TEOAEs) and distortion product otoacoustic emissions (DPOAEs). Evoked OAEs are present in normal hearing individuals and absent only in the presence of a hearing loss, therefore they are used routinely in the clinical setting as a part of the audiological assessment. Distortion product otoacoustic emissions have been elicited in individuals with a moderate hearing loss that does not exceed 40 to 50 dB HL (Harris, 1990). Transient evoked otoacoustic emissions can be elicited in individuals with a mild hearing loss that does not exceed 30 dB HL (Kemp, 1978).

Transient evoked OAEs are accomplished by presenting a series of brief clicks or tone bursts to the cochlea and measuring the resulting sounds from the cochlea. A click is a broad band stimulus that has equal intensity over a range of frequencies. A toneburst is a frequency specific stimulus which is short in duration. Transient evoked otoacoustic emissions are evaluated according to the reproducibility of the resulting OAE waveform and the signal-to-noise ratio in the frequency region where the emission occurs. To be considered as having normal TEOAEs, in a certain frequency range, the waveform must have a predetermined degree of reproducibility (e.g., 70%) as well as have an emission that is present at a predetermined level above the noise floor (e.g., 6 dB signal-to-noise ratio). The noise levels, both internal and external, in the test environment can obscure the TEOAEs resulting in false positive outcomes and additional testing. Due to the broad band stimulus used as the stimulus in TEOAE testing, noise levels in the test environment must be monitored closely.

Distortion product otoacoustic emissions simultaneously present two different stimuli to the cochlea. The two stimuli differ by frequency (F1 and F2) and intensity levels (L1 and L2). Roush (2001) reported that DPOAEs occur at a frequency two times the lower frequency minus the higher frequency (2F1-F2). The intensity level of the higher frequency is often 10 to 15 dB lower than the presentation of the lower frequency (Roush, 2001). The resulting DPOAE is less obscured by the noise floor due to the specificity of the stimuli tones and therefore better suited for measurements that occur outside a sound treated room. According to ASHA's Guidelines for Audiologic Screening (1997), DPOAEs should be obtained with a F2/F1 frequency ratio of 1.2. The

recommended stimulus parameters are F2 at 2000, 3000, and 4000 Hz presented at L2 = 55 dB SPL and L1 = 65 dB SPL (ASHA, 1997).

Objective audiological measures are sometimes used in isolation, without behavioral tests, specifically in hearing screening scenarios. Such programs are used to screen the hearing of newborns within 48 hours after birth and are required before being discharged from the hospital in states that have adopted newborn hearing screening guidelines. Newborn hearing screenings are routinely preformed using OAEs. If the infant fails the initial screening he/she is typically re-screened before being discharged or within one month (Diefendorf, 2002). If the child fails the re-screening the Joint Committee on Infant Hearing (2000) recommends the child have a medical and audiological evaluation before three months of age to evaluate the integrity of the auditory system.

Newborn hearing screenings are used to successfully identify infants with and without hearing loss. However, OAEs used in isolation do not detect all degrees or types of auditory dysfunction. According to Norton et al. (2000), TEOAEs devices are sensitive in detecting hearing losses that are greater than moderate; however, it is not as accurate in detecting slight and mild hearing losses. This is because a click has equal intensity over a range of frequencies and an individual may pass due to the tonotopical organization of the cochlea and the configuration of their hearing loss. Otoacoustic emissions are also ineffective at detecting retrocochlear disorders, such as auditory neuropathy, because they only test to the level of the outer hair cells of the cochlea. Also, in order to record normal OAEs, the patient must have a normal middle ear system and ear canal.

According to Kemper and Downs (2000), approximately one to six children in a thousand are born with a congenital hearing loss, (i.e., a hearing loss that is present at birth). The degree and type of congenital hearing loss can vary depending on the etiology of the loss. Causes of a congenital hearing loss can vary from genetic to environmental factors. Genetic factors include hearing losses caused by associated syndromes and recessive, dominant, or x-linked genes. Maternal viral infections, prematurity, Rh incompatibility, and toxins are all environmental factors that can cause congenital hearing loss (Northern&Downs, 2002).

A child can be born with normal hearing and acquire a hearing loss later in life after passing a hospital's hearing screening. Similar to congenital hearing loss, an acquired hearing loss can vary in degree, type, and configuration. An acquired sensorineural hearing loss can result from stroke, ototoxic medications, meningitis, measles, acoustic tumors, trauma, noise exposure, and aging. Cerumen impaction, growths or tumors in the outer or middle ear, trauma, and otitis media can cause an acquired conductive hearing loss.

Hearing loss, ether congenital or acquired, can be either bilateral (hearing loss in both ears of any degree or type) or unilateral (hearing loss in one ear of any degree or type). In a national survey, Lee, Gomez, Martin, and Lee (1996) reported that a unilateral hearing loss was present in approximately 391,000 minority school aged children. Northern and Downs (2002) reports that individuals with unilateral hearing loss often experience delays in speech and language development and have difficulty with sound localization and understanding in background noise.

Conductive hearing loss is the most common type of hearing loss in children, specifically hearing loss caused by otitis media (Dhooge, 2003; NIDC, 2002; Alsarraf et al, 1998; Canalis & Lambert, 2000). According to Roush (2001), otitis media will occur in 50% of infants by the age of one year and will reoccur in 10 to 20% of children throughout childhood.

Otitis Media

Otitis media is a bacterial or viral infection or inflammation of the middle ear. Streptococcus pneumonia, Haemophilus influenzae, and Moraxella catarrhalis are common pathogens responsible for otitis media (Northern & Downs, 2002). Associating symptoms of otitis media include fever, otalgia, irritability, aural discharge, and hearing loss. The National Institute on Deafness and other Communication Disorders (2002) reported that 75% of children experience at least one incidence of otitis media by the age of three. The prevalence of otitis media is greater in children than adults. According to the National Institute on Deafness and other Communication Disorders (2002), children experience greater incidences of otitis media because a child's Eustachian tube has not fully matured to the size and vertical orientation as that of an adult. Another factor that increases the incidence of otitis media in children is the size of their adenoids. Large adenoids often interfere with the opening and closing of the Eustachian tube. Malfunctioning of the Eustachian tube can result in a buildup of fluid in the middle ear cavity.

Otitis media is classified according to its appearance and severity. Northern and Downs (2002) described four general categories of otitis media: otitis media without

effusion (fluid), acute otitis media, otitis media with tympanic membrane perforation, and otitis media with effusion.

Purulent, mucoid, and serous are classifications of otitis media with effusion. Purulent effusion is described as a pus-like fluid, mucoid otitis media is a thick fluid, and serous otitis media includes a clear non-infected fluid (Northern & Downs, 2002). Otitis media is also classified by duration. Acute otitis media is an infection that can occur up to 21 days and chronic otitis media is described as lasting longer than 8 weeks (Northern & Downs, 2002). Chronic otitis media is often associated with tympanic membrane perforations, due to the fluid accumulation causing the tympanic membrane to rupture under pressure.

Hearing sensitivity can be affected by otitis media due to the fluid accumulation collecting in the middle ear space impeding the natural transmission of sound through the auditory system. The mechanics of the peripheral auditory system are sensitive to obstructions and middle ear fluid impedes tympanic membrane mobility which decreases hearing function and sensitivity. The thicker the fluid the greater the impact on an individual's middle ear system and hearing. Common audiometric findings of otitis media are reduced middle ear compliance, absent acoustic reflex, absent OAEs, and conductive low-frequency hearing loss that does not exceed 35 dB HL. However, in chronic otitis media a maximum flat conductive hearing loss up to 50 dB HL can be observed across all audiological test frequencies including 250 through 8000 Hz. If untreated, chronic otitis media (i.e., otitis media lasting longer than three months) can cause permanent hearing impairments, life threatening infections, and speech and language delays (Northern & Downs, 2002; NIDC, 2002).

Permanent hearing impairments can occur due to repeated damage to the peripheral auditory system including the tympanic membrane and ossicular chain. These structures may be weakened or eroded due to their prolonged exposure to these infectious fluids and become unable to efficiently transmit sound through the middle ear system. If the infective pathogen is aggressive, nearby structures including the inner ear, mastoid, and brain can be infected. Encephalitis, an infection of the brain, can result which can be life threatening especially to children. Whether hearing loss is permanent or transient, speech and language delays are commonly associated with repeated incidences of otitis media.

The development of normal speech and language is accomplished through an imitative process. If a child's hearing is impaired for an extended period of time during speech and language acquisition, a speech and language delay or disorder may be the result (Northern & Downs, 2002; NIDC, 2002). With decreased hearing acuity certain sounds, specifically unvoiced consonants, are frequently missed, and therefore, not properly developed into the child's speech.

The prevalence of otitis media varies as a function of ethnic background, socioeconomic status, and geographical regions. Children from lower socioeconomic families may be more affected by the impact of otitis media than children from higher socioeconomic families. This is due to the reduced availability of adequate healthcare for poorer families as well as a lack of education.

Daly, Pirie, Rhodes, Hunter, and Davey (2007) conducted a study on the risk factor of otitis media among Minnesota American Indians. They investigated the incidence of otitis media from birth to 2 years of age and correlated the results with

socioeconomic characteristics and maternal knowledge and awareness of otitis media. In their study, Daly et al. collected data on 344 children by outer ear examinations, tympanometry, distortion product otoacoustic emissions, and maternal interviews. The results of their study revealed 63% of infants had experienced at least one incidence of otitis media and 34 % had experience two or more incidences of otitis media by 6 months of age. Daly et al. compared their results to a previous study conducted by Daly, Brown, Lindgren, Meland, Le, and Giebink (1999). Their results revealed that there were higher incidences of otitis media in American Indian infants than in the predominantly Caucasian population of Minnesota Twin Cities area in the mid-1990s.

In a similar study, Pang-Ching, Robb, Heath, and Takumi (1995) examined the prevalence of middle ear disorders and hearing loss in native Hawaiian preschoolers. They compared the screening results of pneumatic otoscopy, pure tone testing, and tympanometry in 172 children (86 boys, 86 girls). Pure tone testing was completed in an acoustically treated room, and included screening 500, 1000, 2000, and 4000 Hz at 15 dB HL. The children initially underwent testing in the beginning of the fall semester. Due to the recurrent nature of otitis media, the authors preformed sequential hearing screenings at 3 to 4 week intervals between November and April. Of the initial 172 children only 88 children were included in the sequential screenings. The results of the initial screening revealed that 32% failed otoscopy, 27% failed tympanometry, and 36% failed the pure tone hearing screening. Results of the sequential screening revealed that 30% of the children failed pure tone testing and/or tympanometry at each of the six periodic screenings between November and April. The authors suggested that the seasonal

variations in Hawaii were not significant in impacting test results, as it would be in other states.

The prevalence and occurrence of otitis media varies by geographical regions. Otitis media is prevalent in regions where allergens flourish and upper respiratory infections are common (Northern & Downs, 2002). Climate and seasonal variations are significant factors to the regions where otitis media is prevalent. Humid geographical regions, such as the southeastern United States, provide a warm moist environment for otitis media pathogens to flourish. Children living in regions were occurrences of otitis media are frequent experience greater negative effects than children who do not.

The American Speech-Language Hearing Association reported speech and language development, academic achievement, vocational choices, and socialization can be affected in the presence of a hearing loss (ASHA, 2005). The overall impact hearing loss has on the child's ability to develop speech and language depends on the type and degree of hearing loss present. However, research indicates even a mild hearing loss can negatively affect a child's normal speech and language development (Northern & Downs, 2002). It is imperative that children with hearing impairments are properly identified and receive the appropriate intervention to lessen the physiological, social, and emotional effects of their hearing loss.

The Role of Hearing Screenings in School-Aged Children

According to Northern and Downs (2002), hearing screenings have been conducted in U.S. public schools since the 1930's. A common hearing screening quickly evaluates an individual's hearing sensitivity at 1000, 2000, and 4000 Hz, in both ears through behavioral responses. Hearing screenings are designed to accurately identify

individuals with a hearing loss from those individuals without a hearing loss. Unlike audiological evaluation, hearing screenings are not conducted in sound treated booths. They are typically conducted in the room with the least amount of ambient noise. Another difference between the two measures is audiological evaluations examine the integrity of the outer and middle ear whereas hearing screenings do not do so specifically.

The American Speech-Language Hearing Association (1997) has set forth age specific guidelines on when and how hearing screenings should be performed. According to the Hearing Screening Guidelines age 5 to 18 years, a hearing screening should be conducted by a certified speech-language pathologist or audiologist, or by individuals supervised by a certified audiologist. The American Speech-Language Hearing Association (1997) recommended that school children have their hearing screened:

> on first entry into school and in grades first, second, third, and eleventh, upon entrance into special education, upon grade repetition, upon entering a new school system, without evidence of having passed a previous screening, and other years if there is a family history of hearing loss, head trauma, noise exposure, or recurrent otitis media (p. 364).

The American Speech-Language Hearing Association (1997) has recommended screening the following frequencies for pure tone audiometry: 1000, 2000, and 4000 Hz at 20 dB HL. A pass is considered when the child responds to all of the above mentioned frequencies in both ears. The child fails the screening if they fail to respond at any one frequency in either ear, at which point the practitioner should reposition the earphones, reinstruct the child, and rescreen in the same session. If the child fails again they are to

be referred for further audiological testing. The American Speech-Language Hearing Association states the referred student's hearing sensitivity should be confirmed within one month, and no later than three months, after the initial screening.

While 500 Hz is not a required frequency for hearing screenings, it is proficient in detecting middle ear fluid. Middle ear fluid stiffens the middle ear system and affects the transmission of lower frequencies. Although 500 Hz provides a benefit in detecting middle ear fluid, it is not typically screened because of its susceptibility to be masked by ambient noise levels in the test room, which is typically lower in frequency. However, TEOAEs are also sensitive to lower frequency auditory function and may not be as easily masked by ambient room noise.

Taylor and Brooks (2000) examined the effectiveness of using TEOAEs as a screening tool for hearing loss and middle ear disorders in children. They compared the sensitivity and specificity of TEOAEs, pure tone testing, and tympanometry of 152 children (mean age 5:5 years). Screening protocol and pass/refer criteria for pure tone audiometry and tympanometry were based on the 1997 ASHA Guidelines for audiological screenings. Transient evoked otoacoustic emissions were considered passing if at least three frequency responses were 3 dB over the noise floor along with a sensitivity rate of 90-95%. The results indicated that TEOAEs had significantly greater sensitivity and specificity when compared to pure tone audiometry. Taylor and Brooks suggested that TEOAEs were efficient enough in sensitivity and specificity to replace pure tone screening in children, but were not efficient enough to replace tympanometry.

Hatzopoulos et al. (2001) reported that TEOAEs were typically used in neonatal hearing screening protocols. The purpose of their study was to evaluate the performance

of DPOAEs to the popularly used TEOAEs, in a large neonatal study. The authors examined the performance of DPOAEs to TEOAEs in a neonatal screening program in 250 infants. The data revealed that there was a 98% similar pass rate between the instruments. The authors also reported that the administration time was 50% quicker with DPOAEs than the administration time for TEOAEs. Hatzopoulos et al. suggests that DPOAEs can possibly outperform TEOAEs in noise environments. Based on the correlation of responses between the two instruments, the quicker test time of DPOAEs, and the possibility the DPOAEs devices are more reliable in noisy environments than TEOAEs, the authors stated that DPOAEs have clinical potential in the neonatal population.

In a similar study, Shi et al. (2000) investigated that pass/fail results of TEOAEs to DPOAEs. The participants for this study included 65 children (ages 1 month to 5 years). Participants were divided into two age groups. The first group included infants 6 months of age or younger and the older group included children 7 months to 5 years. Transient evoked otoacoustic emissions and distortion product otoacoustic emissions were performed on each child. The study revealed poor TEOAE / DPOAE comparison agreements between the two instruments. Results were significantly different in the younger children. The authors suggested the difference in agreements could have been caused by the difference of test stimuli between the two instruments, recording method, stimuli intensity differences, and the effect of physiological noise in the test environment.

Allen and Stuart (2004) examined the pass/refer rates of a Head Start preschool hearing screening program in North Carolina (n = 1,462). The Head Start facilities were located in rural areas and included medically underserved individuals. In addition to the

ASHA protocol for hearing screening, the researchers performed otoscopy and tympanometry on each child. Their results indicated that 53.8% passed, 38.4% failed, and approximately 7% of the children were referred for medical examination after the initial screening. Of those that failed the initial screening, 59% of the children passed the re-screen. Using the ASHA guidelines, 75.9% of the children passed the hearing screenings. In this study, the rescreen increased the overall pass rate of the hearing screening. Without the rescreen, initially only 53.8% of the children passed the ASHA recommended hearing screening. The examiners returned to the facility at a later date to rescreen the children who failed. While this is beneficial, because many children would not have received the appropriate follow-up, it is not typically performed in routine hearing screenings.

According to the National Center on Birth Deficits and Developmental Disabilities, in 2004 approximately half of the children who failed their hearing screening received the appropriate follow-up audiological testing. The center reported several factors that led to the loss of follow-up including: families with lack of health insurance, non-white race, young maternal age, late onset of prenatal care, and multiple children in the home. Considering that 50% of children who fail their hearing screening will not follow-up for complete audiological testing, hearing screenings need to be as accurate as possible. This will ensure that "at risk" individuals are accurately screened and do not get lost in the referral process.

Minority Concentration

According to Gallaudet Research Institute (2005), 50% of the hearing impaired children receiving special educational services in the United States are minority students. The results of the 2004-2005 Regional and National summary reported that of the students receiving special educational services 15.3% were African American, 25% were Hispanic/Latino, 4.1% were Asian/Pacific Islanders, and the other percentages were made up of other ethnicities and multi-ethnic backgrounds. Specifically, when the national percentages were compared to the south, there was an increase in the amount of African American and Hispanic/Latino students receiving special educational services. The percentage increased to 22% for African American and 26.5% for Hispanic/Latino children (Gallaudet Research Institute, 2005).

Lee, Gomez-Martin, and Lee (1996) examined the prevalence of childhood hearing loss in Hispanic-American, African-American, and non-Hispanic white American children, who ranged in age from 6 to19 years of age. Their data was published in the Hispanic Health and Nutritional Examination Survey, the National Health and Nutrition Examination Survey II. Their results indicated that Cuban Americans had a higher prevalence of bilateral hearing loss than did African-American, non-Hispanic White, and Mexican-American children. Specifically, their results (per 1000) revealed that 17.0% African Americans, 27.6% Mexican American, and 15.5% non-Hispanic White children had hearing loss.

Union Parish Statistics

The 2000 Census indicated that in Union Parish, the ethnic background varied and revealed that 69.79% were Caucasians, 27.95% African Americans, 2.02% Hispanics, and the remaining of the population consisted of Native Americans, Asians, Pacific Islanders, individuals of two or more races, and other races not listed in the census. The Union Parish School Board reported that for the 2008-2009 school year, 2,849 students were enrolled in grades pre-K thru 12th grade, and of those students 185 were Hispanic and 126 spoke limited English.

Statement of the Problem

Currently, ASHA recommends hearing screenings that rely on behavioral responses to traditional pure tone audiometry for the frequencies 1000, 2000, and 4000 Hz. In most school settings, these screenings are not conducted in sound treated booths and are subject to ambient noise levels that most certainly lead to high false-positive rates. Additionally, high false positive rates can results from language and overall comprehension barriers due to the age and ethnic backgrounds of children. Perhaps of more concern is the omission of 500 Hz which greatly reduces that ability to detect the presence of otitis media. Otitis media is typically manifested by increased thresholds at the lower frequencies. Outside of the test booth, low frequency information can be very difficult to obtain. It is not uncommon for screening administrators to either raise the acceptable response level for 500 Hz or delete its presentation. Either action significantly decreases the effectiveness of the hearing screening to differentiate normal hearing from a hearing loss.

It is hypothesized that objective screening instruments such as otoacoustic emissions (OAEs) and tympanometry can eliminate these influences and allow for accurate hearing screening of young and/or limited English children and other populations where communication barriers might arise. Taylor and Brooks (2000) suggested that otoacoustic emissions could substitute for pure tone audiometry in hearing screenings. With the addition of tympanometry, this hearing screening procedure will be more efficient and more reliable than the procedure currently being preformed.

CHAPTER III

METHODS AND PROCEDURES

Participants

Prior to beginning the study, IRB approval was granted through the Office of University Research at Louisiana Tech University (see Appendix A for IRB Approval Memorandum). Sixty-seven children (31 boys and 36 girls) were recruited from a rural elementary school in Union Parish in order to evaluate the difference among pass and refer rates for young school aged children among the following screening measures: the ASHA recommended screening with the addition of 500 Hz, DPOAEs, TEOAEs, and tympanometry. Additionally, differences between native and non-native English speakers, as well as male and female students were compared among the measures. All parents were mailed, either in English or Spanish, a letter of recruitment explaining the purpose and procedures of this project (see Appendix B for parent recruitment letters) and a human subject informed consent form (see Appendix C for informed consent forms). The school administration sent home the appropriate language forms based on the student's primary language classification within the school system. Students who

returned their signed consents were eligible for inclusion in this study. The inclusion criteria were as follows:

1. students enrolled in kindergarten thru 3rd grade, and
2. A returned and signed informed consent form.
3. Although not a requirement, none of the students had ever been diagnosed with a permanent hearing loss.

Materials and Procedures

All experimental testing was completed in the areas where previous hearing screenings have been conducted by school personnel, as they were deemed the most quiet areas in the school. The school library was the site of the screenings on the first day, and the school auditorium was the screening site for the second and third day. At each screening site, two tables were set up across the room from each other. At one table pure tone screenings were conducted and at the other table OAE and tympanometry screenings was performed. Prior to the screenings, A-weighted sound level readings were recorded using a type 1, Quest Model 1700 sound level meter and ranged in levels from 38 dBA SPL to 56 dBA SPL. No set measures were taken to ensure that ASHA recommended ambient noise levels were met, as they are not done when school personnel conduct the screenings.

A Grason Stadler Model GSI-17 portable audiometer was used for all pure tone behavioral screening. The pure tone screening was performed at 20 dB HL for the ASHA (1997) recommended screening frequencies (1000, 2000, and 4000 Hz) and the addition of 500 Hz. Each student was instructed to raise his/her hand when the stimulus was heard, for the students who did not initially respond to the stimuli, they were re-instructed

and modeled the appropriate gesture for hearing the tone. A student was considered to pass the behavioral hearing screening if he or she responded to all test frequencies in both ears and fail, or refer, if there was no response for one of the screening frequencies for either ear.

A Grason Stadler Model GSI-37 Auto Tymp and a Bio-logic AuDXPro TEOAE / DPOAE Screener were used for the objective portion of the screening. Each student was instructed to remain still and quiet during screening and no child was unable to complete the objective procedure. The child was considered to pass the tympanometry screening if the peak compliance ranged from 0.2 cm^3 to 1.4 cm^3 and the tympanic pressure ranges -150 daPa to +100 daPa (Grason-Stadler Incorporated, 2004). The child was considered to pass the TEOAE screening if a 6 dB signal-to-noise ratio and 70% wave reproducibility was recorded for the click stimuli 1500 thru 4000 Hz (Natus Medical Incorporated, 2009). The child was considered to pass the DPOAE screening if at least three of the four test frequencies resulted in a signal-to-noise ratio of 6 dB over the noise floor, and/or frequency specific signal-to-noise ratios of: 6 dB over the noise floor for 5000 Hz, 5 dB over the noise floor for 4000 Hz, 8 dB over the noise floor 3000 Hz, or 7 dB over the noise floor for 2000 Hz (Natus Medical Incorporated, 2009).

CHAPTER IV

RESULTS

The purpose of the present study was to compare the pass/fail results of the traditional ASHA recommended hearing screening and the ASHA screening method with 500 Hz, to an objective screening protocol consisting of distortion product otoacoustic emissions (DPOAEs), transient evoked otoacoustic emissions (TEOAEs), and screening tympanometry among young students at a rural elementary school. Descriptive statistics were used to analyze the data; each of the five screening measures was observed for pass versus refer results. In addition to the overall results, the data was also analyzed to compare any differences between native English and limited English speaking students, as well as male and female students. The participants included 57 native English and 10 limited English speaking students, 31 male students (5 limited English and 26 native English) and 36 female students (5 limited English and 31 native English). None of the students tested, had any known or diagnosed hearing impairment at the time of testing, per the administration of the elementary school. An overall comparison between each participant groups' experimental test results are illustrated in Figure 1.

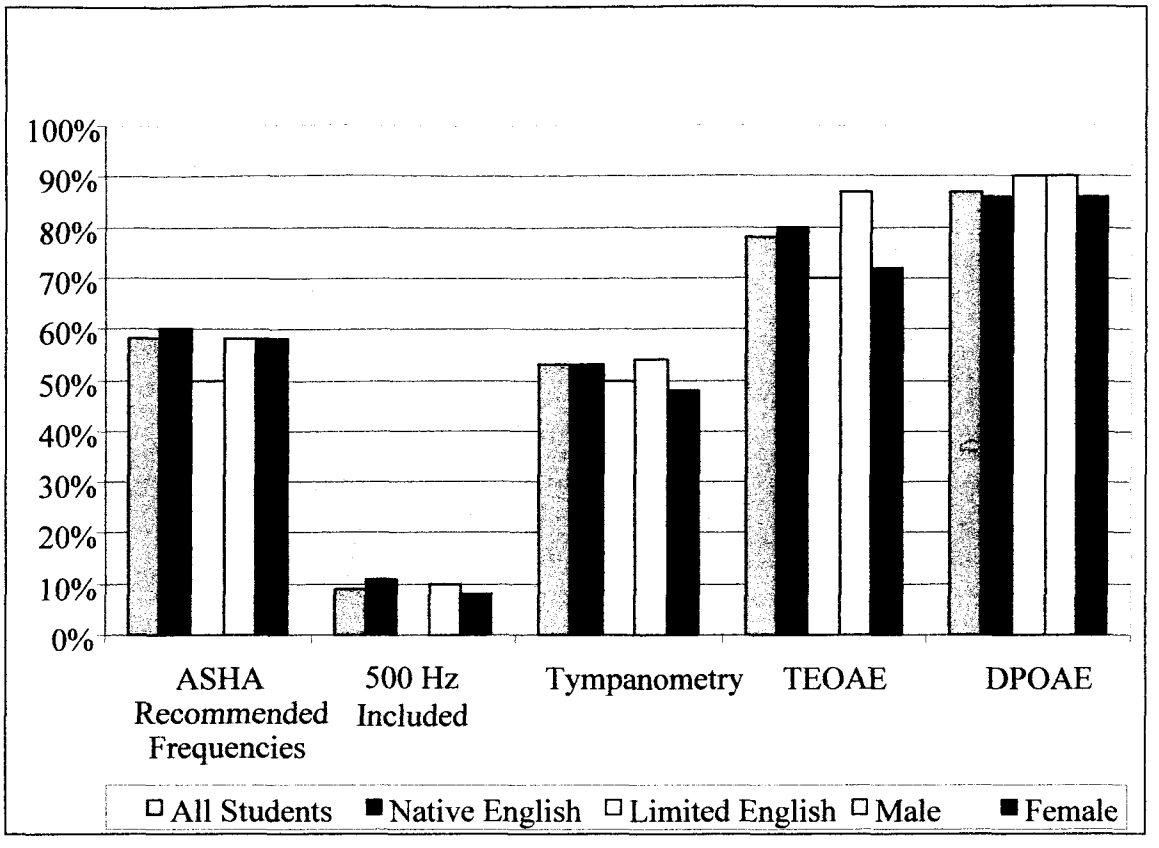

Figure 1: Overall comparison between each subject groups' experimental test results.

All seven students underwent the ASHA recommended pure tone screening (57 native English and 10 limited English students). The 67 students included 31 males and 36 females. A total of 39 students [58%, 39/67] passed the ASHA recommended pure tone screening. The results revealed that 34 native English students [60%, 34/57] and 5 limited English students [50%, 5/10] passed the ASHA recommended pure tone screening. The results also revealed that 18 male students [58%, 18/31] and 21 female students [58%, 21/36] passed the ASHA recommended pure tone screening. The percentages of students passing pure-tone screening are illustrated in Figure 2.

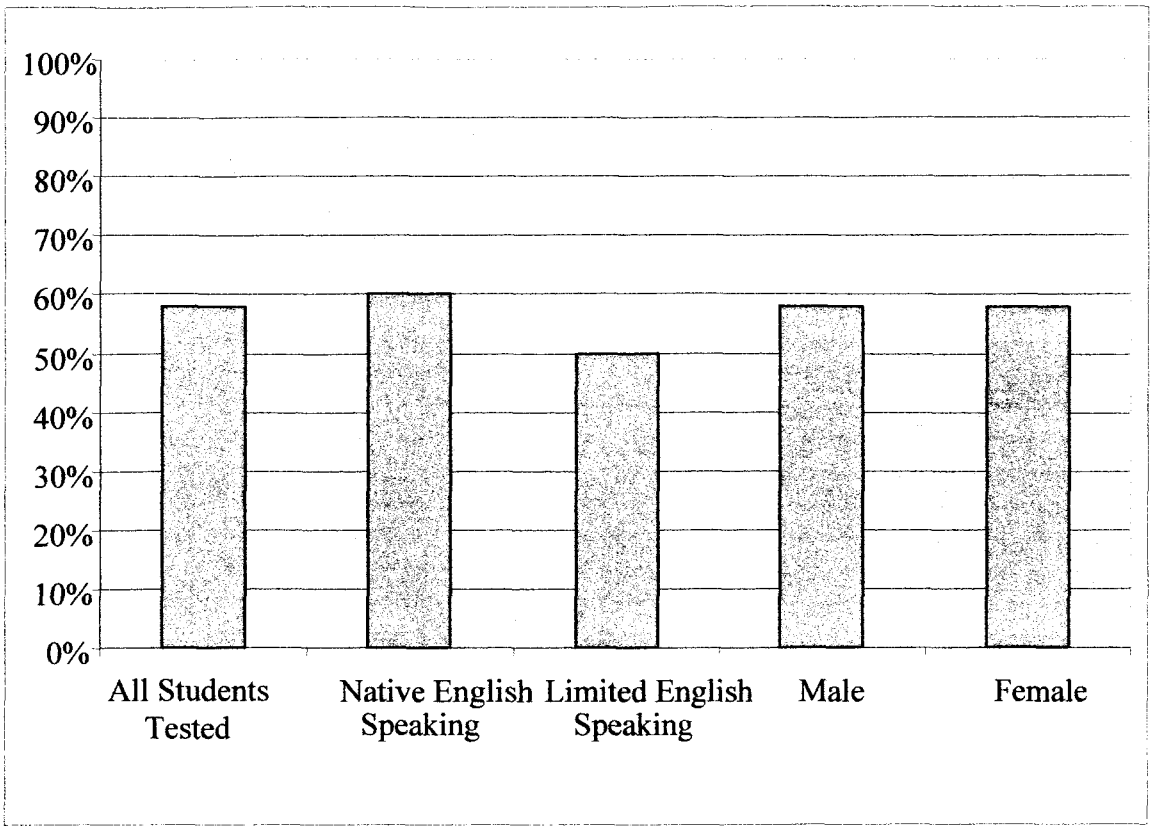

Figure 2: Percentages of all students passing ASHA recommended pure tone screening.

In an attempt to better detect less than normal middle ear function, all 67 students also underwent pure tone screening at 500 Hz. Only 6 students [9%, 6/67] passed the overall pure tone screening with the addition at 500 Hz. The results further revealed that the 6 native English students [11%, 6/57] and none of the limited English students [0%, 0/10] passed the overall pure tone screening with the addition of 500 Hz. Additionally, 3 male students [10%, 3/31] and 3 female students [8%, 3/36] passed. Percentages of students passing the overall pure tone screening when 500 Hz was added are illustrated in Figure 3.

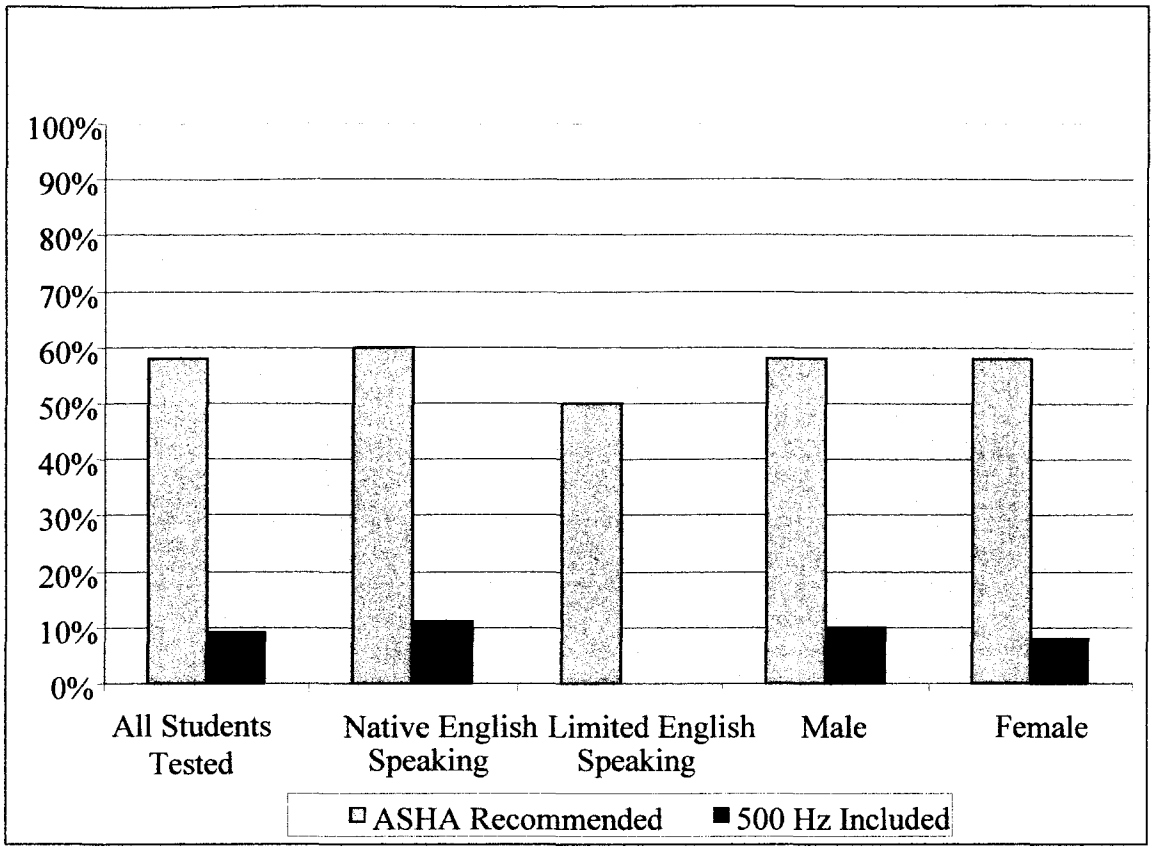

Figure 3: Percentages of all students passing the overall pure tone screening.

Due to an in the field technical difficulty, tympanometry was only performed on 53 students (45 native English students and 8 limited English students). The 53 students included 24 male students and 29 female students. For all the students tested, only 28 [53%, 28/53] passed the tympanometry screening. The results also revealed that 24 [53%, 24/45] of the native English and 4 limited English students [50%, 4/8] passed the tympanometry screening. Additionally, 13 male students [54%, 13/24] and 15 female students [48%, 15/29] passed the tympanometry screening. The percentages of students passing tympanometry are illustrated in Figure 4.

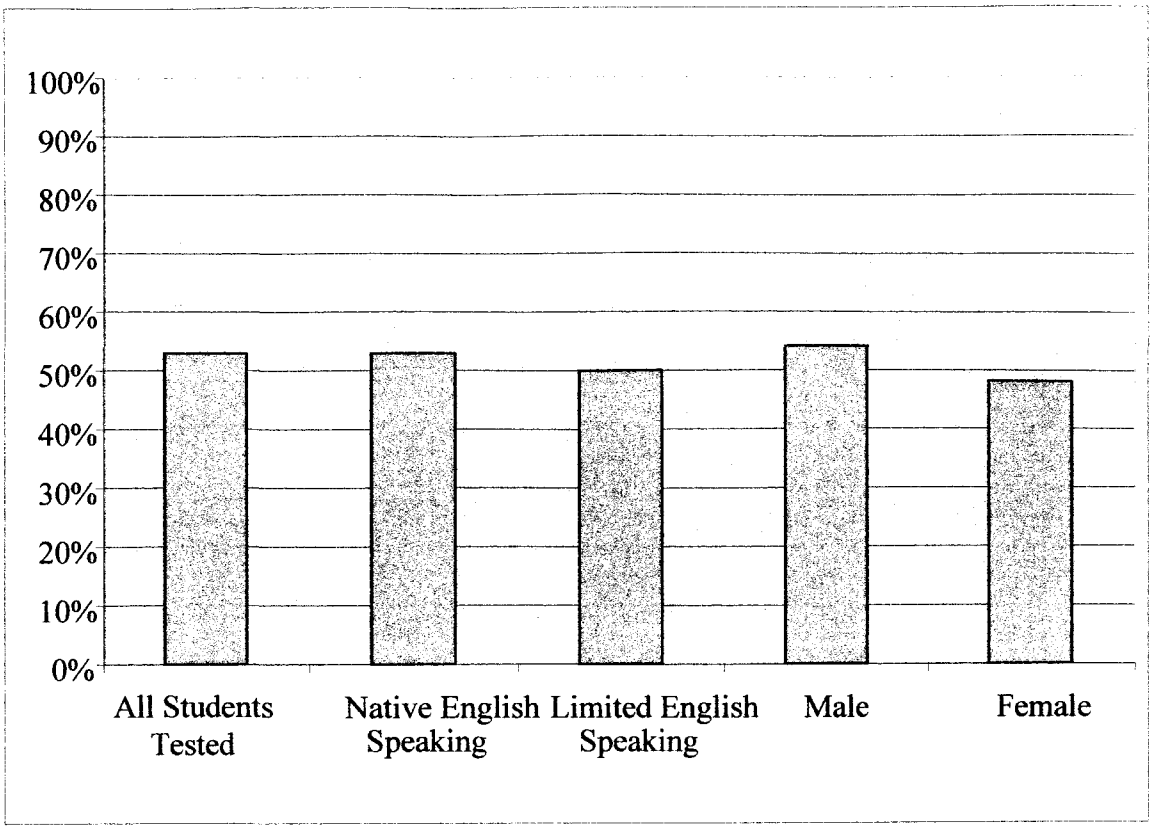

Figure 4: Percentages of all students passing tympanometry.

The TEOAE screening was performed on all 67 students (57 native English and 10 limited English students). A total of 52 students [78%, 52/67] passed the TEOAE screening. The results revealed that 45 native English students [80%, 45/57] and 7 limited English students [70%, 7/10] passed the TEOAE screening. Additionally, 26 male students [87%, 27/31] and 26 female students [72%, 26/36] passed the TEOAE screening. The percentages of all students passing the TEOAE screening are illustrated in Figure 5.

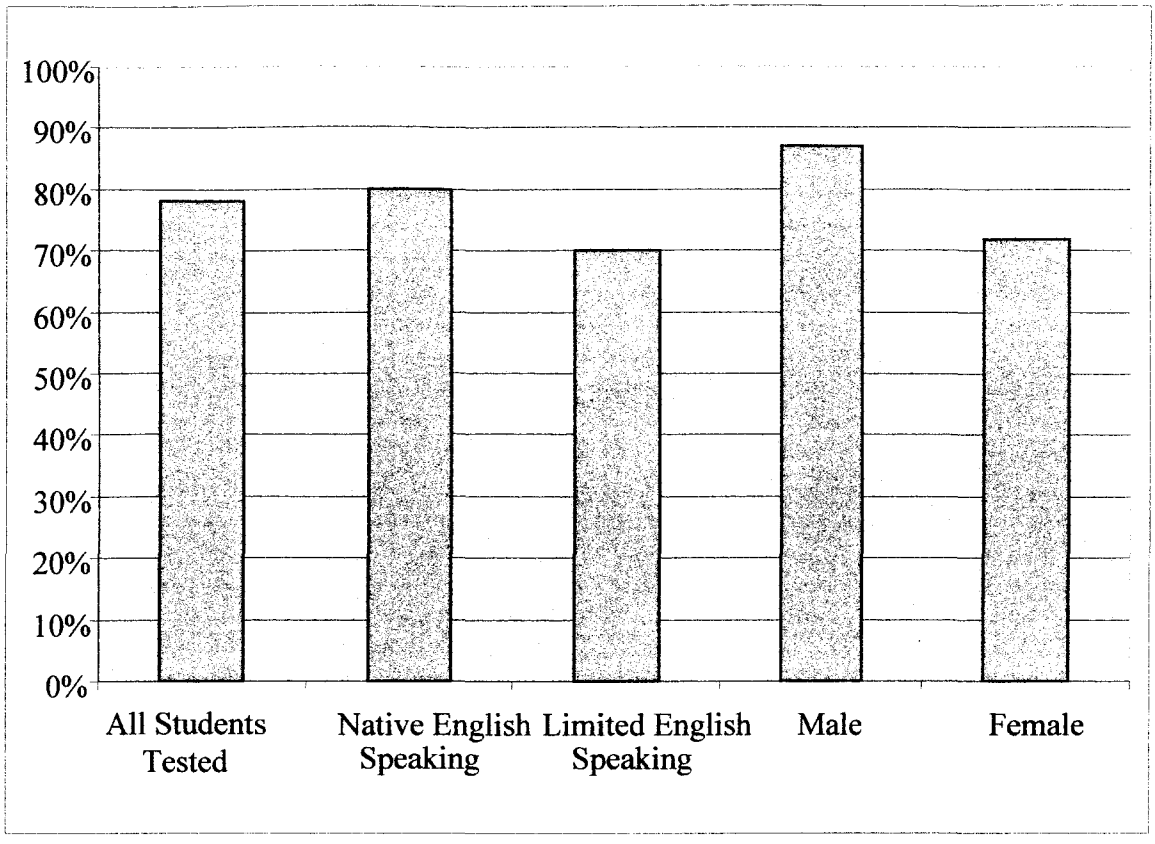

Figure 5: Percentages of all students passing the TEOAE screening.

The DPOAE screening was performed on all 67 students (57 native English and 10 limited English students). A total of 58 students [87%, 58/67] passed the DPOAE screenings. The results revealed that 49 native English students [86%, 49/57] and 9 limited English students [90%, 9/10] passed the DPOAE screening. The results also revealed that 28 male students [90%, 28/31] and 31 female students [86%, 31/36] passed the DPOAE screening. The percentages of all students passing the DPOAE screening are illustrated in Figure 6.

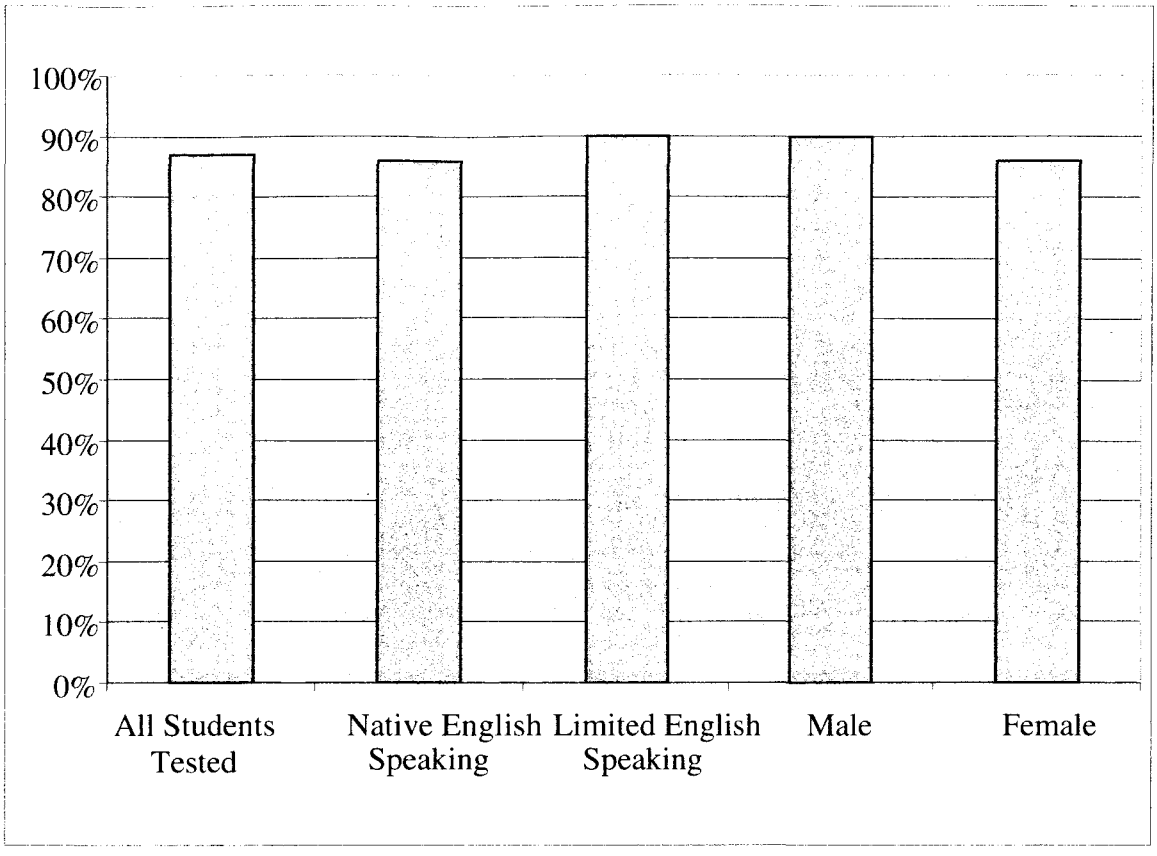

Figure 6: Percentages of all students passing the DPOAE screening.

An overall comparison between the experimental tests revealed that 39 students [58%, 39/67] passed the ASHA recommended pure tone screening, 6 students [9%, 6/67] passed the overall pure tone screening with the addition of 500 Hz, 28 students [53%, 28/53] passed tympanometry, 52 students [78%, 52/67] passed the TEOAE screening, and 58 students [87%, 58/67] passed the DPOAE screenings. Observation of each participant's results can be viewed in Appendix E. The percentages of all students passing pure tone screening, tympanometry, and otoacoustic emissions in isolation are illustrated in Figure 7.

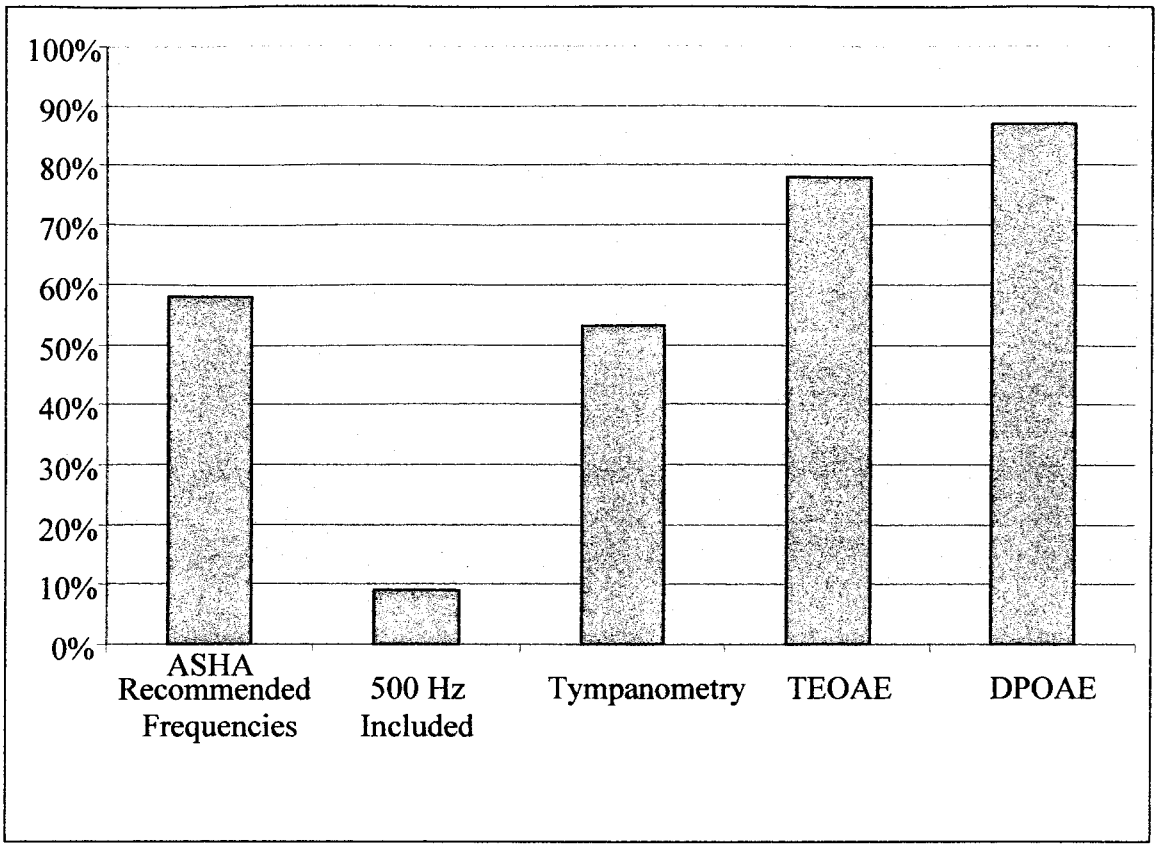

Figure 7: Percentages of all students passing pure tone screening, tympanometry. and otoacoustic emissions.

CHAPTER V

DISCUSSION

The purpose of the present study was to compare the pass/fail results among the ASHA recommended pure tone screening for young school-aged children, the ASHA screening with the addition of 500 Hz, screening tympanometry, screening TEOAEs, and screening DPOAEs. The results of the screenings were also compared as a function of native versus non-native English speaking students as well as male and female students. These screenings were conducted in an effort to observe the pass/fail rates of each measure and also an attempt to determine how sensitive each individual measure was in identifying normal from non-normal hearing. None of the students tested had any known permanent hearing loss or were suspected as having less than normal hearing.

The results for the ASHA recommended screening for young school-aged children revealed that only 58% of the students passed. When reviewing this result, one can logically presume one of three possible reasons for this outcome: 1) the screenings were not conducted accurately, either due to the inexperience of the examiners or lack of protocol adherence, or ambient noise levels were too high; 2) there was a significant number of hearing impaired students; or 3) the ASHA recommended hearing screening for young school-aged children is not ideally suited for environments outside the confines of a sound treated booth or room. The screenings were conducted by a third year Au.D

student in areas that are used by school personnel for hearing screenings, and those areas were believed to be the quietest areas on the campus by the primary investigators, also. With this knowledge, it is the bias of the primary investigators that the ASHA recommended hearing screening for young school-aged children is inappropriate for use outside of a sound treated environment.

As expected, when 500 Hz was included in the frequencies screened the pass rate fell significantly to 9%. The decision to include 500 Hz was made in an effort to better identify abnormal middle ear function. With the exclusion of OAEs, per ASHA guidelines, as a screening measure, feasible options to more readily identify abnormal middle ear function are limited to lower frequency (less than 1000 Hz) screening and tympanometry. However, lower frequencies are not recommended due to the masking effects of ambient noise levels found outside of the sound treated booth and is not a feasible option, as evidenced by this result of the present study. Tympanometry requires a higher skill level for proper probe fit and may be too difficult for professionals who do not have adequate experience in its use.

However, tympanometry is the most appropriate measure of middle ear function. With that being said, the results for screening tympanometry in the present study revealed only a 58% pass rate. Given that middle ear status was not confirmed by a thorough evaluation following this screening and therefore not validated, it can only be speculated if nearly half of the students had abnormal middle ear function. Other possible reasons for this outcome could include improper probe placement or perhaps myogenic or other internal interruptions created by the young students. It should be noted that the screening tympanometry device would not initiate unless a proper probe placement was obtained

and would not indicate a pass/refer if the probe placement became compromised during testing, the measure would simply terminate. Given the experience of the investigator, the low pass rate for this portion of the experiment was surprising and indicates that screening tympanometry, by itself, may not be able to be used in isolation to determine middle ear status.

Screening TEOAEs yielded a pass rate of 78% for the students tested. TEOAEs are sensitive to middle ear status as well as cochlear functioning for lower frequency regions up to approximately 2000 Hz. Although not recommended by ASHA for use as a screening measure in school-aged children, TEOAEs are routinely used as a screening mechanism for auditory function in universal newborn hearing screenings as well as audiological clinical practice. Their reliability and objectivity have been reported in numerous studies and their ease and efficiency of use would appear to make them at least part of a hearing screening process for school-aged children. However, with nearly 20% of the students screened in the present experiment referred by the device for additional testing, it would appear inappropriate for it to be used as a stand-alone screener given none of the students had any suspected hearing loss.

The screening device with the highest pass rate was with the DPOAE screener, yielding a pass rate of 87%. Like TEOAEs, DPOAEs have been shown to be highly reliable in detecting hearing loss and widely used in universal newborn hearing screening programs as well as in audiological clinical practice. In contrast to TEOAEs, DPOAEs offer a glimpse at higher frequency cochlear functioning (approximately 2000 Hz to 8000 Hz). They are ideal for detecting mild high frequency hearing loss, but are not reliable for lower frequency assessment (less than 2000 Hz). Although actual hearing status was

not confirmed with audiological evaluation following screening and given that none of the students had any suspected hearing loss, the DPOAE device yielded a pass rate that was more commensurate with the given population sample than the other screening devices in the present experiment. However, with its limitation of not assessing low frequency auditory functioning, it would not appear suitable to be used in isolation as a screening mechanism for young school-aged children.

It is important to bear in mind that the hearing status of the participants was not confirmed with audiological evaluation following their screening. Although free audiological evaluations were offered to those with "refer" or "fail" status following the results of the screening, no students were seen for follow-up. This was a significant limitation of the present study. However, given that none of the students had any known or suspected hearing loss, the fail rates recorded with behavioral pure tone screening and screening tympanometry would indicate a more than likely problem with the sensitivity of these measures when used for school based screenings for young students. Additionally, the non-native English speaking (Hispanic) students consistently had higher fail rates for these measures. More specifically, the pure tone measures indicated clinically significant differences between the two groups. This could be attributed to possible difficulties understanding the directions due to a language barrier, or due to increased likelihood of middle ear pathology which has been reported with minority populations (Daly et al, 2007). The only significant gender differences were seen with the results of the TEOAE device where more males failed than did females. There are no reported gender differences in the literature for this age group so the differences were attributed to chance in the tested population.

The clinically relevant findings of the present experiment are that most importantly, what would appear to be the least sensitive screening measure for young school-aged children outside the confines of a sound treated room, behavioral pure tone screening, is the ASHA recommended and most widely used measure. Secondly, objective screening measures yielded similar (screening tympanometry) or much higher (TEOAEs and DPOAEs) pass rates than pure tone screening. As stated previously, hearing was not confirmed with audiological evaluation. Given the believed hearing status of the screened population, DPOAEs and TEOAEs yielded more expected and plausible results than behavioral screening measures. Finally it would appear that the most sensitive and specific screening protocol should include more than one objective measure due to the known, as well as observed, limitations of the devices used in the present study. Perhaps a screening protocol should include TEOAEs, DPOAEs, and screening tympanometry with normal auditory function resulting from a pass from two of the three measures. Additional experiments which include immediate follow-up audiological evaluation to confirm hearing status should be conducted.

APPENDIX A

IRB APPROVAL MEMORANDUM

LOUISIANA TECH
UNIVERSITY

MEMORANDUM

OFFICE OF UNIVERSITY RESEARCH

TO: Ms. Meagan Chatelain and Dr. Steven Madix

FROM: Barbara Talbot, University Research

SUBJECT: HUMAN USE COMMITTEE REVIEW

DATE: May 5, 2008

In order to facilitate your project, an EXPEDITED REVIEW has been done for your proposed study entitled:

"Subjective Versus Objective Hearing Screening Results of School-aged Children"

 # HUC-583

The proposed study's revised procedures were found to provide reasonable and adequate safeguards against possible risks involving human subjects. The information to be collected may be personal in nature or implication. Therefore, diligent care needs to be taken to protect the privacy of the participants and to assure that the data are kept confidential. Informed consent is a critical part of the research process. The subjects must be informed that their participation is voluntary. It is important that consent materials be presented in a language understandable to every participant. If you have participants in your study whose first language is not English, be sure that informed consent materials are adequately explained or translated. Since your reviewed project appears to do no damage to the participants, the Human Use Committee grants approval of the involvement of human subjects as outlined.

Projects should be renewed annually. ***This approval was finalized on April 30, 2008 and this project will need to receive a continuation review by the IRB if the project, including data analysis, continues beyond April 30, 2009.*** Any discrepancies in procedure or changes that have been made including approved changes should be noted in the review application. Projects involving NIH funds require annual education training to be documented. For more information regarding this, contact the Office of University Research.

You are requested to maintain written records of your procedures, data collected, and subjects involved. These records will need to be available upon request during the conduct of the study and retained by the university for three years after the conclusion of the study. If changes occur in recruiting of subjects, informed consent process or in your research protocol, or if unanticipated problems should arise it is the Researchers responsibility to notify the Office of Research or IRB in writing. The project should be discontinued until modifications can be reviewed and approved.

If you have any questions, please contact Dr. Mary Livingston at 257-4315.

APPENDIX B

PARENT RECRUITMENT LETTER

PARENT RECRUITMENT LETTER

Dear Parent/Guardian

We will be conducting hearing screenings at your child's school and are requesting the participation of your child. The hearing screenings are being conducted as part of a research project that will be comparing the traditional hearing test to a more conventional hearing assessment. The purpose of the study is to determine which method is best for hearing tests in the school environment. Both types of hearing tests are commonly used in the medical setting and pose no discomfort to your child. The results of this research study will provide important information regarding the best way to evaluate hearing in a school setting.

In order for your child to participate you must sign the informed consent (attached to this letter) and have your child return it with them to school. Your child's participation is not required and their non participation will in no way affect their academic standing. If your child fails the hearing screening that will be provided at school, an audiological evaluation will be provided free of charge at the Louisiana Tech Speech and Hearing Center.

If you have any questions regarding this research study or would like further information, please contact me at (318) 257- 2066 or email at smadix@latech.edu. Thank you for your time and consideration.

_____

Steven G. Madix, Ph.D., CCC-A/SLP
Assistant Professor
Louisiana Tech University

LETRA DEL RECLUTAMIENTO DEL PADRE

Estimado padre/guarda

Conduciremos investigaciones de la audiencia en la escuela de su niño y estamos solicitando la participación de su niño. Las investigaciones de la audiencia se están conduciendo como parte de un proyecto de investigación que esté comparando la prueba tradicional de la audiencia a un gravamen más convencional de la audiencia. El propósito del estudio es determinarse qué método es el mejor para las pruebas de la audiencia en el ambiente de escuela. Ambos tipos de pruebas de la audiencia son de uso general en el ajuste médico y no plantean ningún malestar a su niño. Los resultados de este estudio de la investigación proporcionarán la información importante con respecto a la mejor manera de evaluar la audiencia en un ajuste de la escuela.

Para que su niño a participar usted deba firmar el consentimiento informado (unido a esta letra) y tener su vuelta del niño él con ellos a la escuela. La participación de su niño no se requiere y su no participación afectará de ninguna manera su situación académica. Si su niño falla la investigación de la audiencia que será proporcionada en la escuela, una evaluación audiological será proporcionada gratuitamente en el centro del discurso y de la audiencia del Tech de Luisiana.

Si usted tiene cualquier pregunta con respecto a esta investigación estudia o quisiera la información adicional, me entra en contacto con por favor en (318) 257 - 2066 o el email en smadix@latech.edu. Gracias por su tiempo y consideración.

Steven G. Madix, Ph.D., CCC-A/SLP
Profesor auxiliar
Universidad del Tech de Luisiana

APPENDIX C

HUMAN SUBJECTS PERMISSION FORM

HUMAN SUBJECTS CONSENT FORM

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

TITLE OF PROJECT: Subjective Versus Objective Hearing Screening Results of School-Aged Children

PURPOSE OF STUDY/PROJECT: The purpose of this project is to observe and to determine whether there is a difference in the pass/refer results, of school-aged children, from subjective versus objective hearing screening procedures.

PROCEDURE: If you agree to participate in this research study your child will have their hearing screened through a traditional, behavioral hearing test and also through a middle and inner ear screening. The results of the hearing screenings will be analyzed to determine if there are any differences between the pass/fail rates of traditional pure tone hearing screening and objective hearing screenings.

INSTRUMENTS: Your child's identity will not appear on any of the forms used in the experiment or analysis of the data. Only pass/refer data will be used in the presentation of results.

RISKS/ALTERNATIVE TREATMENTS: The participant understands that Louisiana Tech is not able to offer financial compensation nor to absorb the costs of medical treatment should you be injured as a result of participating in this research. There are no known risks associated with this study and participation is voluntary. These procedures used to test your child's hearing do not vary from routine audiometric measures. The experimental aspect of this study is the difference, if any, the pass/fail rates of traditional pure tone hearing screening and objective hearing screenings.

BENEFITS/COMPENSATION: Free hearing screening and an evaluation if needed.

I, _____, attest with my signature that I have read and understood the following description of the study, "_____", and its purposes and methods. I understand that my 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 my grades in any way. Further, I understand that I may withdraw 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 of my survey will be confidential, accessible only to the principal investigators, 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.

_____ _____

Signature of Participant or Guardian **Date**

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

Steven G. Madix, Ph.D., CCC-A/SLP, Department of Speech, 216 Robinson Hall, 318-257-2066.
Meagan Chatelain, B.A., Department of Speech, 120 Robinson Hall, 318-257-4766

Members of the Human Use Committee of Louisiana Tech University may also be contacted if a problem cannot be discussed with the experimenters:

Dr. Les Guice (257-3056)
Dr. Mary M. Livingston (257-2292 or 257-4315)

FORMA DEL CONSENTIMIENTO DE LOS TEMAS HUMANOS

Lo que sigue es un breve resumen del proyecto en el cual le piden participar. Lea por favor esta información antes de firmar la declaración abajo.

TÍTULO DEL PROYECTO: Subjetivo contra resultados objetivos de la investigación de la audiencia de Niños Escuela-Envejecidos

PROPÓSITO DE STUDY/PROJECT: El propósito de este proyecto es observar y determinarse si hay una diferencia en el paso/refiera los resultados, de niños escuela-envejecidos, de subjetivo contra procedimientos de investigación objetivos de la audiencia.

PROCEDIMIENTO: Si usted acuerda participar en este estudio de la investigación su niño tendrá su audiencia defendió a través de una prueba tradicional, del comportamiento de la audiencia y también a través de una investigación del oido medio e interno. Los resultados de las investigaciones de la audiencia serán analizados para determinarse si hay algunas diferencias entre el paso/los índices del fall de la investigación pura tradicional de la audiencia del tono y de las investigaciones objetivas de la audiencia.

INSTRUMENTOS: La identidad de su niño no aparecerá en las formas unas de los usadas en el experimento o el análisis de los datos. Pase/refiera solamente los datos será utilizado en la presentación de resultados.

TRATAMIENTOS DE RISKS/ALTERNATIVE: El participante entiende que el Tech de Luisiana no puede ofrecer la remuneración financiera ni absorber los costes del tratamiento médico si le dañan como resultado de participar en esta investigación. No hay riesgos sabidos asociados a este estudio y la participación es voluntaria. Estos procedimientos usados para probar la audiencia de su niño no varían de medidas audiométricas rutinarias. El aspecto experimental de este estudio es la diferencia, si la hay, el paso/los índices del fall de la investigación pura tradicional de la audiencia del tono y las investigaciones objetivas de la audiencia.

BENEFITS/COMPENSATION: Investigación libre de la audiencia y una evaluación si está necesitado.

I, _____, atestigua con mi firma que tengo leído y entendido la descripción siguiente del estudio, "_____", y sus propósitos y métodos. Entiendo que mi participación en esta investigación es terminantemente voluntario y mi participación o denegación a participar en este estudio no afectará mi relación con la universidad del Tech de Luisiana o mis grados de ninguna manera. Además, entiendo que puedo retirarme en cualquier momento o rechazar contestar a cualquier pregunta sin pena. Sobre la terminación del estudio, entiendo que los resultados estarán libremente disponibles para mí a petición. Entiendo que serán los resultados de mi examen confidencial, accesible solamente a los investigadores principales, mismo, o a un representante legalmente designado. Me no han solicitado renunciar ni yo renuncio cualesquiera de las mis derechas relacionadas con participar en este estudio.

_____ _____

Firma del participante o del guarda **Fecha**

INFORMACIÓN DEL CONTACTO: Los experimentadores principales enumeraron abajo pueden ser alcanzados a conteste a las preguntas sobre la investigación, las derechas de los temas, o las materias relacionadas.

Steven G. Madix, Ph.D., CCC-A/SLP, departamento del discurso, 216 Robinson Pasillo, 318-257-2066.
Meagan Chatelain, B.A., departamento del discurso, 120 Robinson Pasillo, 318-257-4766

Los miembros del comité humano del uso de la universidad del Tech de Luisiana pueden también ser entrados en contacto con si un problema no se puede discutir con los experimentadores:

El Dr. Les Guice (257-3056)
El Dr. Maria M. Livingston (257-2292 o 257-4315)

APPENDIX D

HEARING SCREENING REFERRAL LETTER

HEARING SCREENING REFERRAL LETTER

Dear Parent/Guardian:

Your child, student's name, failed the hearing screening conducted at Bernice Elementary School. We recommend that your child have their hearing evaluated by an audiologist. Please contact the Louisiana Tech Speech and Hearing Center to schedule your child a free audiological evaluation at 318-257-4764. If you have any questions please feel free to contact Dr. Steven Madix or Meagan Chatelain at 318-257-2066.

Sincerely,

Steven G. Madix, Ph.D., CCC-A/SLP
Assistant Professor
Louisiana Tech University

LETRA DE LA REMISIÓN DE LA INVESTIGACIÓN DE LA AUDIENCIA

Estimado padre/guarda:

Su niño, nombre del estudiante, fallado la investigación de la audiencia conducida en la escuela primaria de Bernice. Recomendamos que su niño hace su audiencia evaluar por un audiologist. Entre en contacto con por favor el centro del discurso y de la audiencia del Tech de Luisiana para programar a su niño una evaluación audiological libre en 318-257-4764. Si usted tiene cualquier pregunta satisface la sensación libre entrar en contacto con a Dr. Steven Madix o Meagan Chatelain en 318-257-2066.

Sinceramente,

Steven G. Madix, Ph.D., CCC-A/SLP
Profesor auxiliar
Luisiana Universidad del Tech

APPENDIX E

STUDENTS' RESULTS (RAW DATA)

ID#	Overall Pure Tone Screening AU	.5 R	1 R	2 R	4 R	.5 L	1 L	2 L	4 L	(TE) OAE R	(TE) OAE L	(DP) OAE R	(DP) OAE L	TYMP R	TYMP L
E1	P	P	P	P	P	P	P	P	P	F	F	P	P	F	F
E1	F	P	P	P	P	F	P	P	P	P	P	P	P	CNT	CNT
E3	F	F	P	P	P	F	P	P	P	P	P	P	P	CNT	CNT
E4	F	P	P	P	P	F	F	P	P	P	F	P	F	CNT	CNT
E5	F	F	P	P	P	F	P	P	P	P	P	P	P	CNT	CNT
E6	F	F	P	P	P	F	P	P	P	P	P	P	P	CNT	CNT
E7	F	F	P	P	P	F	P	P	P	F	F	P	P	CNT	CNT
E8	F	F	P	P	P	P	P	P	P	F	F	P	P	P	P
E9	F	F	P	P	P	P	P	P	P	P	P	P	P	CNT	CNT
E10	P	P	P	P	P	P	P	P	P	P	P	P	P	CNT	CNT
E11	P	P	P	P	P	P	P	P	P	P	P	P	P	CNT	CNT
E12	F	F	P	P	P	F	P	P	P	P	P	P	P	CNT	CNT
E13	F	F	F	P	P	F	P	P	P	F	F	F	F	CNT	CNT
E14	F	P	P	P	P	F	P	P	P	F	P	F	F	CNT	CNT
E15	F	F	P	P	P	P	P	P	P	P	P	P	P	P	P
E16	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
E17	F	P	P	P	P	F	P	P	P	P	P	P	P	P	P
E18	F	F	P	P	P	P	P	P	P	P	P	P	P	P	P
E19	F	F	F	P	P	F	P	P	P	P	P	P	P	P	F
E20	F	F	P	P	P	F	F	P	P	P	P	P	P	P	P
E21	F	F	P	P	P	F	P	P	P	F	F	P	P	P	P
E22	F	P	P	P	P	F	P	P	P	P	P	F	F	F	F
E23	F	F	P	P	P	F	P	P	P	P	P	P	P	F	F
E24	F	F	P	P	P	F	F	F	F	P	P	P	P	F	P
E25	F	F	F	P	P	F	F	P	P	P	P	P	P	P	P
E26	F	F	P	P	P	F	P	P	P	P	P	P	P	P	P
E27	F	F	P	P	P	F	P	P	P	P	P	P	P	F	F
E28	F	F	P	P	P	F	P	P	P	P	P	P	P	F	P
E29	F	F	P	P	P	F	P	P	P	P	P	P	P	F	F
E30	F	F	F	P	P	F	F	P	P	P	P	P	P	F	F
E31	F	F	P	P	P	F	P	P	P	P	P	P	P	P	P
E32	F	P	P	P	P	F	P	F	P	F	F	F	F	F	F
E33	F	F	P	P	P	F	F	P	P	P	P	P	P	P	P
E34	F	F	F	F	F	F	F	F	F	P	P	P	P	F	P
E35	F	P	P	P	P	F	F	P	P	F	F	F	F	F	F
E36	F	F	F	F	P	F	F	F	P	F	F	F	P	F	P
E37	F	F	F	P	P	P	P	P	P	F	F	P	F	P	P
E38	F	F	F	P	P	F	F	P	P	P	P	P	P	P	P
E39	F	F	P	P	P	F	F	P	P	P	P	P	P	P	P
E40	F	F	F	P	P	F	F	P	P	P	P	P	P	F	F

ID#	Overall Pure Tone Screening AU	.5 R	1 R	2 R	4 R	.5 L	1 L	2 L	4 L	(TE) OAE R	(TE) OAE L	(DP) OAE R	(DP) OAE L	TYMP R	TYMP L
E41	F	F	P	P	P	F	P	P	P	P	P	P	P	P	P
E42	F	F	P	P	P	F	P	P	P	P	P	P	P	P	P
E43	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
E44	F	F	F	P	P	F	P	P	P	P	P	P	P	P	P
E45	F	F	P	P	P	F	P	P	P	P	P	P	P	P	P
E46	P	P	P	P	P	P	P	P	P	P	P	P	P	F	P
E47	F	F	P	P	P	P	P	P	P	P	P	P	P	P	P
E48	F	F	F	F	P	P	P	P	P	P	P	P	P	F	F
E49	F	F	F	P	P	F	F	F	P	P	P	P	P	P	P
E50	F	F	F	F	P	F	F	F	F	P	P	P	P	P	P
E51	F	P	P	P	P	F	P	P	P	P	P	P	P	F	F
E52	F	F	P	P	P	F	F	P	P	P	P	P	P	F	P
E53	F	F	F	P	P	F	F	P	P	P	P	P	P	F	F
E54	F	F	P	P	P	F	P	P	P	P	P	P	P	F	F
E55	F	F	P	P	P	P	P	P	P	P	P	P	P	F	F
E56	F	F	P	P	P	F	P	P	P	P	P	P	P	P	P
E57	F	F	F	P	P	F	F	P	P	P	P	P	P	CNT	CNT
H1	F	F	P	P	P	F	P	P	P	P	P	P	P	CNT	CNT
H2	F	F	F	P	P	F	P	P	P	P	P	F	F	F	F
H3	F	F	P	P	P	F	P	P	P	F	F	P	P	P	P
H4	F	F	P	P	P	F	P	P	P	P	P	P	P	F	P
H5	F	F	P	P	P	F	P	P	P	P	F	P	P	P	F
H6	F	F	F	P	P	F	F	P	P	P	P	P	P	P	P
H7	F	F	F	P	P	F	P	P	P	P	P	P	P	F	F
H8	F	P	P	P	P	F	P	P	P	F	P	P	P	P	P
H9	F	F	F	F	F	P	P	P	P	P	P	P	P	P	P
H10	F	F	F	P	P	F	P	P	P	F	P	P	P	P	P

Key:

P = Pass

F = Fail

CNT = Could Not Test

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