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AN ASSESSMENT OF THE EFFICACY OF THE TOWSON UNIVERSITY HEARING AND SPEECH-LANGUAGE SCREENING

by

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ABSTRACT

AN ASSESSMENT OF THE EFFICACY OF THE TOWSON UNIVERSITY HEARING AND SPEECH-LANGUAGE SCREENING

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The efficacy of a college hearing screening program was examined by (1) completing an audiological assessment on 80 randomly selected students after they were screened in 2011 and (2) retrospectively examining hearing and speech-language screening results and follow-up return rates for all students screened over a 10-year period. Results indicated the hearing screening protocol had good specificity and sensitivity when considering the screening frequencies (1000, 2000, 4000 Hz) but missed many students with a high frequency "notch." The retrospective file review for the hearing screenings showed a low positive predictive value (PPV) and a high over-referral rate (ORR). The speech-language screenings had a high PPV and a low ORR. Both screenings had poor follow-up return rates. Two main factors that contributed to the low sensitivity were high levels of ambient noise in the test rooms and the inability of the screener to detect high frequency hearing loss. Based on these findings, ambient noise levels surrounding the rooms where screenings take place should be monitored more closely. Also, college hearing screening program directors should carefully consider the purpose of the screening and adjust the protocol if they wish to identify noise induced hearing loss in college students and additionally, should propose ways to increase the follow-up return rate.

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CHAPTER 1

Introduction

Hearing and speech-language screenings are intended to separate those at risk of hearing or speech-language disorders from others who are not at risk. State law generally mandates participation in the screenings for infants and children from pre-school through high school. Organizations such as the American Speech-Language-Hearing Association (ASHA) and the American Academy of Audiology (AAA) have created screening guidelines for use in institutions such as hospitals, schools, and primary care physician offices. These documents are guidelines, but a nationally accepted hearing and speech-language screening method does not currently exist.

Though hearing and speech-language screenings are not mandated by state law for higher education, universities may offer hearing screenings to students or they may require participation in a screening program as a requirement for graduation. For example, Towson University (TU) requires a hearing and speech-language screening for students in disciplines that include an off-campus teaching or health care internship. For these students, professional development relies heavily on the ability to communicate well with others, particularly in their interactions with other students, patients, and parents. This is critical to the student's success in their respective discipline. At TU, the programs of study that involve teaching include early childhood, special, music, and elementary education, among others. Health care professions include nursing, occupational therapy, speech-language pathology and audiology. The purpose of the hearing and speech-language screening at TU is to identify students at risk of hearing or communication disorders, which could negatively impact the required internship and future career opportunities. The Speech-Language-Hearing Center also offers follow up diagnostic and treatment services.

According to ASHA (1997), an effective hearing and speech-language screening program correctly and quickly identifies students with and without risk of a hearing or speech-language impairment and has an effective follow-up protocol in place. ASHA also recommends that the accuracy of a hearing screening program should be evaluated. One way to measure the accuracy of a screening protocol is by calculating the sensitivity and specificity of the protocol used for screening. These calculations can only be made in a controlled clinical study that re-evaluates hearing and speech-language abilities in patients who fail as well as pass the screening. This type of study can identify how many students were correctly identified by the screening and how many students were missed.

ASHA (1997) recommends that the accuracy of a screening program should be evaluated. To date, an evaluation of the accuracy of the TU hearing and speech-language screening program has not been conducted. For the current study, the sensitivity and specificity of the TU screening program were measured prospectively during the Fall 2011 hearing screening. In addition, the over-referral rate and the positive predictive value of past hearing and speech-language screenings at TU were calculated and return-rate for services was determined based on retrospective analysis of data from spring 1999 to spring 2011.

CHAPTER 2

Review of Literature

The purpose of a hearing and speech-language screening program is to efficiently identify those at risk for a hearing and/or speech-language disorder in order to refer them for additional testing. Organizations such as the American Speech-Language-Hearing Association (ASHA) and the American Academy of Audiology (AAA) have published guidelines for audiologic screenings. ASHA and AAA's current screening guidelines include protocols for various chronological ages and developmental abilities of patients, spanning from neonates to adults. Screening guidelines have also been developed by ASHA for early identification and intervention of speech and/or language disorders. While these guidelines provide suggested protocols for screening, some states have mandated their own screening protocols. For example, in Maryland, hearing screenings are required at birth, when entering a new school system, at the 1st, 4th, 5th or 6th grade, and 9th grade levels. State law does not require participation in hearing and speech-language screening after completion of high school. However, hearing screenings are a program requirement for certain fields of study at universities across the country. For example, hearing screenings are required at Marywood University (Jourdanais, n.d.), the University of Tennessee ("Teacher Education at the University of Tennessee, Knoxville: Admission to Teacher Education," n.d.), the University of Alabama ("The Department of Communicative Disorders: The University of Alabama," n.d.), and Towson University.

Towson University requires undergraduate students in majors such as education, nursing, and occupational therapy as well as graduate students in speech-language pathology and audiology to have their speech-language and hearing status screened in September or February prior to internship placement. The purpose of the hearing and speech-language screening is early detection of communication disorders, which could impact success in the classroom, during clinical/educational internships, and in a future career. At TU, students who do not pass the screening are not excluded from their program; however, they are advised to follow up with a diagnostic evaluation and are offered the opportunity to do so at no charge, through the TU Speech-Language-Hearing Center (SLHC). If applicable, the SLHC can provide treatment as well as recommendations and/or assistance to students requiring classroom and internship accommodations as well as recommendations for future vocational needs, if necessary.

In order for a hearing and speech-language screening to be effective, the screening must be time and cost efficient, correctly differentiate between individuals in need of further evaluation and individuals who do not need further evaluation, and have effective follow-up procedures in place. The screening must also be age-appropriate for the targeted population and, as recommended by ASHA (1997), screening programs should be evaluated for accuracy.

Accuracy of a Screening Program

An effective screening program should accurately identify those at risk of a disorder in order to make a referral for further evaluation. The screening program should, as accurately as possible, separate the sample into two categories: pass (negative) and refer/fail (positive). The accuracy of the screening is based on how well it categorizes the sample, compared with diagnostic testing and is usually evaluated using a contingency table, which is a 2x2 matrix that compares the results of a screening test (positive or negative) to the actual presence of the disorder (present or absent). Table 1 displays the four possible outcomes from this comparison: hit (true positive), false alarm (false positive), miss (false negative), and correct rejection (true negative). Using the values in the matrix, probabilities can be calculated to quantify the accuracy

Table 1

Test result (positive or negative) compared to actual diagnosis of disorder (present or absent)

		Disorder	
		Present (+)	Absent (-)
Screening Result	Positive Abnormal (Refer)	Hit (True Positive) A	False Alarm (False Positive) B
	Negative Normal (Pass)	Miss (False Negative) C	Correct Rejection (True Negative) D

of the screening program. The two probabilities used most frequently in the literature to evaluate accuracy are sensitivity and specificity. Sensitivity is the probability that someone with a positive screening result truly has the disorder and specificity is the probability that someone with a negative screening result does not have the disorder. Ideally, a screening program should correctly fail those with the disorder and should correctly pass those without the disorder, resulting in high specificity and sensitivity.

Statistics that are also important for evaluating the accuracy of a screening program include the false negative rate, false positive rate, positive predictive value, negative predictive value, under-referral rate, and over-referral rate (Table 2). The positive predictive value and the over-referral rate are useful when completing a retrospective case study. In this case, the researcher may be limited to information about the number of subjects who passed and who were referred for additional testing and information about further test results for those who were referred. However, one cannot calculate the sensitivity and specificity of retrospective screening results because a “pass” would not be followed by a diagnostic test. A false positive rate is the probability that someone with the disorder will have a negative test and the over-referral rate is the probability that someone who has a positive test does not have the disorder. The goal of a screening is to have both low false positive and low over-referral rates. Table 2 displays formulas to calculate all of the probabilities mentioned above.

Towson University Hearing Screening Protocol

The protocol for the hearing screening portion of the TU screening program follows guidelines set by ASHA (1997) for school-aged children aged 5-18, which recommends testing 1000, 2000, and 4000 Hz at 20 dB HL. As stated by ASHA(1997), hearing impairment in school-

Table 2

Formulas to calculate accuracy of screening tests.

Column Data (in reference to the disorder)		
Measure of Accuracy	Formula	Probability that…
Sensitivity	A/(A+C)	someone with the disorder has a positive screening result
Specificity	D/(B+D)	someone without the disorder will have a negative screening result
False Negative Rate	C/(A+C)	someone with the disorder will have a negative screening result
False Positive Rate	B/(B+D)	someone without the disorder will have a positive screening result

Row Data (in reference to screening result)		
Measure of Accuracy	Formula	Probability that…
Positive Predictive Value	A/(A+B)	someone who has a positive screening result has the disorder
Negative Predictive Value	D/(C+D)	someone who has a negative screening result does not have the disorder
Under-Referral Rate	C/(C+D)	someone who has a negative screening result has the disorder
Over-Referral Rate	B/(A+B)	someone who has a positive screening result does not have the disorder

aged children is defined as “unilateral or bilateral sensorineural and/or conductive hearing loss greater than 20 dBHL in the frequency region most important for speech recognition (approximately 500 to 4000 Hz).” The misconception that higher frequencies are not important for speech perception and educational success perhaps is the cause for omission of high frequencies from the screening battery. This misconception was contradicted in a study by Davis, Elfenbein, Schum, and Bentler (1986), which found that students with hearing loss, regardless of degree or type of hearing loss, exhibited delays in verbal skill development, academic achievement, and social development.

Higher frequencies such as 6000 and 8000 Hz may also be omitted from the screening protocol due to high false positive rates associated with inclusion of these frequencies (AAA, 2011). The omission of high frequency tones may result in missed cases of sensorineural hearing loss (e.g., noise-induced hearing loss or NIHL) thus lowering the overall sensitivity of the hearing screening (Sekhar et al., 2011). Low frequency tones (250, 500 Hz) are generally omitted because these frequencies are most often associated with false positive results caused by high levels of ambient noise in screening rooms (Alvord, 1993), which would be the case for a large-scale screening conducted in “quiet” but not sound-treated rooms. The omission of these low frequencies may result in missed cases of conductive hearing loss (e.g., loss caused by otitis media); however prevalence of middle ear pathology such as otitis media decreases with age (Maxon & Yamaguchi, 1996).

In addition to ASHA’s published recommendations on screening protocol, the American National Standards Institute (ANSI) has published guidelines for maximum permissible ambient noise levels (MPANLs) during hearing screenings when supra-aural headphones cover the ears (American National Standards Institute, 1999). Table 3 displays the MPANLs adjusted for the 20 dB HL screening level for each octave band during a hearing screening as stated by ANSI S3.1-1999. These levels may be difficult or impossible to achieve outside of a sound-treated room.

Identification of NIHL with a Hearing Screening Program

An abundant amount of research has been completed in the past to assess hearing screening programs' ability to identify NIHL in the school-aged population. Niskar et al. (2001) assessed hearing screening accuracy in identifying NIHL in children and adolescents by analyzing audiometric data from over 5,000 subjects, ages 6 to 19. The data included pure tone thresholds for 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz. The researchers found that the "noise notch," a classic indicator of NIHL (characterized by a threshold at a frequency 3000-6000 Hz poorer than both adjacent thresholds), most frequently occurred at 6000 Hz (77.1% of the cases) in all age groups. It was concluded that a hearing screening that does not include frequencies higher than 4000 Hz will most likely fail to identify many students with NIHL. Similar findings have been published by Cozad, Marston, and Joseph (1974) in a study of 18,600 school-aged children living in rural Kansas, Phillips,Henrich, and Mace (2010) who looked at NIHL in student musicians, Holmes et al. (1997) which included 342 adolescents between the ages of 10-20, and Meinke and Dice (2007), a study which looked at the ability to detect NIHL with the ASHA (1997) protocol. Overall, these studies support the need to include 6000 Hz in the hearing screening protocol. In contrast, Schlauch and Carney (2011) evaluated the false positive rate when including 6000Hz in the screening protocol for school-aged children ages 6-19. Results yielded a high false positive rate, raising concern for the use of 6000 Hz in the hearing screening protocol.

Table 3

Maximum permissible ambient noise levels with use of supra-aural headphones during a hearing screening with 20 dB correction factor (ANSI S3.1-1999).

Octave Band Intervals (Hz)	MPANLs (dB)
125	69
250	55
500	41
1000	46
2000	54
4000	57
8000	57

Studies have been published directly looking at the ASHA hearing screening protocol, (similar to the one used at TU) and its ability to detect noise notches in school aged children. In a study by Meinke and Dice (2007), it was determined that the ASHA hearing screening protocol (20 dB HL at 1000, 2000, and 4000 Hz) is the most frequently used hearing screening method in the country. This study looked at the 18 most commonly used hearing screening protocols in the country and the ability of each protocol to identify a NIHL. The results of this study revealed that the ASHA (1997) protocol for hearing screenings, used by 24 states in America, only correctly identified a noise notch in 10 out of the 45 students with a NIHL. The protocol used by only three states, which includes 500, 1000, 2000, 4000, and 6000 Hz at 20 dB HL, correctly identified the highest number of students with a high frequency notch (Meinke & Dice, 2007).

The most recent article published on the ability of a screening protocol to detect a high frequency hearing loss looked at ways to improve detection of hearing loss in adolescents (Sekhar et al., 2011). In the study, 11th grade high school students in Pennsylvania participated in a mandatory “rapid hearing screen” followed by optional participation in a survey and a complete pure tone threshold test. Of the 296 participants, 15 failed the hearing screening while 78 failed the pure tone threshold test. Out of the 78 students who failed the pure tone threshold test, 67 (85.9%) had a notched audiometric configuration. Sekhar et al. (2011) concluded that omitting high frequency pure tones in a hearing screening for older adolescents negatively impacts the ability of the screening program to identify students with potential hearing loss.

Prevalence of Hearing Loss in College Students

Research focusing on the prevalence of hearing loss in college students and the efficiency of the hearing screening protocol in the university setting is limited to two studies. Specifically, Martin and Church (1991) and Lipscomb (1972) investigated the prevalence of hearing impairment in the college population as part of a hearing-screening program. Table 4 displays the screening protocols and the results found for both studies. Lipscomb (1972) used a screening protocol of 1000, 2000, 4000, and 6000 Hz at 15 dB and found that 60.7% of the students tested (n=1410) failed the hearing screening. Martin and Church (1991) screened 1000, 2000, and 4000 Hz at 20 dB HL and found that of the 18,424 students tested, 1.2% (215 students) failed the hearing screening. Examination of this table shows that a higher screening failure rate was obtained when 6000 Hz was added to the screening protocol as well as the use of 15 dB for a failure criterion. Neither of these studies reported sensitivity or specificity of the hearing screening protocol since students who passed the hearing screening did not receive diagnostic testing to confirm or deny the presence of hearing loss.

Sensitivity and Specificity of University Hearing Screening Programs

Although research is limited regarding university/young adult hearing screenings, there are a number of studies that have been completed on younger populations. Research by Holtby, Foster, and Kumar (1997) provides an example of a controlled clinical study with the goal of measuring the accuracy of a hearing screening protocol on a young population. This study identified the sensitivity and specificity of a two-stage hearing screening program performed by school nurses for children age 5-6 years old entering the school system. Holtby, Forster, and Kumar (1997) used a failure criterion of 20 dB HL at 250, 500, 1000, 2000, and 4000 Hz and calculated sensitivity and specificity as 74.4% and 92.1% respectively. Similar measurements of hearing screening sensitivity and specificity were found by Holtby and Forster (1992) in a slightly younger sample population (sensitivity of 80% and specificity of 95%). Though both of

Table 4

Comparison of number of students who failed the university hearing screening depending on screening protocol.

	Screening Protocol	Students Screened	Students Failed by Screening	Percentage of Failure (%)
Martin and Church (1991)	20 dB @ 1000, 2000, 4000 Hz	18,424	215	1.2
Lipscomb (1972)	15 dB @ 1000, 2000, 4000, 6000 Hz	1,410	856	60.7

these studies measured the sensitivity and specificity of a hearing screening protocol, the young sample population (age 6 and below) limits the use of this research, especially when evaluating hearing screenings for the university population.

Research also exists on the accuracy of the screening protocol for the older adult population. One study includes Scudder, Culbertson, Waldron, and Stewart (2003), where the predictive validity and reliability of hearing screening techniques were analyzed, which included a case history examination, otoscopic examination, pure tone threshold examination, and distortion product otoacoustic emissions (DPOAEs). The sample population included adults above the age of 49. The screenings correctly identified 89% of the sample with a true hearing loss while 11% had normal hearing and were incorrectly identified at the screening. The test protocol used in this study is more in-depth than the current protocol at Towson University, which only includes pure-tone testing. Also, the study screened patients in an older age range.

In the literature, one study does exist that looked at the accuracy of a hearing screening for the college population. In this study by DiCarlo and Gardner (1957) the accuracy of the Massachusetts Pure Tone Screening Test at Syracuse University was evaluated. Results indicated that the test protocol used at Syracuse University in 1957 correctly identified hearing loss in 91.1% of the college students in the sample group. Though this study focused on the college population, screening protocol has changed since 1957, therefore making this literature outdated.

Additional research on the sensitivity and specificity of university hearing screening protocols is needed. In particular, studies including frequencies above 4000 Hz could be of great clinical importance. Current research on the topic of hearing screening accuracy is limited to test protocols that exclude 6000 Hz (Holtby, Forster, and Kumar (1997) used a protocol only including 250-4000 Hz), populations other than university students/young adults Scudder et al.

(2003) tested participants above the age of 49), studies that do not include sensitivity and specificity data (Martin and Church (1991) and Lipscomb (1972) did not re-test students who passed the screening), and studies that are outdated (DiCarlo and Gardner (1957) published this study over 50 years ago).

Efficiency of Follow-Up Procedures

In addition to the need to assess the sensitivity and specificity of university-based screening protocols, the effectiveness of follow-up procedures should also be evaluated. If a screening correctly passes and fails students but has a low return rate of students referred for additional evaluation and treatment services, there is a breakdown in the screening program that must be addressed. Low return rates have been observed in studies conducted on hearing screenings for all age ranges, including newborn hearing screenings, school-based screenings, as well as screenings at the university level. Fonseca, Forsyth, and Neary (2007) found a 23% return-rate for school-based screenings. Martin and Church (1991) reported that 35% of the college students referred for further testing did not return to the university clinic. Allen, Stuart, Everett, and Elangovan (2004) found a similarly low return rate for children enrolled in a head start program between the ages of 3 and 4 years old. Allen et al. (2004) reported that the low compliancy for referred follow-up evaluations had a negative impact on the success of this screening program, as it does with many other mass screening programs. Also of note, the percentage of children referred and followed up for diagnostic vision evaluations during the 2001-2002 school year was three times greater than the percentage of children who were followed up for recommended hearing evaluations after failure of a hearing screening (Allen et al., 2004). Neither study documented how many patients sought services outside of the recommended clinic; therefore, actual return rates are unknown, but the discrepancy between vision and hearing follow up indicates examination of follow up for hearing screening programs should be investigated further.

Some universities, such as The University of Tennessee and Marywood University, require incoming education majors to participate in hearing and speech-language screenings; however, it is the responsibility of the student to follow-up with additional recommended evaluations (Jourdanais, n.d.; "Teacher Education at the University of Tennessee, Knoxville: Admission to Teacher Education, n.d.). Though both of these universities have an on-campus hearing and speech-language clinic, students who fail either screening are not required to seek re-evaluations or intervention through services provided within the university. At the University of Alabama, students who fail the hearing or speech-language screenings are required to seek and provide documentation of treatment either at the on-campus hearing and speech-language clinic or at an outside center prior to admission in the clinical practicum ("The Department of Communicative Disorders: The University of Alabama," n.d.). Again, the return rate for the University of Alabama is unknown; however, it would be logical to assume that the follow up rate is better for universities that require follow-up of recommendations and also for universities that provide conveniently located services in the same university center as the hearing screening. To date, no studies have indicated the return rate of a university-based hearing screening protocol.

In summary, there are limited data in the literature regarding the sensitivity and specificity of university-based hearing screening protocols and there are no data regarding the return rate. According to the U.S. Preventative Services Task Force (1996) for screening for hearing impairment, there is great need for research on the efficacy of adult hearing screening protocols. This guide also stated that there is insufficient evidence in the literature to regulate the hearing screening protocols for asymptomatic adolescents and working-age adults. Prior to this study, a formal evaluation of the screening protocol used at Towson University has never been conducted, although such an evaluation is recommended by ASHA (1997) in addition to the aforementioned Guide to Clinical Preventative Services.

The University Speech-Language Screening

The speech-language screening at TU takes place in conjunction with the hearing screenings and is similarly mandatory for all incoming nursing, education, occupational therapy, audiology and speech-language pathology students. The purpose of the speech-language screening is to detect deviations from normal speech that may impact students' ability to communicate effectively during off campus clinical/educational internships and in employment settings after graduation. Some programs requiring the speech-language screening are considered vocally demanding occupations, which heavily rely on the quality of the voice in order to effectively perform on a daily basis (Simberg, Sala, & Ronnemaa, 2004; Gottliebson, Lee, Weinrich, & Sanders, 2007). Early identification of speech-language deviations and disorders, follow up diagnostic testing, and follow up treatment and education, if applicable, are important for the educational and vocational needs of students in these programs. Similar to the statistical analysis of hearing screening versus diagnostic data previously described, an effective speech-language screening program correctly identifies students at risk for a disorder and makes an appropriate referral for a full evaluation if applicable.

Students in fields of study considered “high risk” for acquiring disorders of the voice (strained vocal cords, hoarse voice, etc.) should have access to speech-language screenings and voice therapy options. Studies such as Roy et al. (2004), Simberg et al., (2004), Bovo, Galceran, Petruccelli, & Hatzopoulos (2007), and Herrington-Hall, Lee, Stemple, Niemi, & McHone

(1988) have all found that teachers are at a high risk for voice impairments due to the daily strain on the voice in the classroom setting. Simberg et al. (2006) found that students identified by the speech-language screening who participated in voice therapy had a significant improvement in voice quality when compared to the students who did not seek therapy for speech-language disorders.

Due to the high incidence of speech, language, or voice disorders in the education field and other vocally demanding professions, Bovo et al. (2007) suggested that students in these fields should have the opportunity to participate in preventative voice programs to minimize the risk of experiencing vocal disorders in the future. Bistrizki and Frank (1981) found that teachers who participated in the preventative voice disorder seminars throughout the first year of their career were less likely to experience voice problems when compared to teachers who did not attend the seminars.

As recommended by ASHA, screening programs should be evaluated for their efficacy in separating the population into two groups: normal or at risk for possible deviation from normal. Available literature only examines the sensitivity and specificity of screening protocols used for the pre-school and elementary school population, highlighting the need for more research on the college/young adult population. Laing, Law, Levin, and Logan (2002) identified a sensitivity and specificity rate for a pre-school speech and language screening as 60% and 90% respectively with a positive predictive value of 73.3%. Research pertaining to the college population is limited in that it does not include measurements of accuracy. For example, Simberg et al. (2006) assessed students using the visual analog scale (VAS), a quick screening protocol suggested by Simberg, Sala, Laine, and Ronnemaa (2001). Students who were identified with deviant speech were referred for a complete speech and/or language evaluation. Measures of sensitivity and specificity were not reported in this article but the importance of obtaining these measures in the future was discussed.

Although it is important that speech-language screenings be effective, the screening program only meets its objective if follow up procedures are in place. If a student is identified as having a potential speech-language disorder but does not return for the recommended speech-language evaluation, the screening process is ineffective. Return rates for the speech and/or language screening have not been studied. This is an omission in the literature, as the follow up is as important as the accuracy of the screening itself.

STATEMENT OF PURPOSE

The purpose of this study was to evaluate the efficacy of the Towson University speech-language and hearing screening protocols to determine if the current program is accurately identifying students with hearing loss and speech-language deviations/disorders in the college population and if students referred for follow up over a 10 year period were participating in the recommended follow up services at Towson University. The sensitivity and specificity were examined for the fall 2011 Towson University hearing screenings using a prospective study. A retrospective study (records review) was also conducted on the hearing and speech-language screening results from the past 10 years in order to identify the over-referral rate and the positive predictive value of the screening protocol for a larger group of participants. The follow-up return rates for students referred by the hearing and speech-language screening were also examined retrospectively for 10 years (not including the current year) to examine the percentage of students who returned to the TU clinic.

CHAPTER 3

Methodology

In order to assess the efficacy of the hearing and speech-language screening protocols used at Towson University, a study was conducted during the fall 2011 mandatory hearing and speech-language screenings after approval was granted by the TU Institutional Review Board (IRB). This research included a carefully controlled clinical study to measure the sensitivity and specificity (and other measures) of the TU hearing screening protocol. In addition, a records review of the 1999-2011 spring and fall hearing and speech-language screenings was conducted to examine the over-referral rate and positive predictive value. Finally, 10 years of return for follow up data were examined. Note throughout this methodology that all screening and diagnostic testing conducted by graduate student clinicians was performed under the supervision of licensed and Maryland state certified audiologists and speech-language pathologists, as appropriate, based on ASHA Council on Academic Accreditation (CAA) requirements.

Part I – Sensitivity and Specificity of the TU Hearing Screening

Of the 669 undergraduate students who attended the fall 2011 mandatory hearing and speech-language screenings, a total of 80 students participated in this study, for a total participation rate of 12%. Of the 80 participants, 22 were male and 58 were female. The average age of the participants was 22.5 years with a range from 18 years to 49 years old. The vast majority of participants were of typical college age; specifically, 83% were 24 years old or younger. Table 5 displays the undergraduate majors of the 80 students.

As per usual SLHC protocol, all hearing screenings were held in a small speech-language therapy room and were conducted by first year speech-language pathology graduate clinicians.

Table 5

The majors of the participants.

Major	Number of Students
Education	38
Occupational Therapy	14
Physical Education	10
Nursing	9
Special Education	3
Mass Communications	1
Masters Degree Programs	1
Recreational Studies	1
Total	80

Using a portable audiometer and supra-aural headphones, the students were screened at 20 dB HL at 1000, 2000, and 4000 Hz in both ears (ASHA, 1997). If the student correctly responded to all six tones presented, no further testing was recommended and "pass" was indicated on the screening form. If the student failed to respond to any of the three tones presented to either ear, "re-screen" was indicated and the student was sent to the audiology suite to be re-screened by an audiology graduate student clinician. Only the tones missed during the first screening were presented at 20 dB HL. If the student correctly responded to the tones at 20 dB HL, "pass" was checked. If a tone was missed during the re-screen in the booth, the student was referred for a full audiological evaluation. However, this protocol was changed for the 80 participants in the research study.

For the purpose of this research study, all students who were willing to participate in the study were directed to the audiology suite for the experimental audiological assessment. This included students who failed the initial hearing screening in the clinic therapy room and were re-screened in the booth (both pass and fail results for re-screen) and students who passed the initial hearing screening in a small therapy room. Both students who passed and who failed initial and/or re-screening were recruited into the study to calculate the specificity and sensitivity of the program. The audiological assessment included otoscopy, tympanometry, and pure-tone air conduction audiometry threshold testing including 250, 500, 1000, 1500, 2000, 3000, 4000, 6000, and 8000 Hz. Results of otoscopy, tympanometry, and pure tone air conduction thresholds were recorded on the data collection sheet. The main pass criterion for the experimental audiological assessment was considered thresholds at or below 20 dB HL at all test frequencies in both ears. The main fail criterion was thresholds above 20 dB HL at any test frequency in either ear.

In addition to calculating the measures of accuracy for the hearing screening protocol, all results from the audiological assessment were analyzed for the presence of a noise notch. The criterion for the presence of a noise notch was based on the definition from Phillips, Henrich, and Mace (2010). Specifically, the presence and extent of a noise notch was determined by subtracting the best threshold (BT) at 4000, 3000, 2000, or 1000 Hz from the poorest threshold (PT) at 3000, 4000, or 6000 Hz followed by recovery of 5 dB or greater. A notch depth of 15 dB or greater was considered a noise notch.

Ambient noise levels. To identify the ambient noise level in the speech-language therapy rooms where the hearing screenings were held, a sound level meter with octave band filters was used during the scheduled screenings. The ambient noise was measured from inside the therapy room with the door closed.

Part II – Records Review: Trends in Over-Referral Rate and Positive Predictive Value

As part of the current hearing and speech-language screening protocol at TU, all hearing and speech-language screening results and referrals are kept on file in a storage facility for a minimum of 10 years. Students who failed and returned for the complete diagnostic evaluation have a file located in the TU SLHC, which is kept for 7 years. In order to investigate previous trends in the over-referral rate and positive predictive value of the hearing screening protocol used at TU, all available past results, from 1999 to 2010 (spring and fall) hearing and speech-language screenings were analyzed.

Hearing screenings. Hearing screening results were categorized into one of three outcomes: passed initial screening, failed initial screening but passed re-screen, or failed initial screening and failed re-screen/referred for complete evaluation. Outcomes were tallied and the

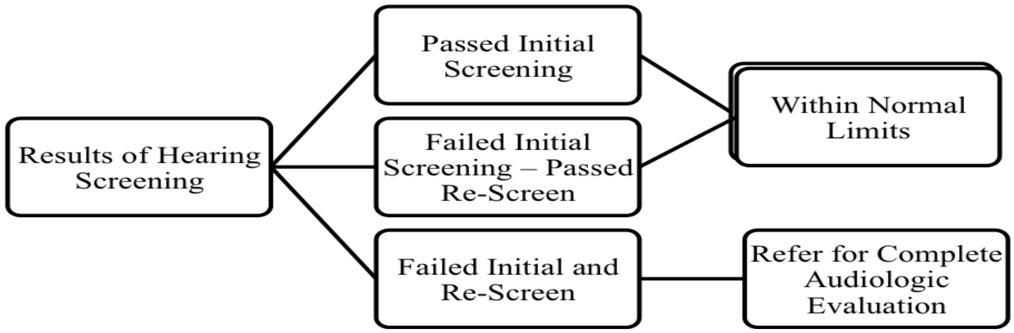

Figure 1. Possible outcomes of the hearing screening. This figure illustrates the different outcomes of the screening depending on if the participant passed the initial screening, failed the initial screening and passed the re-screen, or failed the initial screening and failed the re-screen.

positive predictive values and over-referral rates were calculated. Figure 1 displays the possible outcomes of the hearing screening.

Speech-language screenings. All speech-language screenings were held in a small speech-language therapy room and were conducted by a first year speech-language pathology graduate clinician. The "Rainbow Passage," a common passage used to test for the ability to produce connected speech, was read aloud by the student being evaluated. The graduate clinician listened for any possible deviations from normal in fluency, articulation, voice, rate, etc. If a problem was suspected, the student was immediately re-screened by the supervising faculty member who made the final referral decision. Possible outcomes included "Normal – Pass," "Normal rescreen by supervisor – Pass," "Referral for speech/language/voice evaluation and/or treatment – Refer" or "Return in 3 weeks for rescreening." Students who had dialectal differences that significantly impacted speech intelligibility were considered a referral for a speech/language/voice evaluation and were also informed of the dialect services at TU.

In order to calculate the over-referral rate and positive predictive value of past speech-language screenings, the results from the spring and fall 1999-2011 speech-language screenings were analyzed. Table 6 displays the values used to calculate the over-referral rate and positive predictive value. Screening results were categorized into one of four possible outcomes: passed initial screening, failed initial screening but passed rescreen with clinical supervisor, referral to return for re-screen in 3 weeks, or failed initial screening and failed re-screen and a referral for a complete evaluation. Figure 2 displays the possible outcomes of the speech-language screening pertaining to the students who failed the initial screening in addition to failing the re-screen with the advisor (value X in Table 6). In addition to calculating these measures of accuracy, common speech-language disorders identified in the TU student population were examined. This includes abnormalities such as frontal lisps, distortion of specific speech sounds, and dialectal differences.

Part III – Records Review: Efficiency of Follow-Up Procedures

Following the hearing and speech-language screenings, students who were referred for a speech/language/voice evaluation and/or treatment or a full audiological evaluation were informed that they may obtain these services at the TU SLHC at no charge. According to TU protocol, it was the student's responsibility to schedule a diagnostic evaluation if a problem was suspected. As mentioned previously, charts were made for all students who returned to the SLHC for services and were filed in the clinic. In order to examine the efficiency of the follow-up procedures at TU, the number of students referred for a speech/language/voice evaluation and/or treatment for a full audiological evaluation was documented. All students referred for further testing were divided into two groups: returned to SLHC for additional recommended services or did not return for recommended services after initial referral was made. This was accomplished by checking the SLHC records for all students who were referred for services. The return rate was calculated separately for the hearing screening and the speech-language screening. Unfortunately, it could not be tracked if a student went elsewhere for additional services, which could affect the return rate.

Table 6

A comparison of the initial screening results and the results from the re-screen with the advisor.

		Re-Screen with Advisor	
		Fail	Pass
Initial	Fail	X	Y
Screening	Pass	?	?

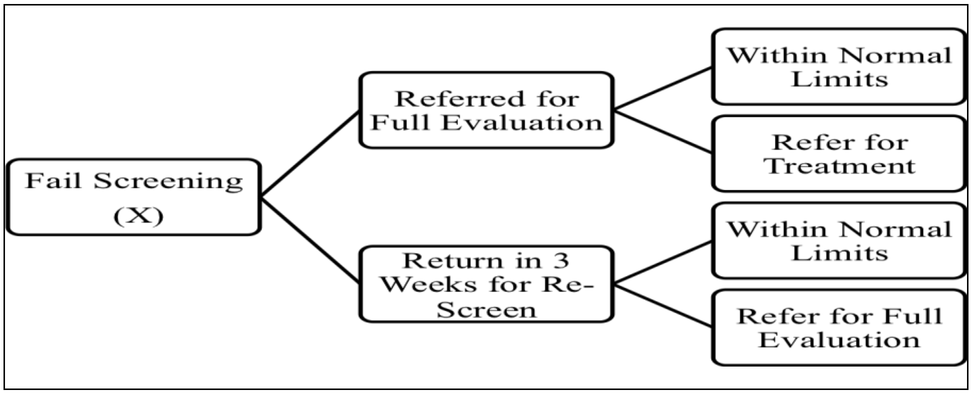

Figure 2. Possible outcomes for students who failed the speech-language screening. This figure displays the four different outcomes of the speech-language screening for students who failed depending on if the student was referred for a full evaluation or if they were asked to return in 3 weeks for a re-screen.

CHAPTER 4

Results

Part I – Sensitivity and Specificity of the TU Hearing Screening

Initial hearing screening. The results of the initial hearing screening in the small therapy room compared to the re-screening of missed tones in the sound booth are displayed in Table 7. Of the 80 total participants, 60 students passed the initial hearing screening and 20 students failed and were re-screened in the sound treated booth. Of these 20 participants, 11 passed and 9 failed the re-screen, making a total of 71 participants who passed the hearing screening. Table 8 displays the calculated positive predictive value and over-referral rate based on the initial results (comparing initial screen to re-screen, prior to diagnostic assessment) of the 80 initial hearing screenings for the participants in this study. Examination of Table 8 indicates if the student failed the initial screening, there was a 55% chance they would pass the re-screening.

Ambient noise levels. Table 9 displays the maximum permissible ambient noise levels (MPANLs) as stated by ANSI 3.1-1999, the ambient noise levels at each octave band measured during the hearing screening from inside a closed speech-language therapy room, and the difference between the maximum ambient noise permitted and the amount measured inside the booth. A negative sign (-) indicates the ambient noise measured during the hearing screening was above the MPANLs. Results show that ambient noise levels from inside the therapy room exceeded the MPANLs by 14 dB at 500 Hz and by 10 dB at 1000 Hz, but the levels were within the ANSI standard at all other tested frequencies.

Audiological assessment. After both portions of the screening for all 80 participants, a total of 71 passed and 9 failed. The overall screening results (final decision of pass or fail after initial and re-screen) compared to the full audiological assessment are shown in Table 10. Of the

71 students who passed the hearing screening, 13 failed the audiological assessment with thresholds greater than 20 dB HL and 58 passed with thresholds at or below 20 dB HL. All 8 participants who failed the hearing screening also failed the audiological assessment. Therefore, a total of 22 participants failed the audiological assessment and 58 passed. Of the 22 participants who failed, 16 were female and 6 were male. Bilateral hearing loss was noted for 13 of the participants, 5 had hearing loss in the right ear only, and 4 had hearing loss in the left ear only.

Measures of accuracy. The sensitivity, specificity and other statistics associated with the accuracy of the TU hearing screening were calculated based on data from Table 10 and are displayed in Table 11. The false negative rate was found to be 0.6, meaning 60% of the participants with hearing loss were incorrectly passed by the hearing screening. The sensitivity in this analysis was poor; specifically it was 0.40, which means that the screening identified less than half of the students with hearing loss. The specificity of 1.0 was much better; meaning all students without a hearing loss passed the screening.

Of the 13 participants who were incorrectly classified as “Pass” during the screening when they truly had thresholds above 20 dB HL, 11 of the 13 students failed solely due to hearing impairment found at 6000 and/or 8000 Hz. If the audiological assessment had only included frequencies considered relevant for speech understanding (500, 1000, 2000, and 4000 Hz), i.e., if the assessment frequencies matched the screening frequencies, the results would be different and these are shown in Table 12. By limiting the assessment to those frequencies, only 1 participant was incorrectly identified by the hearing screening, which lowered the false negative rate from 0.60 (the false negative rate when including all frequencies) to 0.10 (only including speech frequencies). If only considering the speech frequencies, the hearing screening at TU appeared to be an accurate method to screen for hearing loss.

Table 7

Results of the initial screening compared to the results of the re-screen in terms of fail or pass.

(DNT = Did Not Test, UNK = Unknown).

		Re-Screen		
		Fail	Pass	Total
Initial Screening	Fail	9	11	20
	Pass	DNT	DNT	60
	Total	UNK	UNK	80

Note. Those who passed the initial screening were not re-screened hence “Did Not Test,” therefore making the totals for the column data “Unknown.”

Table 8

Formulas to calculate accuracy of screening tests and the overall statistic.

Measure of Accuracy	Formula	Probability that….	Overall Statistic
Positive Predictive Value	A/(A+B)	someone who has a positive initial screening result failed the re-screen	0.45
Over-Referral Rate	B/(A+B)	someone who has a positive initial screening result passed the re-screen	0.55

Note. These data are in reference to row data from Table 7. See Table 2 in Literature Review for further information.

Table 9

Ambient noise levels measured (ANLM) in dB SPL during the hearing screening inside a closed speech-language therapy room and the difference between the MPANLs and the ANLM.

Octave Band Intervals (Hz)	MPANLs (dB)	ANLM (dB SPL)	MPANLs - ANM (dB)
125	69	40	29
250	55	42	13
500	41	55	-14
1000	46	56	-10
2000	54	42	12
4000	57	35	22
8000	57	23	34

Table 10

Results of the screening compared to the results of the audiological assessment.

		Audiological Assessment		
		Positive (hearing loss)	Negative (normal hearing)	Total
Screening Result	Fail	9	0	9
	Pass	13	58	71
	Total	22	58	80

Presence of a noise notch. Based on the definition by Phillips, Henrich, and Mace (2010), it was determined that 38 of the 80 students had a noise notch. Of the 58 female participants and the 22 male participants, 29 females (50%) and 9 males (41%) had a noise notch. Of the 38 students with a notch, 17 had a noise notch in the right ear only, 11 had a notch in the left ear only, and 10 had a notch in both ears. The average pure tone air conduction thresholds for these 38 students were calculated and are displayed in Figure 3.

Part II – Records Review: Trends in Over-Referral Rate and Positive Predictive Value

Hearing screenings. A records review was completed in order to calculate trends in over-referral rate and positive predictive values of hearing screenings completed from spring 1999 to spring 2011. Table 13 displays the calculations for each semester's hearing screening. The average positive predictive value from spring 1999 to spring 2011 was 0.46 with an average over-referral rate of 0.54. This means that if a student failed the hearing screening, there was a 46% chance that they actually had a hearing loss.

Speech-Language Screenings. Table 14 displays the calculated positive predictive values and over-referral rates from spring 1999 to spring 2011 speech-language screenings at TU. The average positive predictive value was 0.70 with an over-referral rate of 0.30. A total of 123 students were identified and referred for a complete diagnostic evaluation or a 3-week follow-up during the past 17 speech-language screenings. The three most common speech/language abnormalities in this population included dialectal differences (37% of students), hoarse voice (30%), and distortion/articulation errors (17%). One percent of the population had issues with stuttering.

Part III – Records Review: Efficiency of Follow-Up Procedures

Table 15 displays the follow-up return rates for the past 17 semesters. A total of 193 students were referred for an audiological evaluation after failing the screenings between spring 1999 and spring 2011. Of these 193 students, 68 returned for the evaluation, resulting in an overall return rate of 35%. The follow-up return rates were also calculated for the speech/language screenings for those students referred for a complete speech/language evaluation or a follow-up in three weeks and are displayed in Table 16. Of the 141 students referred for additional testing after failing the speech/language screening, a total of 27 students returned to the TU SLHC for recommended testing resulting in an overall follow-up return rate of 19%. It is unknown if any students referred for follow up testing went to another facility for these services.

Table 11

Formulas to calculate accuracy of screening tests and the calculated statistic.

Column Data (in reference to the disorder)			
Measure of	Formula	Probability that…	Calculated Statistic
Sensitivity	A/(A+C)	someone with the disorder has a positive screening result	0.40
Specificity	D/(B+D)	someone without the disorder will have a negative screening result	1
False Negative Rate	C/(A+C)	someone with the disorder will have a negative screening result	0.60
False Positive Rate	B/(B+D)	someone without the disorder will have a positive screening result	0
Row Data (in reference to screening result)			
Measure of Accuracy	Formula	Probability that…	Calculated Statistic
Positive Predictive Value	A/(A+B)	someone who has a positive screening result has the disorder	1
Negative Predictive Value	D/(C+D)	someone who has a negative screening result does not have the disorder	0.82
Under-Referral Rate	C/(C+D)	someone who has a negative screening result has the disorder	0.18
Over-Referral Rate	B/(A+B)	someone who has a positive screening result does not have the disorder	0

Table 12

Results of the screening compared to the results of the audiological assessment when only including 500, 1000, 2000, and 4000 Hz.

		Audiological Assessment		
		Fail	Pass	Total
Screening Result	Fail	9	0	9
	Pass	1	70	71
	Total	10	70	80

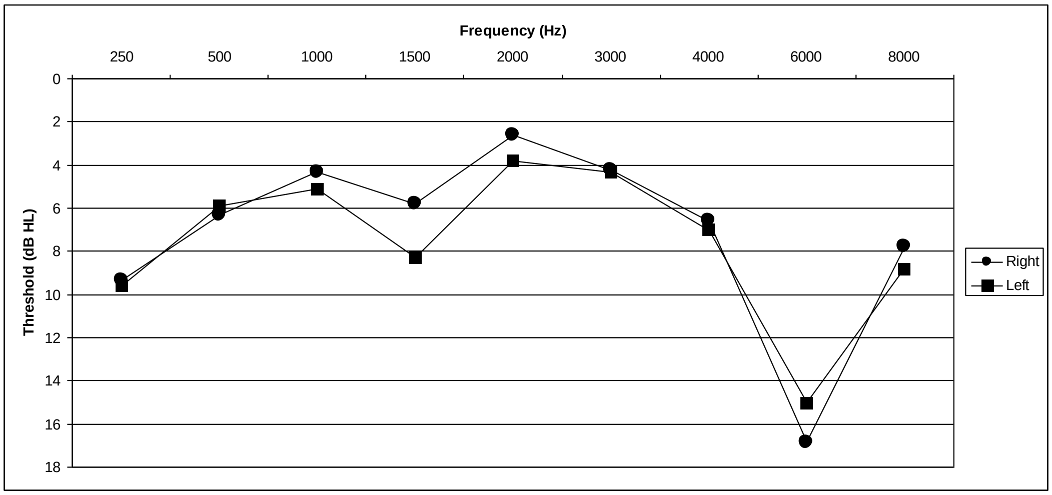

Figure 3. The average pure-tone thresholds of the 38 students with a noise notch. Thresholds found for the right ear are compared to left ear. The figure illustrates that a majority (88%) of the notches were centered at 6000Hz.

Table 13

The positive predictive values and over-referral rates calculated for Towson University hearing screenings from 1999 to 2011 based on records review.

Year	Total Participants	Passed Initial Screening	Re-Screened	Failed Initial; Passed Re-Screen	Failed Re-Screen; Referred	Positive Predictive Value	Over-Referral Rate
Spring 2011	354	336	18	12	6	0.33	0.67
Fall 2010	699	651	48	24	24	0.5	0.5
Spring 2010	412	392	20	10	10	0.5	0.5
Fall 2009	589	551	38	18	20	0.53	0.47
Spring 2008	316	296	20	7	13	0.65	0.35
Fall 2007	596	555	41	25	16	0.39	0.61
Fall 2006	595	570	25	10	15	0.6	0.4
Spring 2006	44	44	0	0	0	N/A	N/A
Fall 2005	497	460	37	25	12	0.32	0.68
Spring 2005	249	230	19	11	8	0.42	0.58
Spring 2004	609	597	12	3	9	0.75	0.25
Spring 2003	299	280	19	9	10	0.53	0.47
Fall 2002	508	487	41	20	21	0.51	0.49
Spring 2002	295	276	19	13	6	0.32	0.68
Fall 2001	428	401	27	14	13	0.48	0.52
Spring 2000	185	173	12	4	8	0.67	0.33
Spring 1999	261	251	11	9	2	0.18	0.82

Table 14

The positive predictive value and over-referral rate calculated for the past Towson University speech-language screenings.

Year	Total Participants	Passed Initial Screening	Re-Screened	Failed Initial; Passed Re-Screen	Failed Re-Screen; Referred	Positive Predictive Value	Over-Referral Rate
Spring 2011	354	330	24	15	9	0.38	0.62
Fall 2010	699	671	28	14	14	0.5	0.5
Spring 2010	412	407	5	0	5	1	0
Fall 2009	589	575	14	4	10	0.71	0.29
Spring 2008	316	313	3	2	1	0.33	0.67
Fall 2007	596	566	30	11	19	0.63	0.37
Fall 2006	595	590	5	0	5	1	0
Spring 2006	44	42	2	0	2	1	0
Fall 2005	497	484	13	3	10	0.77	0.23
Spring 2005	249	239	10	2	8	0.8	0.2
Spring 2004	609	602	7	1	6	0.86	0.14
Spring 2003	299	293	6	0	6	1	0
Fall 2002	508	498	10	0	10	1	0
Spring 2002	295	281	14	7	7	0.5	0.5
Fall 2001	428	404	24	12	12	0.5	0.5
Spring 2000	185	174	11	3	8	0.73	0.27
Spring 1999	261	244	17	8	9	0.53	0.47

Table 15

Follow-up return rates calculated for the hearing screenings from Spring 1999 to Spring 2011.

Year	Number Referred	Number Returned	Follow-Up Return Rate
Spring 2011	6	0	0
Fall 2010	24	5	0.2
Spring 2010	10	2	0.2
Fall 2009	20	10	0.5
Spring 2008	13	3	0.23
Fall 2007	16	8	0.5
Fall 2006	15	7	0.47
Spring 2006	0	0	N/A
Fall 2005	12	0	0
Spring 2005	8	1	0.13
Spring 2004	9	6	0.67
Spring 2003	10	6	0.6
Fall 2002	21	4	0.19
Spring 2002	6	4	0.67
Fall 2001	13	5	0.38
Spring 2000	8	5	0.63
Spring 1999	2	2	1
Total	193	68	0.35

Table 16

Follow-up return rates calculated for the speech/language screenings from Spring 1999 to Spring 2011.

Year	Number Referred	Number Returned	Follow-Up Return Rate
Spring 2011	9	2	0.22
Fall 2010	14	1	0.07
Spring 2010	5	2	0.4
Fall 2009	10	0	0
Spring 2008	1	1	1
Fall 2007	19	3	0.16
Fall 2006	5	1	0.2
Spring 2006	2	N/A	N/A
Fall 2005	10	2	0.2
Spring 2005	8	3	0.38
Spring 2004	6	1	0.17
Spring 2003	6	1	0.17
Fall 2002	10	2	0.2
Spring 2002	7	0	0
Fall 2001	12	4	0.33
Spring 2000	8	2	0.25
Spring 1999	9	2	0.22
Total	141	27	0.19

CHAPTER 5

Discussion

Background noise and the presence of a high frequency noise notch in almost half the students appeared to be the two main issues that affected the accuracy of the hearing screenings. Overall effectiveness of the Towson University hearing and speech-language screening program was also affected by a low return rate of students for follow up services.

Part I – Sensitivity and Specificity of the TU Hearing Screening

Initial hearing screening accuracy. Ideally, a screening protocol should have a high positive predictive value (PPV) and a low over-referral rate (ORR). Overall, the TU hearing screening incorrectly failed 11 of the 20 students in the therapy room, and these students required a rescreen in the sound booth, resulting in a poor PPV (0.45) and a poor ORR (0.55). This means there was only a 45% chance that someone who failed the screening in the speech-language therapy room would also fail the re-screen in the sound-treated booth.

The low PPV value is most likely attributed to high ambient noise levels in the speech-language therapy rooms where screenings were held, resulting in a disadvantaged screening environment. Hundreds of students passed through the TU SLHC for the mandatory screenings, causing high traffic outside of the therapy rooms. It should be noted that, anecdotally, many of the students who failed the initial hearing screening stated to the audiology student examiners that the high level of noise in the therapy rooms was distracting and made it difficult to hear the tones.

Table 9 displayed the ANSI S3.1-1999 maximum permissible ambient noise levels (MPANLs) for a hearing screening for use with pure-tones presented at 20 dB and compared the values to the ambient noise levels measured during the TU hearing screening from inside the therapy room. Comparisons showed that the ambient noise exceeded the ANSI standards at two of the octave band intervals, 14 dB at 500 Hz and 10 dB at 1000 Hz,. This issue has been noted in other studies. For example, Sekhar et al. (2011) speculated that high levels of background noise affected the screening results in a high school hearing-screening program.

In the current Towson University system, hall monitors are positioned outside of the therapy rooms to direct foot traffic and help control the noise levels. The results from the sound level measurements showed that even with these monitors, the levels of noise in the hallways are unacceptable. Future efforts need to be made to control for noise to create a more favorable screening environment. It is hoped that the new TU SLHC location, within the Institute for Well Being (IWB), with significantly expanded clinical areas, will be more conducive to hearing screening testing.

Hearing screening results vs. audiological assessment. Sensitivity and specificity are two measurements used to quantify the accuracy of a screening program. Overall, the screening had a low sensitivity (0.40) and a high specificity (1.0). This less than ideal sensitivity rate was the result of high frequency hearing thresholds, which were included in the audiological assessment but not the screening. Of the 13 students who were incorrectly passed by the screening but failed the audiological assessment, 11 failed due to hearing impairment at 6000 and/or 8000 Hz. When only considering the speech frequencies, the accuracy of the screening improved but by omitting frequencies higher than 4000 Hz in the screening protocol, students with potentially significant high frequency hearing loss will be missed. If the purpose of a hearing screening is to efficiently identify those at risk for a hearing disorder in order to refer for additional testing, the TU screening is failing to achieve this purpose. If, on the other hand, the screening is conducted only to determine a specific minimum “functional” hearing ability for teaching and clinical work, it may be considered adequate to limit screening to 4000 Hz.

The prevalence of hearing loss in this sample of college students who participated in the study was 0.28 with 22 of the 80 students having a hearing loss in one or both ears. Lipscomb (1972) completed two separate studies (done during different years) and estimated a prevalence of 0.329 and 0.607 for the first and second year of testing, respectively. The higher prevalence found by the Lipscomb study could have been due to the more stringent passing criteria of 15 dBHL instead of 20 dBHL, as used in the TU screening. Martin and Church (1991) found a prevalence of only 0.006 in a sample size of 18,424 college students, but this calculation was only based on hearing loss at 1000, 2000, and 4000 Hz only. When only considering 1000, 2000, and 4000 Hz, the prevalence of hearing loss in the TU sample of 80 students was 0.13. Since an audiological evaluation was not completed on either sample group from both studies previously mentioned, it is hard to estimate the actual prevalence of hearing loss when including all frequencies between 250 and 8000 Hz.

Presence of a noise notch. Out of the 80 participants in this study, it was discovered that 38 had a noise notch The noise notch findings are in agreement with past literature. Similar to findings of Niskar et al. (2001) and Sekhar et al. (2011), the majority (88%) of the noise notches were centered at 6000 Hz. It was previously thought that NIHL was more likely to affect males when compared to females (Cozad et al., 1974; Loch, 1943). More recently, Henderson, Testa, and Hartnick (2011) noted a significant increase in the prevalence of NIHL in the female population, showing a trend that differed from those shown in older literature. In the sample population at TU, 50% of the female participants (29 of the 58) and 41% of the male participants (9 of the 22) had noise notches, agreeing with the more recent literature by Henderson et al.

(2011). Past literature also supports that noise notches are more likely found unilaterally than bilaterally, which is in agreement with the TU finding of 74% unilateral NIHL (Sekhar et al., 2011; Niskar et al., 2001).

Similar to findings of Niskar et al. (2001), this study showed that a screening, which includes frequencies at or below 4000 Hz will fail to identify students with a noise notch. Noise induced hearing loss, though irreversible, can be potentially prevented through increased awareness and education (Meinke & Dice, 2007). If a student is identified with a noise notch, the harm of excessive noise exposure should be discussed along with the importance of limiting high intensity noise exposure and wearing hearing protection. TU could implement this awareness program by including 6000 and 8000 Hz in the screening protocol and counseling students with potential noise notches on the hazards of high levels of noise.

Part II: Records Review - Trends in over-referral rate and positive predictive value

Hearing screenings. The average PPV and ORR measurements from spring 1999 to spring 2011 hearing screenings are in almost exact agreement with the PPV and ORR values calculated for the fall 2011 hearing screening. This means that the screeners are consistently failing students in the therapy room only to find normal hearing in the sound-treated booth. This is most likely due to the consistent noise levels generate by foot traffic outside of the therapy rooms used for screening. This is further evidence supporting the need for increased attention towards controlling the ambient noise levels in the hallways surrounding the speech-language therapy rooms where the initial hearing screenings are conducted.

Speech-language screenings. Results from the records review indicated a PPV of 0.70 with an ORR of 0.30 for the speech-language screenings. It is difficult to determine if these results are reasonable, as comparable efficacy studies have not been published for speech-language screening conducted at the college level. However, Laing et al. (2002) found similar PPV (0.73) and ORR (0.27) measurements for a pre-school speech-language screening, even though they used a different screening protocol, due to the age of the population. Further research is needed to determine if the current results can be generalized to other university screenings. In order to measure sensitivity and specificity, future studies of the efficacy of speech-language screening should include a prospective study of students who pass and who fail the screening, similar to the current study conducted with the hearing screenings.

The three most common speech/language anomalies in the TU population included dialectal differences, voice quality (hoarseness) and distortion/articulation errors. Culton (1986) identified common speech disorders among 30,586 college freshmen over a 13-year period and found that articulation (1.37%), disorders of voice (0.75%), and fluency disorders (0.30%) were the top three disorders in this population. Results from the college population from the TU records review are in agreement with similar aged peers from Culton (1986). Further, Hull, Mielke, Willeford, & Timmons (1976) found similar speech/language errors in a sample of 3,234 twelfth grade students.

Part III: Records Review - Efficiency of Follow-Up Procedures

The records review conducted in the current study indicated the TU speech-language and hearing screening had a low follow-up return rate. An average follow-up return rate of 35% and 19% was found for the hearing and speech-language screenings, respectively. Low follow-up return rates for mass screening programs are not uncommon. Allen et al. (2004) found that only 10% of preschoolers referred for full hearing evaluations were actually brought back to the clinic for the evaluation.

Participation in the TU screenings is mandatory but follow-up of recommendations is the responsibility of the student and documentation of follow-up is not required by most majors. This lack of follow-up requirement is most likely responsible for TU's low follow-up return rate. In addition, student clinicians may not be adequately emphasizing the importance of returning to the clinic, in terms of the impact of communication issues on the internship and on future job responsibilities. It is also possible, although it was considered less likely, that students who chose to return for full diagnostic evaluations sought services outside of the university. It was considered unlikely because the services are provided free to TU students and the clinic is conveniently located in the center of campus. Despite this assumption, the follow-up return rate may actually be low, based on the possibility that the fact that students could pursue follow up services elsewhere. The University of Alabama requires students to provide documentation of treatment either on-campus or at an outside center prior to admission into the clinical practicum ("The Department of Communicative Disorders: The University of Alabama," n.d.). In order to increase the return rate, TU should consider making follow-up a requirement. Instead of just making the recommendation at the end of the screening, the student clinician could walk the student to the front office window to schedule the follow-up appointment. This act of aiding the student in making the appointment might improve the return rate by taking responsibility off of the student. Additionally, TU could create literature specifically targeted to this population, stressing the importance of optimal communication on their future career.

CHAPTER 6

Summary, Limitations, and Future Research

A prospective clinical study and two retrospective records reviews were completed at TU to examine the accuracy and outcomes of the speech-language and hearing program for college students. Factors which negatively affected the overall effectiveness of the screening protocol included high levels of ambient noise in the therapy rooms where screenings were held, the high number of participants with a noise notch in the high frequencies, and the low follow-up return rate.

Implications of these findings include the need for college-level hearing screening program directors to consider the purpose of their screening. Specifically, if the focus is to identify students for whom hearing loss may affect an internship placement, then 1000-4000 Hz may be sufficient; however, if the focus is to identify students at risk for any hearing loss, including early signs of NIHL, then the traditional screening frequencies will not be an accurate predictor of "at risk" students. Also, if students are not following up with recommendations from the screenings, the program director must decide if the screening program serves a purpose. Program directors should implement protocols to increase the accuracy and follow-up return rates.

One limitation of this study was that students who passed the screening were not re-screened in the sound-treated booth so it is unknown if those students truly passed the screening. It should be noted that the screening environment was more favorable in the sound-treated booth, so it was assumed that students who passed the screenings in the therapy rooms would also to pass in the booths. Another limitation of the study was the sample size. Over 600 students attended the screenings and only 80 participated in the prospective trial. This was due to time constraints (all students were tested by one audiology graduate student). For future research regarding the college screening protocol, more participants should be included.

Future research on this topic should include a study of the sensitivity and specificity of the speech-language portion of the screening for college aged students. Also, measurements of accuracy should be calculated for a hearing screening that includes 6000 and 8000 Hz. Current ASHA screening guidelines are limited to school-age children, 5 through 18 years old. After further research is completed, it is recommended that ASHA consider creating guidelines that apply to the college population.

APPENDICES

APPENDIX A
IRB Approval

TOWSON UNIVERSITY

EXEMPTION NUMBER: 12-0X02

To: Emily Farbman
From: Institutional Review Board for the Protection of Human Subjects Steven Mogge, Member WRP
Date: Tuesday, July 05, 2011
RE: Application for Approval of Research Involving the Use of Human Participants

Office of University Research Services
Towson University
8000 York Road
Towson, MD 21252-0001
t. 410 704-2236
f. 410 704-4494

Thank you for submitting an application for approval of the research titled,

An assessment of the efficacy of the Towson University hearing and speech-language screening

to the Institutional Review Board for the Protection of Human Participants (IRB) at Towson University.

Your research is exempt from general Human Participants requirements according to 45 CFR 46.101(b)(2). No further review of this project is required from year to year provided it does not deviate from the submitted research design.

If you substantially change your research project or your survey instrument, please notify the Board immediately.

We wish you every success in your research project.

CC: D. Emanuel
File

APPENDIX B
Signed Consent Form

Speech, Language & Hearing Center
Towson University-8000 York Road-Towson, MD 21252-0001
Voice or TTY: 410-704-3095 - Fax: 410-704-6303

TOWSON UNIVERSITY

INFORMED CONSENT FORM

As part of a thesis requirement, Emily Farbman, a student in the Doctor of Audiology (Au.D.) Program at Towson University, is examining the accuracy of the hearing and speech-language screening protocol. Your role in this project will consist of participating in one 15-minute audiological examination immediately following your hearing and speech-language screening. Other time slots will also be available for students willing to participate in the research but unable to stay after the screening.

The audiological examination will include otoscopy (looking in the ear with a light), tympanometry (a measure of ear drum mobility and ear canal volume by placing a soft probe tip in the ear), and pure tone audiometry (a measure of hearing sensitivity). During otoscopy and tympanometry you will be asked to sit quietly. During pure tone audiometry, a pair of headphones will be placed over your ears and you will be asked to press a button every time you hear a tone (beep). There are no known risks or discomforts associated with this procedure. If results of the modified audiologic evaluation are abnormal, you will be referred for a complete audiologic evaluation, a free service offered to students at the Speech-Language and Hearing Center at Towson University. This additional evaluation is not mandatory and lack of participation in the study or in referred services will not affect your class grade or ability to graduate.

Participation in this study is voluntary. All information will remain strictly confidential. Although the descriptions and findings may be published, at no time will your name be used. You are at liberty to withdraw your consent to the study and discontinue participation at any time without prejudice. If you have any questions after today, please feel free to call Emily Farbman (the primary investigator) at (443) 465-4998 and ask for or Dr. Diana C. Emanuel (thesis advisor) at (410) 704-2417, or Dr. Debi Gartland, Chairperson of the Institutional Review Board for the Protection of Human Participants at Towson University at (410) 704-2236.

I, _______________________________,affirm that I have read and understood the above statement and have had all of my questions answered.

Date: ___________________

Signature: ____

Witness: ____

APPENDIX C
Data Collection Form

Gender: M F **Tester's Initials: ___________**
Age: __________ **ID #: ____________**
Undergraduate Major: _______________________

Hearing Screening (circle one): Passed Failed
If failed, indicate which frequencies were missed by placing an "X" in the correct box:

	500 Hz	1000 Hz	4000 Hz
Right Ear			
Left Ear			

Audiologic Assessment

1. **Otoscopy** (circle one): Clear canals bilaterally Non-occluding cerumen (Ear: R / L) TM not visible (Ear: R / L)
   Additional Observations: ____

2. **Tympanometry** **Right** **Left**

Right	Left
Ear Canal Volume: ________	Ear Canal Volume: ________
Peak Pressure: ___________	Peak Pressure: ___________
Static Admittance: ________	Static Admittance: ________
Type A Tymp? Yes No	Type A Tymp? Yes No

3. Pure Tone Thresholds (threshold seek)

	250 Hz	500 Hz	1000 Hz	1500 Hz	2000 Hz	3000 Hz	4000 Hz	6000 Hz	8000 Hz
Right									
Left									

REFERENCES

Allen, R.L., Stuart, A., Everett, D., & Elangovan, S. (2004). Preschool hearing screening: pass/refer rates for children enrolled in a head start program in eastern North Carolina. *American Journal of Audiology, 13*, 29-38.

Alvord, L. S. (1993). Miniature audiometric devices: Are they clinically accurate? *Hearing Instruments*, *44*(6), 24-25.

American Academy of Audiology. (2011). Childhood hearing screening guidelines. Retrieved from http://www.cdc.gov/ncbddd/hearingloss/documents/AAA_ Childhood% 20Hearing %20Guidelines_2011.pdf.

American National Standards Institute. (1999). *Maximum permissible ambient noise levels for audiometric test rooms (ANSI S3-1999).* New York: Author.

American Speech-Language-Hearing Association. (1997). *Guidelines for audiologic screening.* Retrieved from www.asha.org/policy.

Bistrizki, Y. & Frank, Y. (1981). Efficacy of voice and speech training of prospective elementary school teachers. *Israel Journal of Speech and Hearing, 10,* 16-32.

Bovo, R., Galceran, M., Petruccelli, J., & Hatzopoulos, S. (2007). Vocal problems among teachers: Evaluation of a preventative voice program. *Journal of Voice, 12*(6), 705-722.

Cozad, R.L., Marston, L., & Joseph, D. (1974). Some implications regarding high frequency hearing loss in school-age children. *Journal of School Health, 44*(2), 92-96.

Culton, G.L. (1986). Speech disorders among college freshmen: A 13-year survey. *Journal of Speech and Hearing Disorders, 51,* 3-7.

Davis, J.M., Elfenbein, J., Schum, R., & Bentler, R.A. (1986). Effects of mild and moderate hearing impairments on language, educational, and psychological behavior of children. *Journal of Speech and Hearing Disorders, 51*, 53-62.

Department of communicative disorders: The university of Alabama. (n.d.). Retrieved from http://catalogs.ua.edu/catalog10/501428.html.

DiCarlo, L.M. & Gardner, E.F. (1953). The efficiency of the Massachusetts pure tone screening test as adapted for a university testing program. *Journal of Speech and Hearing Disorders, 18,* 175-182.

Fonseca S., Forsyth, H., & Neary, W. (2005). School hearing screening programme in the UK: Practice and performance. *Archives of Disabled Children, 90,* 154-156.

Gottliebson, R.O., Lee, L., Weinrich, B., & Sanders, J. (2007). Voice problems of future speech-language pathologists. *Journal of Voice, 21*(6), 699-704.

Henderson, E., Testa, M.A., & Hartnick, C. (2011). Prevalence of noise-induced hearing-threshold shifts and hearing loss among US youths. *Pediatrics, 127*(1), 39-46

Herrington-Hall, B.L., Lee, L., Stemple, J.C., Niemi, K.R., & McHone, M.M. (1988). Description of laryngeal pathologies by age, sex, and occupation in a treatment-seeking sample. *Journal of Speech and Hearing Disorders, 53,* 57-64.

Hull, F.M., Mielke, P.W., Willeford, J.A., & Timmons, R.J. (1976). National speech and hearing survery. *U.S. Department of Health, Education, & Welfare, National Institute of Education.* Washington D.C.,1-317.

Holmes, A.E., Kaplan, H.S., Phillips, R.M., Kemker, F.J., Weber, F.T., & Isart, F.A. (1997). Screening for hearing loss in adolescents. *Language, Speech, and Hearing Services in Schools, 28,* 70-75.

Holtby, I. & Forster, D.P. (1992). Evaluation of pure tone audiometry and impedance screening in infant school children. *Journal of Epidemiol Community Health, 46,* 21-25.

Holtby, I., Forster, D.P., & Kumar, U. (1997). Pure tone audiometry and impedance screening of school entrant children by nurses: Evaluation in a practical setting. *Journal of Epidemiology and Community Health, 51,* 711-715.

Jourdanais, R. (n.d.). Marywood university speech-language-hearing screening policy. Retrieved from http://www.marywood.edu/csd/admission-requirements/speech-language-hearing-screening-policy.html.

Laing, G.L., Law, J., Levin, A., & Logan, S. (2002). Evaluation of a structured test and a parent led method for screening for speech and language problems: Prospective population based study. *British Medical Journal*, *325*(7373), 1152.

Lipscomb, D. (1972). The increase in prevalence of high frequency hearing impairment among college students. *Audiology, 11,* 231-237.

Loch, W.E. (1943). Incidence and permanency of tonal dips in children. *Laryngoscope, 53,* 347-356.

Martin, K.A. & Church, G.T. (1991). Prevalence of hearing impairment among university students. *Journal of American Academy of Audiology, 2,* 32-35.

Maxon, S. & Yamaguchi, T. (1996). Acute otitis media. *Pediactric Rev., 17*(6), 191-196.

Meinke, D. K., & Dice, N. (2007). Comparison of audiometric screening criteria for the identification of noise-induced hearing loss in adolescents. *American Journal of Audiology, 16,* S190-S202.

Niskar, A. S., Kieszak, S. M., Holmes, A., Esteban, E., Rubin, C., & Brody, D. J., (2001). Estimated prevalence of noise-induced hearing threshold shifts among children 6 to

19 years of age: The third national health and nutrition examination survey, 1988-1994, United States. *Pediatrics, 108,* 40-43.

Phillips S.L., Henrich V.C., & Mace, S.T. (2010) Prevalence of noise-induced hearing loss in student musicians. *International Journal of Audiology, 49*(4), 309-316.

Roy, N., Merrill, R. M., Thibeault, S., Parsa, R.A., Gray, S.D., & Smith, E.M. (2004). Prevalence of voice disorders in teachers and the general population. *Journal of Speech, Language, and Hearing Research, 47*(2), 281-93.

Sekhar, D.L, Rhoades, J.A., Longenecker, A.L., Beiler, J.S., King, T.S., Wildome, M.D., & Paul, I.M. (2011). Improving detection of adolescent hearing loss. *Archives of Pediatric and Adolescent Medicine, 165*(12), 1094-1100.

Schlauch, R.S. & Carney, E. (2011). Are false-positive rates leading to an overestimation of noise-induced hearing loss? *Hearing Research, 54,* 679-693.

Scudder, S.G., Culbertson, D.S., Waldron, C.M., & Stewart, J. (2003). Predictive validity and reliability of adult hearing screening techniques. *Journal of the American Academy of Audiology, 14,* 9-19.

Simberg, S., Sala, E., Laine, A., & Ronnemaa, A. (2001). A fast and easy screening method for voice disorders among teacher students. *Log Phon Vocol, 26,* 10-16.

Simberg, S., Sala, E., & Ronnemma, A. (2004). A comparison of the prevalence of vocal symptoms among teacher students and other university students. *Journal of Voice, 18*(3), 363-368.

Simberg, S., Sala, E., Jyrki, T., Jaana, S., & Ronnemaa, A. (2006). The effectiveness of group therapy for students with mild voice disorders: a controlled clinical trial. *Journal of Voice, 20*(1), 97-109.

Stott, C. M., Merricks, M. J., Bolton, P. F., & Goodyer, I. M. (2002). Screening for speech and language disorders: The reliability, validity, and accuracy of the general language screen. *International Journal of Speech-Language Disorders*, *37*(2), 133-151.

Teacher education at the university of Tennessee, Knoxville: Admission to teacher education. (n.d.). Retrieved from http://catalog.utk.edu/content.php?catoid=5&navoid=398.

U.S. Preventative Services Task Force (1996). *Guide to clinical preventative services, 2nd ed.: screening for hearing impairment.* Retrieved from www.ncbi.nlm.nih.gov.

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Professional publications: N/A

Professional positions held: N/A