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The Development of Word Recognition Materials for Native Speakers of Tongan

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THE DEVELOPMENT OF WORD RECOGNITION MATERIALS FOR NATIVE SPEAKERS OF TONGAN

by

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GRADUATE COMMITTEE APPROVAL

of a thesis submitted by

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ABSTRACT

THE DEVELOPMENT OF WORD RECOGNITION MATERIALS FOR NATIVE SPEAKERS OF TONGAN

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The purpose of this study was to develop, digitally record, evaluate, and psychometrically equate a set of Tongan bisyllabic word lists for use in measurement of word recognition testing. Commonly used bisyllabic words were digitally recorded by male and female native talkers of Tongan. The psychometric performance of the words was measured at ten intensity levels (- 5 to 40 dB HL) in 5 dB increments by 20 listeners with normal hearing acuity. The 200 words with the highest rate of listener identification were included in four relatively psychometrically equivalent word lists of 50 words each and eight half-lists of 25 words each. Using logistic regression, the mean psychometric slope across the created word lists at 50% intelligibility was found to be 6.3%/dB for materials created from the male talker recordings and 6.2%/dB for the female talker recordings. To increase auditory homogeneity of the word recognition lists, the intensity of words in each list was digitally adjusted so that the threshold of each list was equal to the midpoint between the mean thresholds of the male and female half-lists. Digital

recordings of the psychometrically equivalent word recognition lists are available on compact disc.

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Introduction

Audiological evaluations are used to assess an individual's hearing in terms of degree and type of impairment. Pure-tone audiometry is often used to test the sensitivity of the auditory system by presenting sinusoidal tones to the listener. This type of hearing evaluation provides pure-tone thresholds for specific frequencies. However, the use of pure-tone audiometry on its own, as a measure of hearing acuity, does not provide a comprehensive assessment of an individual's ability to perceive and understand speech (Egan, 1979).

Speech audiometry has been developed in order to more fully describe the effects that hearing impairment may have on an individual’s ability to hear and understand spoken language (Epstein, 1978). Speech audiometry testing can provide diagnostic information about the extent and nature of a possible hearing impairment. Many of the materials developed for speech audiometry testing have been created for speakers of Standard American English. However, recently researchers have worked to develop speech audiometry materials for a variety of languages, such as Portuguese (Harris, Goffi, Gygi, & Merrill, 2001), Polish (Harris, Nielson, McPherson, Skarzynski, & Eggett, 2004), Spanish (Christensen, 1995), French (Nelson, 2004), Italian (Greer, 1997; Turrini et al., 1993), Russian (Harris et al., 2007) and Mandarin Chinese (Nissen, Harris, Jennings, Eggett, & Buck, 2005). These materials have been beneficial for testing individuals in their native language and to more accurately describe hearing abilities within the context of an individual’s native spoken language. Although speech audiometry materials are available in English and many additional languages, materials have not yet been developed in Tongan. Thus, the purpose of this study is to develop, evaluate, describe, and record a set of high-quality digital speech audiometry materials that can be used to evaluate the hearing abilities of individuals whose native language is Tongan.

Literature Review

Types of Speech Audiometry Materials

Speech recognition threshold. Speech audiometry materials have been developed as a means by which audiologists can assess patient's abilities to hear and understand spoken language. Two common types of speech audiometry are speech recognition threshold (SRT) and word recognition testing. SRT testing determines a patient's threshold for speech, which is defined as the lowest level at which the person can recognize 50% of the presented words (American Speech-Language-Hearing Association [ASHA], 1988). The test stimuli used for assessing an individual's SRT are often part of a closed-response-set of spondaic words; with equal stress on each syllable. This type of audiologic evaluation is commonly conducted in conjunction with word recognition testing, as it determines the level at which subsequent word recognition testing should be performed.

Word recognition testing. Historically known as word discrimination or speech discrimination testing, word recognition testing evaluates an individual's ability to understand speech when it is presented at a supra-threshold level, generally 30 to 50 dB above the SRT. The results are expressed as a percentage of correct word identification termed the word recognition score (WRS), thereby providing audiologists information regarding how well a patient is able to recognize words at a particular supra-threshold level. Traditionally, lists containing 50 words or half-lists containing 25 words are used in word recognition testing (Elpern, 1961).

Early studies to develop lists of appropriate English words for use in word recognition testing were conducted by Egan (1948). While working at the Psycho-

Acoustic Laboratories at Harvard University, Egan used 1,000 monosyllabic American English words to create 20 phonetically-balanced lists, each containing 50 words. Eight of these lists were then recorded and became known as the PB-50 lists. However, these original recordings were found to contain a number of words unfamiliar to many listeners, as well as poor inter-list reliability (Hirsh et al., 1952). Thus, Hirsh et al. created a revised set of four 50-word phonetically-balanced lists by rerecording 120 of the most commonly used words from Egan's original list of 1,000 and an additional set of 80 high-usage words. The recordings developed by Hirsh et al. were made using a male talker producing the carrier phrase *you will say* prior to saying each target word. This set of American English word recognition materials was named the CID Auditory Test W-22 (CID W-22) and is still commercially available.

The Northwestern University Auditory Test Number 6 (NU-6) was created using phonemically balanced lists, rather than lists that are phonetically balanced (Tillman & Carhart, 1966). Phonetically balanced lists are designed to contain all the phonetic components of spoken English in the same proportion in which they occur during connected discourse. Phonemic balance is based on the supposition that due to the amount of coarticulation found in conversational speech, a true phonetic balancing of lists is extremely difficult if not impossible to obtain. However, phonemically-balanced lists are created to contain a series of consonant-nucleus-consonant (CNC) words which cumulatively contain first and final phonemes at a rate that is relatively proportion to their occurrence in connected speech (Lehiste & Peterson, 1959). Tillman and Carhart based the NU-6 recordings on a series of CNC word lists created by Lehiste and Peterson. The NU-6 word recognition materials were recorded by a male talker who said the carrier phrase *say the word* prior to each test word. The materials were also later recorded by a female speaker (Causey, Hermanson, Hood, & Bowling, 1983) and both types of lists are commercially available on digital compact disc (CD). Martin, Champlin, and Chambers (1998) report that both the NU-6 and CID W-22 continue to be the most widely used word recognition materials used by audiologists to evaluate the hearing of American English speakers.

Evaluation of Hearing in Noise

Single word stimuli tests. Presenting test stimuli in the presence of a competing noise signal is often used by audiologists to more accurately simulate the listening demands a patient may experience in their daily environment. When this type of presentation is used a signal-to-noise ratio (SNR), the difference in intensity between the test stimulus and the competing noise, is often reported. Examples of various types of noise include: white noise (a random signal with a flat power spectral density), a single competing talker, a combination of several competing talkers, and multitalker babble (Martin & Clark, 2009). An example of an assessment that evaluates an individual's hearing in the presence of noise is the Speech in Noise (SIN) test (Jayaram, Baguley, & Moffat, 1992). This evaluation presents single words to the listener in the presence of white noise. Words are presented at a 40 dB HL level along with white noise that is equal to or 10 dB lower than the speech signal.

Sentence stimuli tests. Word recognition tests using sentences presented in conjunction with noise have also been developed. Intensity functions of a listener's word recognition performance have been found to be somewhat steeper for sentences than for words (Brandy, 2002). In addition, using sentences as stimuli helps the audiologist gain a better understanding of how the patient is able to understand words within context and can also be used if the patient has significant difficulty identifying the single words. The main argument made against the use of sentence tests is that extra contextual information provided in the sentence gives listeners who are good guessers an advantage in predicting the target words (Martin & Clark, 2009).

The Speech Perception in Noise (SPIN) test (Kalikow, Stevens, & Elliott, 1977) consists of eight sets of 50 sentences, which are presented to the listener along with multitalker babble (12 talkers simultaneously reading text) as the competing noise. The sentence stimuli and babble are each recorded on a separate channel of a two-channel CD, which allows the two hearing-level dials found on an audiometer to control the SNR between the presented signals (Martin & Clark, 2009). Each sentence is comprised of five to eight words and the listener's task is to identify the final word in each sentence. Half of the sentences are considered to be *high predictability sentences* and the other half are referred to as *low predictability sentences*. The high predictability sentences contain contextual, syntactic, and prosodic cues that help the listener determine the final word of the sentence. The low predictability sentences provide little or no cues as to the final word (Brandy, 2002). The SPIN test provides separate scores for both the high and low predictability sentences and therefore is a valuable measure in providing information about the verbal auditory closure abilities of an individual (Elliott, 1995).

The QuickSIN is a shorter version of the SIN test and also evaluates the speech recognition abilities of patients with hearing loss in the presence of background noise using sentences (Killion, Niquette, Gudmundsen, Revit, & Banerjee, 2004). The test includes three practice lists and 18 test lists, each taking approximately 55 seconds to administer. The background noise used in the QuickSIN is multitalker babble which is presented along with the sentences in different SNR's ranging from 25 to 0 dB. Scoring is calculated using a SNR loss and represents the increase in SNR required by the patient to perform comparably to normal listeners (McArdle & Wilson, 2006).

Open and Closed Response Sets

All the tests discussed thus far have been *open-response-set* tests, meaning that the patient is not familiarized with the words prior to receiving the test item nor are they given a choice of responses. In an open-response test, patient response choices could be any word in English. Though not as common, word recognition tests that use *closed-response-sets* have also been developed. In a closed-response-set the patient is familiarized with the words beforehand or is given a set of word choices from which to select their response. Closed-response-set tests are most often used with the severely hearing-impaired population, who generally perform poorly on open-response tests (Brandy, 2002). They can also be used with patients who have difficulty responding verbally, are unable to write, or are young children (Martin & Clark, 2009).

The use of closed-response-set tests was introduced through the development of the Rhyme Test by Fairbanks (1958). The original test was not a true closed-response test, as it required the listener to fill in the missing first letter of each word that was presented. Fairbanks' Rhyme Test was modified by House, Williams, Hecker, and Kryter (1965) and published as the Modified Rhyme Test (MRT). The MRT is composed of six word lists, each containing 50 monosyllabic words. Half of the words differ only in the initial phoneme, while the other half differs in the final phoneme. Items are presented in the presence of noise in the test ear and the patient is instructed to select a response from a set of six rhyming words (Martin & Clark, 2009). The California Consonant Test (Owens & Schubert, 1977) is also a closed-response test that has been found to be helpful in the identification of patients with high-frequency hearing loss (Schwartz & Surr, 1979). The patient is required to select a response from a given set of four words.

Child Appropriate Materials

The need for speech audiometry materials to evaluate the hearing acuity in young children has also led to the development of several tests. The Phonetically Balanced Test of Speech Discrimination for Children (PBK-50) consists of three 50-word lists comprised of monosyllabic words considered to be familiar to children beginning first grade (Haskins, 1949). As with many of the tests designed for adults, the PBK-50 is an open-response test requiring a verbal response from the child. The revised edition of the Word Intelligibility by Picture Identification (WIPI) test (Ross & Lerman, 1970) can be used with children as young as 4 years and requires the child to select a response from among six pictured possibilities. The WIPI test is a closed-response test and the child is asked to point to the appropriate picture. The Northwestern University Children's Perception of Speech test (Elliott & Katz, 1980) also uses pictured response choices and is appropriate for use with young children. When presenting lists to young children monitored live voice (MLV) is often used over recorded presentations due to the increased need for flexibility (Brandy, 2002).

Factors in Developing Word Recognition Materials

When developing materials to be used in word recognition testing several factors should be taken into consideration, such as the type and quality of stimuli to be used in testing, the method of presentation, and talker variables that may improve the validity and reliability of the word recognition evaluation (Christensen, 1995; Greer, 1997; Harris et al., 2001; Nielson, 2000).

Test stimuli. When selecting individual words to include in a word recognition list both frequency of use and phonetic dissimilarity should be considered. Studies have found that words selected should be high-usage words for that particular language. Luce (1986) reports that a word's frequency of use within the language affects how quickly and accurately a person can recognize the word when it is heard. In addition, Bell and Wilson (2001) not only found that words that occurred at a higher frequency were more intelligible in both quiet and noise listening conditions, but also reported that phonetically unique words also provided an advantage in perceptual intelligibility.

Phonetic dissimilarity refers to how different or phonetically unique a word is as compared to other words within the language. The listener's ability to correctly repeat the stimulus word can be affected by how many other words the target word is closely related to. If there are several words that the target could be confused with and mistaken for, then phonetic dissimilarity is low and the word is considered to be more difficult (Gelfand, 2001). The Neighborhood Activation Model describes how similar sounding words comprise a lexical neighborhood and that words with a dense lexical neighborhood will be harder to recognize than words with a sparse lexical neighborhood (Luce, 1986; Luce & Pisoni, 1998).

It is also important to consider the phonetic or phonemic balance of the lists, homogeneity of audibility between the lists, and whether or not to use full or half-lists. Historically word recognition lists developed for speakers of American English have been designed to be phonetically or phonemically balanced (Egan, 1948), however several studies have addressed whether or not it is necessary in word recognition testing (Martin, Champlin, & Perez, 2000; Tobias, 1964). Martin et al. used phonetically-balanced word recognition lists, as well as lists comprised of 200 randomly selected monosyllabic words from an English dictionary to evaluate the hearing acuity of individuals with normal hearing and individuals with a sensorineural hearing loss. Scores obtained from the randomly selected lists and the PB lists were nearly identical, suggesting that phonetic balance does not have a strong influence on test performance. In an earlier study Tobias also found phonetic balance to be an unnecessary requirement for lists used in diagnostic testing.

Another important factor is homogeneity with respect to list audibility (Hood & Poole, 1977; Hudgins, Hawkins, Karlin, & Stevens, 1947; Wilson & Carter, 2001), in other words, each list should be equal in terms of perceptual difficulty. A psychometric function can be used to describe the listener's ability to correctly perceive the presented speech stimuli; the slope of which refers to the change in the number of words correctly recognized across differing presentation intensity levels. Wilson and Carter found that greater homogeneity in the psychometric characteristics of the words resulted in a steeper slope of the mean psychometric function for the list, with words that are too difficult to perceive often yielding a shallow psychometric function for the word list.

Historically, word lists consisting of 50 words each have been used for word recognition testing (Egan, 1948). However to reduce testing time and patient fatigue, audiologists currently often only use a half-list, containing 25 words, to evaluate an individual's word recognition abilities. Concerns over using half-lists include a loss of phonetic balance in the lists, as well as decreased reliability and validity (Brandy, 2002;

Elpern, 1961; Martin & Clark, 2009; Penrod, 1980). Several studies have looked at the use of half-lists and their validity as a diagnostic tool. Elpern made comparisons between full and half-lists by looking at the mean discrimination loss and standard deviation for half-list and full-list results on nine tests in the CID W-22 series. He found that the greatest difference in scores was 2 percent and concluded that either half of any test in the series could be administered in place of the full-list without sacrificing accuracy. Penrod administered each half of List 1A of CID W-22, as well as the full-list, to geriatric patients with sensorineural hearing loss. A statistical analysis of the results supported the use of half-lists with the participating population. Penrod also discussed the variability in scores and suggested that the degree of precision sought should determine whether to use a full or half-list. A number of additional studies have also found a high correlation in word recognition scores obtained from full and half-list (Campanelli, 1962; Deutsch & Kruger, 1971; Resnick, 1962; Thorton & Raffin, 1978).

Method of presentation. In word recognition testing speech stimuli are commonly presented by recorded media or by MLV. Audiologists and researchers have expressed various opinions about the use of each method, however the ASHA guidelines (1988) recommend the use of recorded materials over MLV methods when presenting speech stimuli. Studies have shown that recorded presentations of word lists are significantly more reliable than MLV presentations of stimuli (Brandy, 1966). Recorded presentations allow for more control over the test stimuli and ensure the presentation is the same each time (Egan, 1979). It eliminates variations that could occur between different MLV presentations such as differences in speech rate, stress patterns, voice quality, and production patterns.

Digital recordings of word recognition materials for testing in American English are commonly available commercially in CD format. Several advantages lie in the use of digital technology over analog recordings on magnetic tape. These include high fidelity recordings, an enhanced signal-to-noise ratio, no print through, a recording that will not worsen with repeated use, instantaneous access to any of the tracks, and larger memory capacity for recorded material (Wilson, Preece, & Thornton, 1990). Thus, speech audiometry materials that are digitally recorded are typically of higher quality and durability, as well as allow an audiologist greater flexibility in evaluating an individual's hearing ability.

Talker variables. Differences amongst talkers can also affect the reliability of the test. Some variables that have been explored are gender of the talker and native language or dialect of the talker (Bartholomew, 1993; Cambron, Wilson, & Shanks, 1991; Weisleder & Hodgson, 1989). Some researchers have explored the effects of talker gender when presenting stimuli by both MLV and recorded voice techniques. Cambron et al. investigated if talker gender would differentially affect normal-hearing listeners ability to perceive word lists from the CID W-1. The results of their study indicated no significant difference between the test results obtained using the female and male talkers. Penrod (1979) conducted a study involving 30 adults all with some degree of sensorineural hearing impairment. The stimuli consisted of tape recordings made by four different talkers. The study concluded that the differences between scores were not due to a single talker but spread across all the talkers. Penrod reported that the most influential factor on performance was talker-listener interaction and that differences among talkers had an effect on only a small portion of scores.

Weisleder and Hodgson (1989) conducted a study investigating the possible effects of talker dialect on word recognition. Lists of Spanish words recorded by a native Spanish speaker native to Mexico were presented to participants native to Mexico, Central American, and South American countries. It was found that at low-intensity presentation levels, those participants that were native to Mexico scored much higher than the participants who spoke a different dialect of Spanish. These findings indicate that speech audiometry recordings made by a speaker with a different dialect from the listener may be more difficult at lower intensity levels. Nielson (2000) also suggests that to avoid contamination of test results the talker dialect should be similar to that of the test population.

The effects of testing patients in their non-native or second language also need to be considered. As has been previously discussed, familiarity of the stimulus words to the listener can affect how the words will be perceived. An individual being tested in a non-native language would not be familiar with the majority of the presented words. As Hodgson (1985) points out, this could result in the stimulus words becoming nonsense test items. Even individuals who are considered bilingual, have been shown to perform poorly on speech audiometry tests as compared to monolingual speakers of the test language (Crandell & Smaldino, 1996; Florentine, 1985; Mayo, Florentine, & Buus, 1997; Padilla, 2003; von Hapsburg, Champlin, & Shetty, 2004). A comparison of SRT scores between Spanish-English bilinguals and English monolingual participants was made by von Hapsburg et al. using English stimuli from the Hearing in Noise Test (HINT). Results showed that performance on the test was significantly poorer in the bilingual test group. Interestingly, tests that are administered without interfering background noise yield an increase in performance by bilingual listeners (Padilla, 2003; von Hapsburg et al., 2004). These results may suggest that when background noise is present, bilingual listeners process their second language differently than individuals who are native-speakers of the test language.

Research in areas other than speech audiometry also supports the idea that bilingual individuals process their two languages in different ways (Grosjean, 1989; Lemhofer et al., 2008). Lemhofer et al. compared visual recognition of English words by native and bilingual speakers. Results showed a significant difference in each group's ability to visually recognize English words, with the bilingual group performing more poorly. They concluded that there may be subtle differences in how bilinguals process their native and second languages.

Overall the research supports performing speech audiometry testing in an individual's native language or dialect. Using word recognition materials that are linguistically appropriate for each individual avoids the creation of nonsense test items due to unfamiliarity and also so that the test is a valid and reliable measure of hearing abilities rather than of English proficiency.

Speech Audiometry in Non-English Languages

Most of the previously discussed materials have been developed for use with individuals who speak American English. Recently researchers have worked to develop speech audiometry materials for other world languages, such as Portuguese (Harris et al., 2001), Polish (Harris et al., 2004), Spanish (Christensen, 1995), French (Nelson, 2004), Italian (Greer, 1997; Turrini et al., 1993), Russian (Harris et al., 2007) and Mandarin Chinese (Nissen et al., 2005). However, there remain many languages without developed materials for speech audiometry. Currently there are no documented materials available for word recognition testing of native speakers of Tongan. The total number of Tongan speakers worldwide is estimated to be around 100,000 to 130,000 (Campbell, 2000; Katzner, 1995). The total number of Tongans living in the United States is approximately 27,700; one-third of which report that they have a limited English proficiency (U.S. Census Bureau, 2005). The lack of available speech audiometry materials for a fairly significant population demonstrates a clear a need for the development of word recognition materials in the Tongan language.

Speech Audiometry Materials for Native Tongan Speakers

Tongan culture and language. Tongan is the national language of the Kingdom of Tonga. Tongan communities can also be found in many other areas of the world, including, but not limited to, American Samoa, Australia, Canada, Fiji, New Zealand, Niue, the United States, and Vanuatu (Gordon, 2005; Omniglot, 2007). The two northern-most islands of the Tongan nation, Niuatoputapu and Niuafo'ou, primarily speak the Niuafo'ou language but are able to understand and use Tongan as well (M. Havea, personal communication, April 19, 2008). Among Tongan speakers there are slight dialect differences from north to south and the ethnic group is primarily monolingual (Gordon, 2005).

Tongan is part of the Polynesian subgroup in the family of Austronesian languages, also sometimes known as the Malayo-Polynesian family. Other languages contained in the Polynesian subgroup are Maori, Uvea, Samoan, Niuean, Rarotongan, Tahitian, Tuamotu, Marquesan, and Hawaiian. Language subgroups also included within the Austronesian family are Indonesian, Micronesian, and Melanesian (Katzner, 1995).

Similarities between the languages of Indonesia, Polynesia, and Madagascar were first noticed in the early 18th century. It wasn't until 1934 that the Austronesian languages were first systematically classified (Comrie, Matthew, & Polinksy, 2003).

More than 1,000 Austronesian languages exist world-wide and cover most of the Pacific Islands, Indonesia, Malaysia, and the Philippines. They all appear to have descended from the same ancestral language, known as Proto-Austronesian. There is currently no written evidence for the existence or development of this language, however it is estimated to be about 6,000 years old (Marti, 2005). There is a general acceptance, based on archeological evidence, that Proto-Austronesian was spoken in and around Taiwan about 5-7,000 years ago. There are also speculated relationships between the Austronesian family and the Austro-Thai family, as well as a link with Japanese. Distinctive features of the Austronesian languages include a relatively small inventory of vowels and consonants, open consonants, and longer words resulting from agglutination and reduplication of words and syllables. Another important feature is the historical use of distinct vocabulary subsystems for different social classes. In some areas this is known as *the chiefs' language*, because a unique lexicon was designated for use when speaking to the chief or that only the chief was allowed to use certain words that were considered sacred (Comrie et al., 2003).

The Tongan alphabet consists of 5 vowels, each having short and long forms, and the following 12 consonants: /f/, /h/, /k/, /l/, /m/, /n/, /ŋ/, /p/, /s/, /t/, /v/, and /'/ and is written using a standard Roman script. In Tongan there are no diphthongs, consonant combinations do not exist, and all words must end in a vowel. Since there are no diphthongs, whenever vowels co-occur each vowel is pronounced individually. Each syllable in Tongan words contains only one vowel, so the number of syllables is equal to the number of vowels (Churchward, 1953; Shumway, 1988). Most Tongan words consist of two or more syllables. Words of only one syllable are generally definite articles or plural markers (Campbell, 2000). In most cases, the stress of a word falls on the second-to-last syllable. However, stress is flexible and in some cases will shift to the last vowel (syllable) of the word (Shumway, 1988).

Availability of word recognition materials in Tongan. In the current published literature there is no mention of the development of speech audiometry materials for native speakers of Tongan. In view of the lack of available materials a project focused on the development of such materials would be appropriate and beneficial. Thus the purpose of this study is to create speech audiometry materials that can be used and distributed among Tongan speakers for the purpose of obtaining word recognition scores based on Tongan word lists. This project was designed to meet the following specific objectives: (a) to create word lists for word recognition testing that are composed of frequently used words, (b) to identify both a native male and female Tongan who use a standard dialect of Tongan to serve as talkers for the recordings, (c) to develop four equivalent word recognition lists of 50 words each and eight equivalent half-lists of 25 words each, (d) to obtain normative data from a normal hearing population on the word recognition word lists, (e) to create high-quality digital recordings of the word recognition word lists.

Method

Participants

A total of 20 native speakers of Tongan (8 male, 12 female) participated in evaluating the Tongan bisyllabic words. Participants ranged in age from 19 to 41 years (M = 25.3). The amount of time that each participant had lived in the U.S. at the time of testing ranged from 1.2 to 27 years (M = 11.5). Sixteen of the participants reported knowing some English; however all indicated that they speak Tongan on a daily basis. All participants had pure-tone air-conduction thresholds of 15 dB HL or lower at octave and mid-octave frequencies from 125 to 8000 Hz and had static acoustic admittance between 0.3 and 1.4 mmhos with peak pressure between -10 and +50 daPa (ASHA, 1990; Roup, Wiley, Safady, & Stoppenbach, 1998). Summary statistics of the subject thresholds are presented in Table 1.

Materials

Words. Bisyllabic words were chosen as stimuli for the construction of the word recognition materials based on previous research in other languages (Harris et al., 2004; Harris et al., 2007; Nissen et al., 2005). Initially, 396 bisyllabic words were selected for recording from a text book used for teaching beginning Tongan (Shumway, 1988). Words that had the same pronunciation but different meanings or were part of a closed set (such as numbers, days of the weeks, months of the year, etc.) were avoided as much as possible. The selected words were then judged by three native Tongan speakers using a rating scale of 1 to 5 based on how familiar each word would be to a native Tongan speaker (5 = extremely familiar, 4 = very familiar, 3 = somewhat familiar,

Table 1

Pure Tone Threshold (dB HL) Descriptive Statistics for 20 Normally Hearing Tongan Participants

	M	*Minimum*	*Maximum*	*SD*
0.125 Hz	4.8	-5	15	5.0
0.25 Hz	3.8	-5	15	6.0
0.5 Hz	5.5	0	15	4.8
0.75 Hz	5.3	-5	15	6.4
1.0 Hz	6.0	0	15	4.5
1.5 Hz	7.5	0	15	3.8
2.0 Hz	6.3	0	15	4.8
3.0 Hz	6.8	0	15	3.7
4.0 Hz	7.5	0	15	4.7
6.0 Hz	7.5	0	15	4.4
8.0 Hz	8.8	-5	15	6.9
PTA[a]	5.9	0.0	11.7	3.5

[a]PTA = arithmetic average of thresholds at 0.5, 1.0, and 2.0 Hz

2 = infrequently used, and 1 = rarely used). Words that received a rating of 3 or less, were thought to be culturally insensitive, or were thought to possibly represent inappropriate content by any of the judges were eliminated from the study prior to listener evaluation. Of the 396 bisyllabic words considered, 265 were selected for recording and evaluation in this study.

Talkers. Initial test recordings were made using seven native Tongan-speaking individuals, four males and three females. After the initial recordings were made, a panel of eight native Tongan-speaking judges evaluated the performance of each talker, rank ordering the talkers from best to worst based on vocal quality, Tongan accent, and pronunciation. The highest ranked male and female talkers were selected as the talkers for all subsequent recordings.

Recordings. All recordings were made in a large anechoic chamber, with approximately a 65 dB signal-to-noise ratio with the sound floor measuring 0 dB SPL, located on the Brigham Young University campus in Provo, Utah, USA. A Larson-Davis model 377B41, 1.27 cm microphone was utilized for all recordings. The microphone was positioned approximately 15 cm from the talker at a 0° azimuth and was covered by a 7.62 cm windscreen. The microphone was connected to a Larson-Davis model PRM902 microphone preamp, which was coupled to a Larson-Davis model 2221 microphone preamplifier power supply. The signal was digitized by an Apogee AD-8000 24-bit analog-to-digital converter and subsequently stored on a hard drive for later editing. A 44.1 kHz sampling rate with 24-bit quantization was used for all recordings, and every effort was made to utilize the full range of the 24-bit analog-to-digital converter. Ambient noise levels in the anechoic chamber were approximately 0 dB SPL, which allowed a signal-to-noise ratio of at least 65 dB during recording, which was verified by measurement of ambient noise and speech levels on the recording.

During the recording sessions, the talker was asked to pronounce each bisyllabic word at least four times with a slight pause between each production. Talkers were asked to speak at a natural rate with normal intonation patterns. To avoid possible list effects, the first and last repetition of each word were excluded from the study. In addition, a native judge rated the medial repetitions of each word for perceived quality of production, and the best production of each word was then selected for inclusion in the Tongan speech audiometry test CD. Any word that was judged to be a poor recording (peak clipping, extraneous noise, etc.), mispronounced, or produced with an unnatural intonation pattern was eliminated from the study prior to listener evaluation. The final number of recorded words chosen for use in the testing presentations was 250.

After the rating process, the intensity of each bisyllabic word to be included on the test CD was edited as a single utterance using Sadie Disk Editor software (Studio Audio & Video Ltd., 2007) to yield the same average RMS power as that of a 1000 Hz calibration tone in an initial attempt to equate test word audibility (Harris et al., 2004**;** Wilson & Strouse, 1999). Each of the individually recorded and edited words were then saved as 24-bit *wav* files.

Procedures

Custom software was used to control randomization and timing of the presentation of the words from the 24-bit wav files to the external input of a Grason Stadler model 1761 audiometer. The stimuli were routed from the audiometer to the subject via a single TDH-50P headphone. All testing was carried out in a double-walled sound suite that met ANSI S3.1 standards for maximum permissible ambient noise levels for the ears not covered condition using one-third octave-bands (American National Standards Institute [ANSI], 1999).

Prior to testing each subject, the external inputs to the audiometer were calibrated to 0 VU using a 1000 Hz calibration tone. The audiometer was calibrated prior to, weekly during, and at the conclusion of data collection. Audiometric calibration was performed in accordance with ANSI S3.6 specifications (ANSI, 2004). No changes in calibration were necessary throughout the course of data collections.

Each participant attended one testing session after passing a hearing evaluation of pure-tone air-conduction thresholds at 15db HL or better. The participants were not familiarized with the bisyllabic words prior to testing. The 250 bisyllabic words were randomly grouped into ten lists of 25 words each. These ten lists were used for presentation to the first ten participants. The 250 words were then randomly grouped into ten different lists for presentation to the next group of ten participants. Ten presentation levels were selected for evaluation of the lists; -5 to 40 dB HL in 5 dB increments. One list was presented at each intensity level. The order of presentation of the lists and the order of the words within the list were randomized for each subject. Each word was presented an equal number of times at each intensity level across the entire participant population. Each response had to match the presented stimuli in both lexical tone and pronunciation across both syllables to be scored as correct. Prior to the administration of the word recognition test, each individual was given the following instructions in English:

You will hear lists of Tongan words at a number of different loudness levels. Each word is two syllables in length. At the very soft levels it may be difficult for you to hear the words. Please listen carefully and repeat out loud the word that you hear. If you are unsure of a word, you are encouraged to guess. If you have no guess say, *I don’t know*, or wait silently for the next word. Do you have any questions?

Results

The results of the listener evaluations were analyzed using descriptive and inferential statistical methods. The 250 words from each talker were then rank-ordered from best to worst performance based on the rate of listener identification. The 50 lowest ranked words from each list were removed and the 200 words with the highest rate of listener identification were then divided into four balanced lists of 50 words each for both the male and female talkers. This was done by random block assignment in which the four highest ranking words were each randomly assigned to lists 1, 2, 3, or 4. This process was repeated for each succeeding group of four words until all the words had been used and each list contained 50 words. The four equivalent Tongan bisyllabic word lists for the male and female recordings are presented in Tables 2 and 3, respectively. Linguistic details of the words included in the male and female lists (e.g., English translation and part of speech) are presented in Appendix B.

Eight half-lists of 25 words were constructed after the creation of the four balanced 50-word lists. Two half-lists were formed from each full-list by designating the first word in the rank-ordered list randomly as either an A or a B, designating the second word with the other letter, and then counterbalancing the assignment of the remaining words. Once all words were assigned to a letter, the full-list could be divided into two half-lists: Half-list A and Half-list B. The male and female half-lists are presented in Tables 4 and 5, respectively.

Once the bisyllabic lists and half-lists were created, logistic regression was used to calculate regression slopes and regression intercepts for each of the four lists and eight half-lists for the male and female talker recordings. The logistic regression slope and

Table 2

Tongan Male Bisyllabic Lists in Rank Order from Most Difficult to Easiest

List 1		List 2		List 3		List 4	
hu'a	'ita	kulo	moho	pele	lanu	fuka	keli
limu	ika	la'e	Sune	fohi	hoka	teke	fale
tufi	kato	lesi	palu	masi	fo'i	sosa	moli
homo	motu	koa	kete	'aho	namu	ta'o	popo
unu	puna	talu	mali	'uli	kili	ta'u	lova
topu	lua	pamu	mole	'ai	pulu	sisi	kokō
olo	puke	'utu	'ota	huo	hifo	monū	lulu
oli	nifo	holo	ui	'omi	kumā	misi	keke
ipu	kai	fala	vave	pasi	loki	viku	papa
kalo	sote	helu	kulī	'ene	kemo	vale	vala
ivi	'uha	toto	luma	uku	pehē	aka	vela
ifi	'ofa	fiha	ma'a	kia	'eva	piko	efu
loli	fahi	pīpī	mohe	le'o	kote	feke	'uma
foha	kaka	a'u	pepa	fesi	mate	tuku	mata
piki	tu'u	peku	lue	inu	tahi	pēpē	niu
tele	fusi	sipi	mālō	kole	tatā	ihu	mana
na'a	tuli	pusi	sōkē	lole	nusi	hopo	suka
kehe	veve	fonu	moko	'ave	atu	pani	'uto
mafu	'osi	tunu	patō	kovi	va'e	putu	lalo
hoa	tu'a	sea	laka	koe	lupe	lolo	poto
hia	la'ā	'ilo	mama	sivi	lea	momo	supo
kofu	tohi	kolo	loka	pito	lotu	vaka	leka
manu	luo	sino	'alu	ako	oma	ono	lava
maka	konā	hola	ifo	tuki	malu	pea	lose
lele	fa'ē	haka	lahi	loto	soka	laku	kākā

Table 3

Tongan Female Bisyllabic Lists in Rank Order from Most Difficult to Easiest

List 1		List 2		List 3		List 4	
moko	kole	sote	'uha	foki	puna	limu	tolo
pulu	oma	mole	aka	pele	pani	kolo	ketu
'uli	kulī	tapu	keke	'ota	pato	feke	lotu
'ita	lalo	sipi	kaka	hoa	pehē	fohi	suka
paka	kato	hu'a	kete	peka	fiha	vela	ava
'osi	lanu	hifo	laku	misi	lele	pīpī	peku
atu	leka	ika	efu	a'u	namu	kui	niu
helu	ipu	tete	luo	vilo	'ave	sivi	'omi
nusi	patō	tupu	kemo	kalo	mama	putu	loka
moli	pepa	teke	tahi	haka	lua	fala	'eva
sōkē	mu'a	inu	va'e	'ulu	tuli	tali	vave
kokō	'uto	Sune	foha	keli	lahi	'ai	puke
sino	fahi	'uta	moho	masi	lole	pasi	veve
tuki	kehe	nifo	tatā	peni	'ea	la'e	mana
'afu	'alu	lulu	lupe	papa	tunu	koa	lose
puha	'uma	kote	fuhu	tele	konā	viku	lava
loli	'aho	tufi	tohi	motu	fale	mali	lea
momo	mata	popo	le'o	pata	ta'u	supo	maka
muli	toto	loki	pea	vala	talo	tu'o	luma
pēpē	fonu	'utu	lova	ihu	na'a	tafi	'ofa
'ene	fo'i	pito	kai	lesi	holo	uku	lolo
hoka	tu'a	kulo	tuku	afi	fa'ē	fa'a	mate
monū	kofu	toli	fa'u	topu	lue	kumā	manu
mohe	la'ā	huo	ma'a	loto	hele	kovi	malu
poto	ta'o	ako	mālō	koe	kākā	tanu	tu'u

Table 4

Tongan Male Bisyllabic Half-lists in Rank Order from Most Difficult to Easiest

1A	1B	2A	2B	3A	3B	4A	4B
hu'a	limu	kulo	la'e	pele	fohi	sosa	fuka
tufi	unu	lesi	talu	'aho	masi	monū	teke
homo	topu	koa	'utu	'ai	'uli	misi	ta'o
olo	ipu	pamu	holo	huo	'omi	viku	ta'u
oli	kalo	fiha	fala	'ene	pasi	vale	sisi
ivi	foha	pīpī	helu	kia	uku	aka	piko
ifi	piki	peku	toto	fesi	le'o	pēpē	feke
loli	tele	sipi	a'u	inu	kole	ihu	tuku
na'a	kehe	tunu	pusi	'ave	lole	hopo	pani
hoa	mafu	sea	fonu	sivi	kovi	putu	momo
hia	maka	'ilo	kolo	ako	koe	lolo	vaka
kofu	'ita	hola	sino	tuki	pito	pea	ono
manu	kato	haka	moho	loto	lanu	keli	laku
lele	motu	Sune	palu	fo'i	hoka	moli	fale
ika	puna	kete	mole	kili	namu	kokō	popo
lua	puke	mali	'ota	hifo	pulu	lulu	lova
nifo	kai	kulī	ui	kemo	kumā	papa	keke
fahi	sote	luma	vave	pehē	loki	vala	vela
kaka	'uha	mohe	ma'a	'eva	mate	niu	efu
tu'u	'ofa	pepa	lue	kote	tahi	mana	'uma
veve	fusi	sōkē	mālō	tatā	atu	suka	mata
'osi	tuli	moko	laka	nusi	lupe	poto	'uto
la'ā	tu'a	patō	mama	va'e	lea	supo	lalo
luo	tohi	loka	'alu	lotu	oma	leka	lava
konā	fa'ē	lahi	ifo	soka	malu	lose	kākā

Table 5

Tongan Female Bisyllabic Half-lists in Rank Order from Most Difficult to Easiest

1A	1B	2A	2B	3A	3B	4A	4B
pulu	moko	sote	mole	pele	foki	feke	limu
paka	'uli	tapu	hu'a	misi	'ota	fohi	kolo
'osi	'ita	sipi	ika	a'u	hoa	pīpī	vela
atu	helu	hifo	tupu	vilo	peka	sivi	kui
nusi	moli	tete	Sune	kalo	haka	putu	tali
kokō	sōkē	teke	'uta	'ulu	tele	fala	pasi
sino	loli	inu	lulu	keli	motu	'ai	la'e
tuki	momo	nifo	tufi	masi	pata	koa	mali
'afu	pēpē	kote	'utu	peni	vala	viku	supo
puha	'ene	popo	pito	papa	lesi	tu'o	uku
muli	hoka	loki	kulo	ihu	afi	tafi	fa'a
mohe	monū	ako	toli	topu	loto	kumā	tanu
poto	oma	aka	huo	koe	pani	kovi	tolo
kole	kato	keke	'uha	puna	pato	ketu	suka
kulī	leka	kaka	kete	pehē	namu	lotu	ava
lalo	ipu	efu	laku	fiha	'ave	peku	niu
lanu	pepa	luo	tahi	lele	mama	'omi	loka
patō	kehe	kemo	moho	lahi	lua	'eva	vave
mu'a	'alu	va'e	lupe	lole	tuli	lose	puke
'uto	'uma	foha	fuhu	'ea	tunu	lava	veve
fahi	'aho	tatā	tohi	konā	fale	lea	mana
toto	mata	kai	le'o	ta'u	na'a	maka	mate
fonu	fo'i	tuku	pea	talo	lue	luma	manu
kofu	tu'a	fa'u	lova	holo	hele	'ofa	malu
la'ā	ta'o	ma'a	mālō	fa'ē	kākā	lolo	tu'u

intercept values for the male and female lists and half-lists are presented in Table 6 and Table 7, respectively. These regression slope and intercept values were then inserted into a modified logistic regression equation (Equation 1) that was designed to calculate percentage of correct performance at any specified intensity level. The percent of correct values yielded from Equation 1 were subsequently used to construct psychometric functions for each list.

$$P = (1 - \frac{\exp(a + b \times i)}{1 + \exp(a + b \times i)}) * 100 \qquad (1)$$

The following is a description of Equation 1. *P* is the percentage correct recognition, *a* is the regression intercept, *b* is the regression slope, and *i* is the presentation intensity level in dB HL. By inserting the regression slope, regression intercept, and intensity level into Equation 1, it is possible to predict the percentage of correct word recognition at any specified intensity level. Percentage of correct word recognition was predicted for each of the bisyllabic lists and half-lists for a range of -5 to 40 dB HL in 5 dB increments. Psychometric functions were then produced using the predicted percentages. The threshold (presentation intensity required for 50% word recognition performance), the slope at threshold, and the slope from 20 to 80% were calculated for the bisyllabic lists and half-lists by inserting specific proportions into Equation 2.

$$i = \frac{\log \frac{p}{1-p} - a}{b} \qquad (2)$$

In Equation 2, *i* is the presentation level in dB HL, *p* is the proportion of correct recognition, *a* is the regression intercept, and *b* is the regression slope. Tables 6 (male)

Table 6

Mean Performance of Tongan Male Bisyllabic Lists and Half-lists

List	a[a]	b[b]	Slope at 50% [c]	Slope 20-80%[d]	Threshold[e]	ΔdB[f]
1	3.83914	-0.25523	6.4	5.5	15.0	2.41
2	3.44779	-0.22857	5.7	4.9	15.1	2.45
3	3.85926	-0.25403	6.4	5.5	15.2	2.56
4	4.03730	-0.26398	6.6	5.7	15.3	2.66
M	3.79587	-0.25045	6.3	5.4	15.2	2.52
Minimum	3.44779	-0.26398	5.7	4.9	15.0	2.41
Maximum	4.03730	-0.22857	6.6	5.7	15.3	2.66
Range	0.58951	0.03541	0.9	0.8	0.3	0.25
SD	0.24855	0.01525	0.4	0.3	0.1	0.11
1A	4.00258	-0.26518	6.6	5.7	15.1	2.46
1B	3.69100	-0.24624	6.2	5.3	15.0	2.36
2A	3.76658	-0.25126	6.3	5.4	15.0	2.36
2B	3.19586	-0.21058	5.3	4.6	15.0	2.54
3A	4.04848	-0.26822	6.7	5.8	15.1	2.46
3B	3.69653	-0.24177	6.0	5.2	15.3	2.66
4A	4.10665	-0.26850	6.7	5.8	15.3	2.66
4B	3.97105	-0.25966	6.5	5.6	15.3	2.66
M	3.80984	-0.25143	6.3	5.4	15.2	2.52
Minimum	3.19586	-0.26850	5.3	4.6	15.0	2.36
Maximum	4.10665	-0.21058	6.7	5.8	15.3	2.66
Range	0.91079	0.05792	1.4	1.3	0.3	0.31
SD	0.29616	0.01934	0.5	0.4	0.1	0.13

[a]*a* = regression intercept. [b]*b* = regression slope. [c]Psychometric function slope (%/dB) at 50% was calculated from 49.999 to 50.001%. [d]Psychometric function slope (%/dB) from 20-80%. [e]Intensity required for 50% intelligibility. [f]Change in intensity required to adjust threshold to the mean threshold for male and female lists (12.63 dB HL)

Table 7

Mean Performance of Tongan Female Bisyllabic Lists and Half-lists

List	a[a]	b[b]	Slope at 50%[c]	Slope 20-80%[d]	Threshold[e]	ΔdB[f]
1	2.44256	-0.24430	6.1	5.3	10.0	-2.64
2	2.53758	-0.25232	6.3	5.5	10.1	-2.58
3	2.41915	-0.23734	5.9	5.1	10.2	-2.44
4	2.56470	-0.25125	6.3	5.4	10.2	-2.43
M	2.49100	-0.24630	6.2	5.3	10.1	-2.52
Minimum	2.41915	-0.25232	5.9	5.1	10.0	-2.64
Maximum	2.56470	-0.23734	6.3	5.5	10.2	-2.43
Range	0.14555	0.01498	0.4	0.3	0.2	0.21
SD	0.07097	0.00695	0.2	0.2	0.1	0.10
1A	2.69958	-0.26292	6.6	5.7	10.3	-2.37
1B	2.22482	-0.22883	5.7	5.0	9.7	-2.91
2A	2.52314	-0.24608	6.2	5.3	10.3	-2.38
2B	2.55658	-0.25926	6.5	5.6	9.9	-2.77
3A	2.55107	-0.24637	6.2	5.3	10.4	-2.28
3B	2.29811	-0.22916	5.7	5.0	10.0	-2.61
4A	2.66654	-0.25728	6.4	5.6	10.4	-2.27
4B	2.46892	-0.24566	6.1	5.3	10.1	-2.58
M	2.49860	-0.24695	6.2	5.3	10.1	-2.52
Minimum	2.22482	-0.26292	5.7	5.0	9.7	-2.91
Maximum	2.69958	-0.22883	6.6	5.7	10.4	-2.27
Range	0.47476	0.03409	0.9	0.7	0.6	0.64
SD	0.16533	0.01288	0.3	0.3	0.2	0.24

[a]*a* = regression intercept. [b]*b* = regression slope. [c]Psychometric function slope (%/dB) at 50% was calculated from 49.999 to 50.001%. [d]Psychometric function slope (%/dB) from 20-80%. [e]Intensity required for 50% intelligibility. [f]Change in intensity required to adjust threshold to the mean threshold for male and female lists (12.63 dB HL)

and 7 (female) also include the results for threshold, slope at threshold, and slope from 20 to 80% for each list and half-list.

A two-way Chi-Square (χ^2) analysis (intensity and list as independent variables with response as the dependent variable) was performed in order to discern any statistically significant differences among the word lists or half-lists created from the male and female recordings. The results of the analysis indicated there were no significant differences among the 50-word lists for the male and female talkers, $\chi^2(3, N = 20) = 2.83$, $p = 0.42$, and $\chi^2(3, N = 20) = 0.37$, $p = 0.95$. Results also indicated that there was no significant differences found among the 25-word half-lists for the male and female talkers, $\chi^2(7, N = 20) = 5.16$, $p = 0.64$ and $\chi^2(7, N = 20) = 2.49$, $p = 0.93$. While there were not any statistically significant differences among the lists or half-lists, some digital adjustments could be made to the lists and half-lists to further increase their psychometric equivalency. These intensity-level adjustments were made using Sadie Disk Editor software (Studio Audio & Video Ltd., 2007). The intensity of each word from the male and female bisyllabic lists and half-lists was adjusted so that the 50% threshold of each list was equal to the midpoint (12.63 dB HL) between the mean threshold of the eight male half-lists and the mean threshold of the eight female half-lists. Intensity adjustments made to each word in the male and female lists and half-lists are presented in Tables 6 and 7, respectively. Shown in Figure 1 are the psychometric functions for the male talker and female talker bisyllabic lists and half-lists prior to the intensity adjustments. Figure 2 displays the psychometric functions for the female talker and male talker bisyllabic lists and half-lists after the intensity adjustments were performed to produce 50% performance at 12.63 dB HL. The mean psychometric functions for the

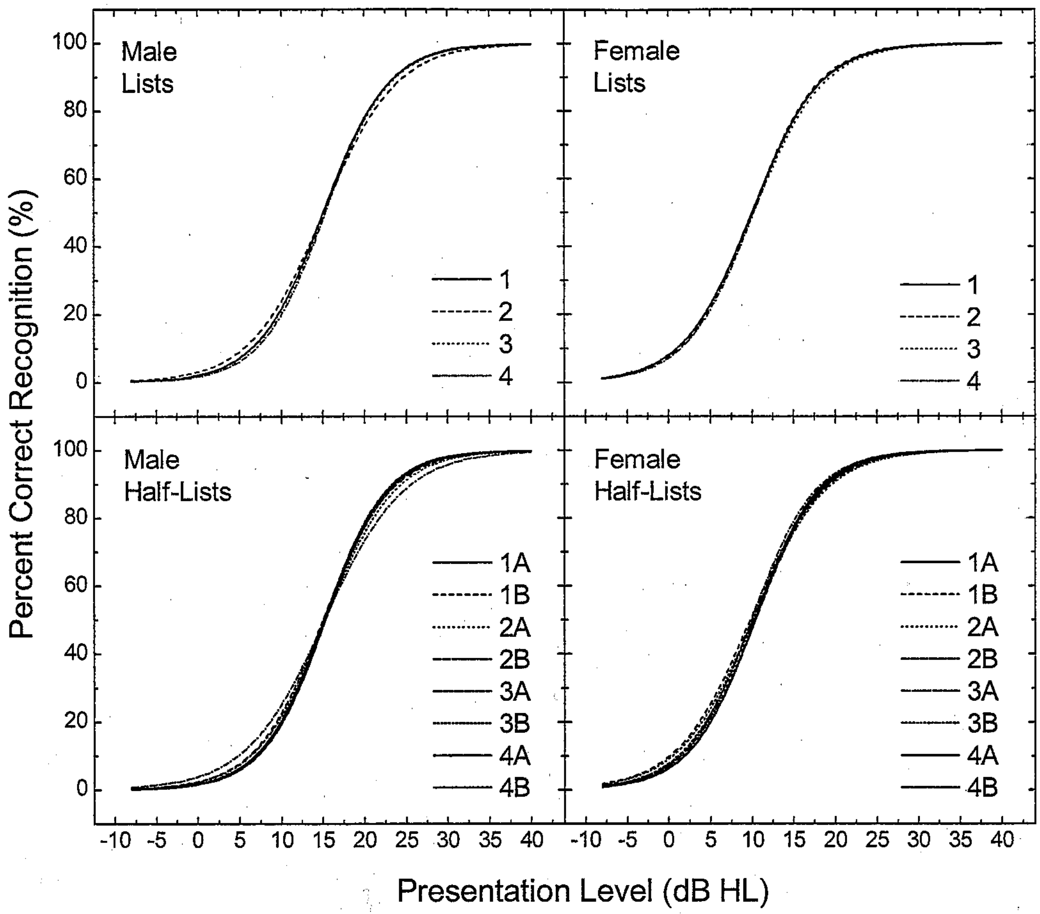

Figure 1.

Psychometric functions for the four Tongan bisyllabic lists and eight half-lists for male talker and female talker recordings before intensity adjustments.

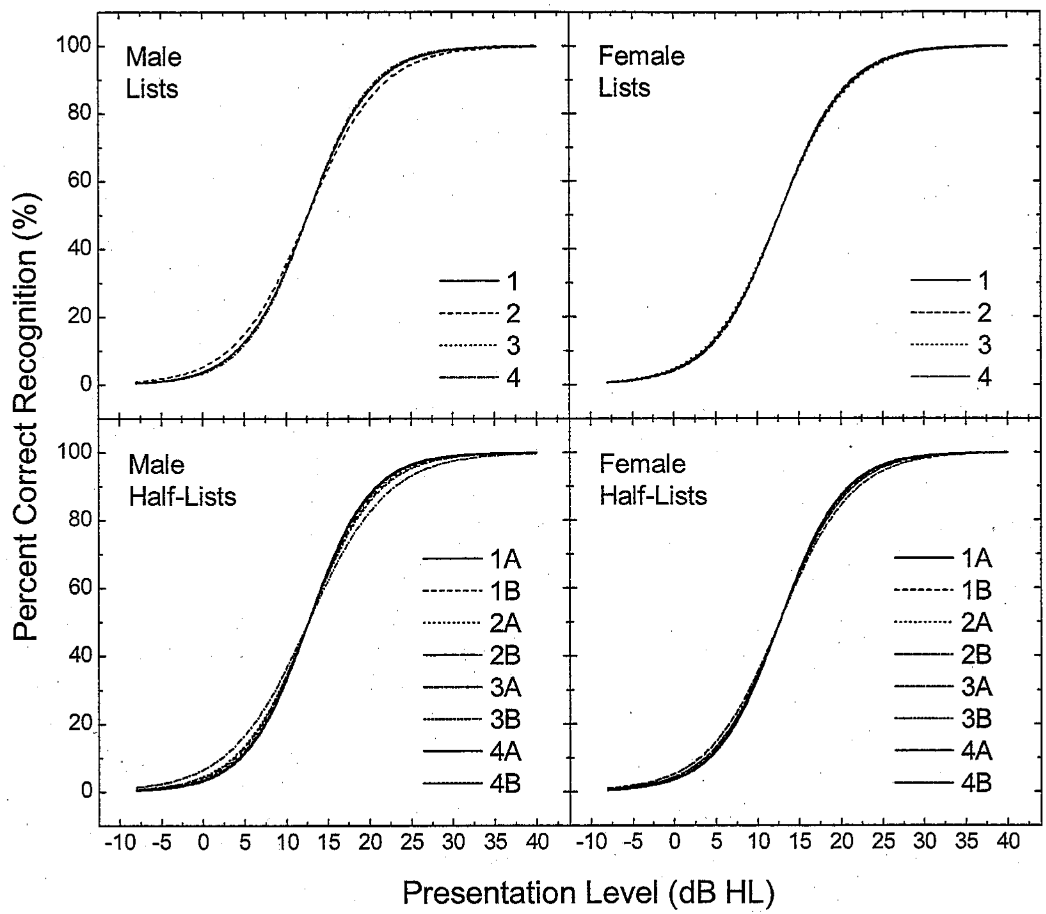

Figure 2.

Psychometric functions for the four Tongan bisyllabic lists and eight half-lists for male talker and female talker recordings after intensity adjustments to produce 50% performance at 12.63 dB HL.

combined male and female talker bisyllabic lists both before and after the intensity adjustments are shown in Figure 3. This comparison between Figures 1 and 2 illustrates the small adjustments that were required (≤3 dB) in order to equate the 50-word lists and 25-word half-lists for the male and female talkers.

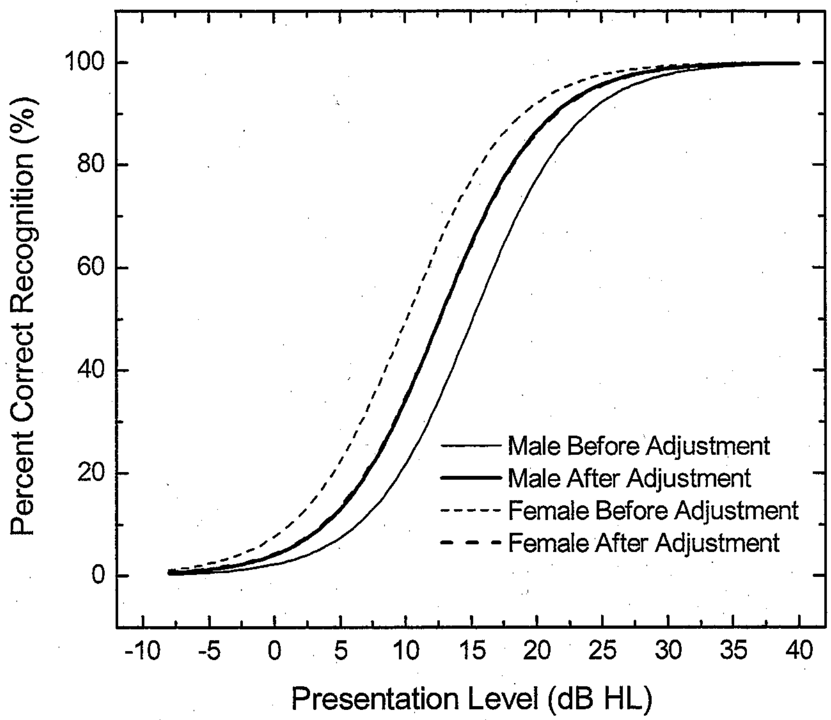

Figure 3.

Mean psychometric functions for male and female Tongan talker bisyllabic word lists before and after intensity adjustment. Intensity adjustments were made to each list and half-list to produce 50% correct performance at 12.63 dB HL.

Discussion

The current study resulted in the creation of bisyllabic lists and half-lists designed for use in word recognition testing with native speakers of Tongan. As demonstrated in Figures 1-3, these materials are relatively homogenous with one another with regard to audibility and psychometric slope. Statistical analysis showed that there were no significant differences among the lists as they were presented to listeners with normal-hearing within a double-walled sound suite. The word lists created in this study will be beneficial for use in audiological evaluations of Tongan speaking individuals. As these are the only known speech audiometry materials to be developed in Tongan, further research on these materials should be made.

A point of interest in the results of this study was the change in intensity required for the male and female lists in order to adjust the threshold to the mean threshold of 12.63 dB HL. As can be seen in Table 6, the adjustments required for all the male lists necessitated an increase in intensity. Conversely, the female lists required a decrease in intensity, as is shown in Table 7. These results indicate that words presented by the female talker were perceived at lower intensity thresholds than words presented by the male talker. During testing, it was also informally observed that the test participants performed better on lists presented by the female talker. Specific reasons for this difference are unknown, but could be due to a number of possible factors: spectral differences between the voices of the male and female speakers, differences in harmonics found between the two speakers, and possibly the different speaking rate of each talker. It was noted that the female talker spoke with a slightly slower rate of speech than did the male talker. Previous studies, using English word lists, have indicated that test results obtained using female and male talkers were not significantly different from each other (Cambron et al., 1991). A two-way Chi-Square analysis between the male and female lists was not performed in this study. Such an analysis would indicate if the differences found in this study between the male and female talkers were significant and could open up possibilities to future research on the effects of talker gender on word recognition scores in Tongan. It would also be of interest to investigate if such differences are specific to native speakers of Tongan. A future study might compare spectral differences between the male and female Tongan recordings made in this study and determine whether those differences are both statistically and clinically significant.

A comparison between the psychometric slopes of the Tongan word lists and previously developed word recognition materials in American English shows that the mean slopes of the Tongan lists are slightly steeper than the English lists. The mean slopes from 20 to 80% for the NU-6 and CID W-22 word lists have been measured as 4.2%/dB and 4.6%/dB, respectively (Beattie, Edgerton, & Svihovec, 1977). The mean slopes from 20 to 80% for the Tongan male and female full-lists created in this study were 5.4%/dB and 5.3%/dB, respectively.

A possible reason for this difference is that the underlying linguistic structure of the Tongan language is different from English. Tongan is heavily loaded with vowels and the consonants consist of three nasals, four voiceless stops, two liquids, and only three fricatives. Many of the English sounds that contain relatively high frequencies, such as the fricatives, are not found in great abundance in Tongan. As a result, a frequency spectrum of Tongan speech would likely reveal a relatively greater proportion of low frequency sounds. It is unknown what effects these spectral differences may have upon speech perception and performance on word recognition tests; however it is possible that such differences might have contributed to the steeper psychometric slopes of the Tongan word lists as compared to English word lists.

The fewer number of high-frequency sounds contained in the Tongan language also brings into question how a Tongan speaking individual with a high-frequency hearing loss would perform on a word recognition test in comparison with an English speaking individual. It is hypothesized that a Tongan individual with a high-frequency hearing loss would perform better than their English counterpart due to the decreased demand of interpreting high-frequency signals in the Tongan language. This could possibly result in an under-diagnosis of high-frequency hearing loss in Tongan speaking patients.

Evaluating the materials created in this study with a group of hearing-impaired individuals is a possible topic for future research and would provide a valuable comparison to this current study. Understanding how hearing-impaired populations perform on word recognition tests is imperative to diagnosis and treatment. In order for the test results to be accurate, performance data for the test population should be available (Jerger, 2006).

This study could also be expanded by documenting test performance on the developed word lists in the presence of noise, such as is done with the SIN test (Jayaram et al., 1992). Testing word recognition in the presence of noise puts greater demands upon the patient and can provide the audiologist with more diagnostic information about difficulties the patient may be experiencing in their daily communication (Martin & Clark, 2009). Wilson and McArdle (2005) report on the problems that arise from trying to predict performance on word recognition tests administered in the presence of background noise based on results of previous testing performed in quiet environments and suggest that performance intensity functions be calculated for performance in noise using a test in which noise has actually been presented.

Further expansion of the study could also involve administering the developed lists using a carrier phrase before each word presentation, as is done in the CID W-22 (Hirsh et al., 1952) and the NU-6 (Tillman & Carhart, 1966). Brandy (2002) reports that many audiologists prefer the use of carrier phrases because they feel that it helps alert the patient to the stimulus. Carrier phrases were first used by Fletcher and Steinberg (1929), who reported that word identification increased when a carrier phrase was used. Martin, Hawkins, and Bailey (1962) dispute the use of carrier phrases as they found no significant difference in scores when such phrases were used. Other studies (Gelfand, 1975; Gladstone & Siegenthaler, 1971) have found word recognition test scores to be lower when a carrier phrase was not used.

The test-retest reliability of the Tongan word lists developed in this study is another possible area of investigation. A test cannot be considered reliable unless test and retest scores for the same individual has been shown to not be significantly different from one another (Gelfand, 1998). Test items in this study were administered to each subject only once. Information on consistency in performance of the same subject across a second administration of the test remains to be gathered.

The reliability of using the word recognition lists developed in the current study with Tongan speaking children also remains to be determined. According to Ashoor and Prochazka (1985), words used as test stimuli with young children should be collected from age-appropriate references as unfamiliar test items threaten the validity of the test. The words chosen for use in the current study were collected from a book meant for use in teaching beginning Tongan (Shumway, 1988). While these words are among the most common words used in the Tongan language it is unknown if a young child would be familiar with all the words.

A final observation made during the course of this study led to some concerns about the perceived amount of exposure those individuals native to Tonga have had to hearing evaluations and their awareness of materials and services available to assist in evaluating hearing loss. When being instructed in the procedures for their hearing screening, several of the participants were informally asked if they had received such a screening in the past. Exact numbers were not collected; however a majority of the participants reported that they had never previously received a hearing screening. In order for the recently developed Tongan speech audiometry materials to be used as intended, attempts to educate Tongan speakers about the importance of hearing screenings, and the materials that are available to evaluate hearing, may be in order.

The materials created in this study are valuable tools in providing linguistically appropriate hearing evaluations for speakers of the Tongan language, and it is hoped that these materials will make a meaningful contribution to the efforts of many researchers and audiologists to ease the burden of hearing disability in populations of non-English speakers. In summation, the study that has been presented was completed in order to create bisyllabic lists and half-lists that could be used in word recognition testing with native speakers of the Tongan language. These materials were created and final lists recorded by both male and female talkers, that are relatively homogenous with one another with regard to audibility and psychometric function slope, were compiled. After small intensity adjustments were made to further increase homogeneity, a CD with digital recordings of each list was created for distribution. A description of the materials contained on the CD can be found in Appendix C.

References

American National Standards Institute. (1999). *Maximum permissible ambient noise levels for audiometric test rooms* (ANSI S3.1–1999). New York: ANSI.

American National Standards Institute. (2004). S*pecification for audiometers* (ANSI S3.6–2004). New York: ANSI.

American Speech-Language-Hearing Association. (1988). Guidelines for determining threshold level for speech. *ASHA*, *30*(3), 85–89.

American Speech-Language Hearing Association. (1990). Guidelines for screening for hearing impairments and middle-ear disorders. *ASHA*, *32* (Suppl. 2), 17–24.

Ashoor, A. A., & Prochazka, T. (1985). Saudi Arabic speech audiometry for children. *British Journal of Audiology, 19*, 229–238.

Bartholomew, C. R. (1993). *Performance intensity functions for digitally recorded spondees*. Unpublished master's thesis, Brigham Young University, Provo, Utah.

Beattie, R. C., Edgerton, B. J., & Svihovec, D. V. (1977). A comparison of the Auditec of St. Louis cassette recordings of NU-6 and CID W-22 on a normal hearing population. *Journal of Speech and Hearing Disorders, 42*, 60–64.

Bell, T. S., & Wilson, R. H. (2001). Sentence recognition materials based on frequency of word use and lexical confusability. *Journal of the American Academy of Audiology, 12*, 514–522.

Brandy, W. T. (1966). Reliability of voice tests of speech discrimination. *Journal of Speech and Hearing Research, 9*, 461–465.

Brandy, W. T. (2002). Speech audiometry. In J. Katz (Ed.), *Handbook of Clinical Audiology* (pp. 96–110). Philadelphia: Lippincott Williams & Wilkins.

Cambron, N. K., Wilson, R. H., & Shanks, J. E. (1991). Spondaic word detection and recognition functions for female and male speakers. *Ear and Hearing, 12,* 64–70.

Campanelli, P. A. (1962). A measure of intra-list stability of four PAL word lists. *The Journal of Auditory Research, 2,* 50–55.

Campbell, G. L. (2000). *Compendium of the world's languages: Vol. 2. Ladakhi to Zuni.* (2nd ed.). New York, NY: Routledge.

Causey, G. D., Hermanson, C. L., Hood, L. J., & Bowling, L. S. (1983). A comparative evaluation of the Maryland NU-6 auditory test. *Journal of Speech and Hearing Disorders, 48*, 62–69.

Christensen, L. K. (1995). *Performance Intensity Functions for Digitally Recorded Spanish Speech Audiometry*. Unpublished master's thesis, Brigham Young University, Provo, Utah.

Churchward, C. M. (1953). *Tongan Grammar.* New York, NY: Oxford University Press.

Comrie, B., Matthews, S., & Polinksy, M. (Eds.). (2003). *The atlas of languages: The origin and development of languages throughout the world* (Rev. ed.). London: Quarto Publishing.

Crandell, C. C., & Smaldino, J. J. (1996). Speech perception in noise by children for whom English is a second language. *American Journal of Audiology, 5,* 47–51.

Deutsch, L. J., & Kruger, B. (1971). The systematic selection of 25 monosyllables which predict the CID W-22 speech discrimination score. *The Journal of Auditory Research, 11*, 286–290.

Egan, J. J. (1979). Basic aspects of speech audiometry. *Ear, Nose, & Throat Journal, 58,* 190–193.

Egan, J. P. (1948). Articulation testing methods. *Laryngoscope*, *58*, 955–991.

Elliott, L. L. (1995). Verbal auditory closure and the speech perception in noise (SPIN) test. *Journal of Speech and Hearing Research*, *38*, 1363–1376.

Elliott, L. L., & Katz, D. (1980). *Development of a new children's test of speech discrimination.* St. Louis, MO: Auditec.

Elpern, B. S. (1961). The relative stability of half-list and full-list discrimination tests. *Laryngoscope*, *71*, 30–36.

Epstein, A. (1978). Speech audiometry. *Otolaryngologic Clinics of North America, 11*, 667–676.

Fairbanks, G. (1958). Test of phonemic differentiation: The rhyme test. *Journal of the Acoustical Society of America*, *30*, 596–599.

Fletcher, H., & Steinberg, J. C. (1929). Articulation testing methods. *Bell System Technical Journal, 7*, 806–854.

Florentine, M. (1985). Non-native listeners' perception of American-English in noise. *Proceedings of Inter-noise, 85*, 1021–1024.

Gelfand, S. A. (1975). Use of the carrier phrase in live voice speech discrimination testing. *Journal of Auditory Research*, *15*, 107–110.

Gelfand, S. A. (1998). Optimizing the reliability of speech recognition scores. *Journal of Speech, Language, and Hearing Research, 41*, 1088–1102.

Gelfand, S. A. (2001). *Essentials of Audiology* (2nd ed.). New York, NY: Thieme.

Gladstone, V. S., & Siegenthaler, B. M. (1971). Carrier phrase and speech intelligibility score. *Journal of Auditory Research, 11*, 101–103.

Gordon, R. G., Jr. (Ed.). (2005). *Ethnologue: Languages of the world* (15th ed.). [Electronic version]. Dallas, TX: SIL International. Retrieved April 18, 2008, from http://www.ethnologue.com/.

Greer, L. F. (1997). *Performance intensity functions for digitally recorded Italian speech audiometry materials.* Unpublished master's thesis, Brigham Young University, Provo, Utah.

Grosjean, F. (1989). Neurolinguists, beware! The bilingual is not two monolinguals in one person. *Brain and Language, 36*, 3–15.

Harris, R. W., Goffi, M. V. S., Gygi, M. A., & Merrill, A. (2001). Psychometrically equivalent Brazilian Portuguese trisyllabic words spoken by male and female talkers. *Pro-Fono, 13,* 37–53.

Harris, R. W., Nielson, W. S., McPherson, D. L., Skarzynski, H., & Eggett, D. L. (2004). Psychometrically equivalent Polish bisyllabic words spoken by male and female talkers. *Audiofonologia, 25*, 1–15.

Harris, R. W., Nissen, S. L., Pola, M. G., McPherson, D. L., Tavartkiladze, G. A., & Eggett, D., L. (2007). Psychometrically equivalent Russian speech audiometry materials by male and female talkers. *International Journal of Audiology, 11*(1), 47–66.

Haskins, H. (1949). *A phonetically balanced test of speech discrimination for children.* Unpublished master's thesis, Northwestern University, Evanston, Illinois.

Hirsh, I. J., Davis, H., Silverman, S. R., Reynolds, E. G., Eldert, E., & Benson, R. W. (1952). Development of materials for speech audiometry. *Journal of Speech and Hearing Disorders, 17*, 321–337.

Hodgson, W. R. (1985). *Basic audiologic evaluation.* Malabar, FL: Krieger.

Hood, J. D., & Poole, J. P. (1977). Improving the reliability of speech audiometry. *British Journal of Audiology, 11*, 93–101.

House, A. S., Williams, C. E., Hecker, M. H. L., & Kryter, K. D. (1965). Articulation testing methods: Consonantal differentiation with a closed-response set. *Journal of the Acoustical Society of America, 37*, 158–166.

Hudgins, C. V., Hawkins, J. E., Karlin, J. E., & Stevens, S. S. (1947). The development of recorded auditory tests for measuring hearing loss for speech. *Laryngoscope, 57*, 57–89.

Jayaram, M., Baguley, D. M., & Moffat, D. A. (1992). Speech in noise: A practical test procedure. *Journal of Laryngology and Otology, 106*, 105–110.

Jerger, J. (2006). Are some more equal than others? *Journal of the American Academy of Audiology, 17*, 156.

Kalikow, D. N., Stevens, K. N., & Elliott, L. L. (1977). Development of a test of speech intelligibility in noise using sentence materials with controlled word predictability. *Journal of the Acoustical Society of America, 61*, 1337–1351.

Katzner, K. (1995). *The languages of the world* (New ed.). New York, NY: Routledge.

Killion, M. C., Niquette, P. A., Gudmundsen, G. I., Revit, L. J., & Banerjee, S. (2004). Development of a quick speech-in-noise test for measuring signal-to-noise ratio loss in normal-hearing and hearing-impaired listeners. *Journal of the Acoustical Society of America, 116*, 2395–2405.

Lehiste, I., & Peterson, G. E. (1959). Linguistic considerations in the study of speech intelligibility. *Journal of the Acoustical Society of America, 31*, 280–286.

Lemhofer, K., Dijkstra, T., Schriefers, H., Baayen, R. H., Grainger, J., & Zwitserlood, P. (2008). Native language influences on word recognition in a second language: A megastudy. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 34*, 12–31.

Luce, P. A. (1986). A computational analysis of uniqueness points in auditory word recognition. *Perception and Psychophysics, 39,* 155–158.

Luce, P. A., & Pisoni, D. B. (1998). Recognizing spoken words: The Neighborhood Activation Model. *Ear and Hearing, 19*, 1–36.

Marti, F. (2005). *Words and worlds: World languages review.* Buffalo, NY: Multilingual Matters.

Martin, F. N., Champlin, C. A., & Chambers, J. (1998). Seventh survey of audiometric practices in the United States. *Journal of the American Academy of Audiology, 9*, 95–104.

Martin, F. N., Champlin, C. A., & Perez, D. D. (2000). The question of phonetic balance in word recognition testing. *Journal of the American Academy of Audiology, 11*, 489–493.

Martin, F. N., & Clark, J. G. (2009). *Introduction to audiology* (10th ed.). New York: Pearson.

Martin, F. N., Hawkins, R. R., & Bailey, H. A. T. (1962). The non-essentiality of the carrier phrase in phonetically balanced (PB) word testing. *Journal of Auditory Research, 2,* 319–322.

Mayo, L. H., Florentine, M., & Buus, S. (1997). Age of second-language acquisition and perception of speech in noise. *Journal of Speech Language and Hearing Research, 40*, 686–693.

McArdle, R. A., & Wilson, R. H. (2006). Homogeneity of the 18 QuickSIN lists. *Journal of the American Academy of Audiology, 17*, 157–167.

Nelson, A. (2004). *Performance intensity functions for digitally recorded French speech audiometry.* Unpublished master's thesis, University of Colorado, Boulder, Colorado.

Nielson, W. S. (2000). *Performance intensity functions for digitally recorded Polish speech audiometry materials.* Unpublished master's thesis, Brigham Young University, Provo, Utah.

Nissen, S. L., Harris, R. W., Jennings, L., Eggett, D. L., & Buck, H. (2005). Psychometrically equivalent Mandarin bisyllabic speech discrimination materials spoken by male and female talkers. *International Journal of Audiology, 44,* 379–390.

Omniglot (2007). *Tongan*. Retrieved March 10, 2007, from http://www.omniglot.com/writing/tongan.htm.

Owens, E., & Schubert, E. D. (1977). Development of the California Consonant Test. *Journal of Speech and Hearing Research, 20*, 463–474.

Padilla, M. (2003). *English phoneme and word recognition by non-native English speakers as a function of spectral resolution and English experience.* Unpublished Ph.D., University of Southern California, Los Angeles.

Penrod, J. P. (1979). Talker effects on word-discrimination scores of adults with sensorineural hearing impairment. *Journal of Speech and Hearing Disorders, 44*, 340–349.

Penrod, J. P. (1980). A comparison of half- vs full-list speech discrimination scores in a hearing impaired geriatric population. *The Journal of Auditory Research, 20*, 181–186.

Resnick, D. M. (1962). Reliability of the twenty-five word phonetically balanced lists. *The Journal of Auditory Research, 2*, 5–12.

Ross, M., & Lerman, J. (1970). A picture identification test for hearing impaired children. *Journal of Speech and Hearing Research, 13*, 44–53.

Roup, C. M., Wiley, T. L., Safady, S. H., & Stoppenbach, D. T. (1998). Tympanometric screening norms for adults. *American Journal of Audiology, 7*, 55–60.

Schwartz, D. M., & Surr, R. (1979). Three experiments on the California Consonant Test. *Journal of Speech and Hearing Disorders, 64*, 61–72.

Shumway, E. B. (1988). *Intensive course in Tongan.* Laie, Hawaii: The Institute for Polynesian Studies.

Studio Audio & Video Ltd. (2007). Sadie disk editor software (Version 5.6).

Thornton, A. R., & Raffin, M. J. M. (1978). Speech discrimination scores modified as a binomial variable. *Journal of Speech and Hearing Research, 21*, 507–518.

Tillman, T. W., & Carhart, R. (1966). *An expanded test for speech discrimination utilizing CNC monosyllabic words. Northwestern University auditory test no. 6* (Tech. Rep. No. SAM-TR-66-55). San Antonio, TX: USAF School of Aerospace Medicine, Brooks Air Force Base.

Tobias, J. V. (1964). On phonemic analysis of speech discrimination tests. *Journal of Speech and Hearing Research, 7,* 98–100.

Turrini, M., Cutugno, F., Maturi, P., Prosser, S., Leoni, F. A., & Arslan, E. (1993). Bisyllabic words for speech audiometry: A new Italian material. *Acta Otorhinolaryngologica Italica, 13,* 63–77.

U.S. Census Bureau. (2005). *We the people: Pacific islanders in the United States* (No. CENSR-26). Washington, DC: U.S. Government Printing Office.

von Hapsburg, D., Champlin, C. A., & Shetty, S. R. (2004). Reception thresholds for sentences in bilingual (Spanish/English) and monolingual (English) listeners. *Journal of the American Academy of Audiology, 15*, 88–98.

Weisleder, P., & Hodgson, W. R. (1989). Evaluation of four Spanish word-recognition-ability lists. *Ear and Hearing, 10,* 387–393.

Wilson, R. H., & Carter, A. S. (2001). Relation between slopes of word recognition psychometric functions and homogeneity of the stimulus materials. *Journal of the American Academy of Audiology, 12*, 7–14.

Wilson, R. H., & McArdle, R. (2005). Speech signals used to evaluate functional status of the audiometry system. *Journal of Rehabilitation and Development, 42*, 79–94.

Wilson, R. H., Preece, J. P., & Thornton, A. R. (1990). Clinical use of the compact disc in speech audiometry. *ASHA, 32*(6), 47–51.

Wilson, R. H., & Strouse, A. (1999). Psychometrically equivalent spondaic words spoken by a female speaker. *Journal of Speech, Language, and Hearing Research, 42,* 1336–1346.

Appendix A

Informed Consent Research Participant Form

Participant:____Age:__________

You are asked to participate in a research study sponsored by the Department of Audiology and Speech Language Pathology at Brigham Young University, Provo, Utah. The faculty director of this research is Richard W. Harris, Ph.D. Students in the Audiology and Speech-Language Pathology program may assist in data collection.

This research project is designed to evaluate a word list recorded using improved digital techniques. You will be presented with this list of words at varying levels of intensity. Many will be very soft, but none will be uncomfortably loud to you. You may also be presented with this list of words in the presence of a background noise. The level of this noise will be audible but never uncomfortably loud to you. This testing will require you to listen carefully and repeat what is heard through earphones or loudspeakers. Before listening to the word lists, you will be administered a routine hearing test to determine that your hearing is normal and that you are qualified for this study.

It will take approximately two hours to complete the test. Testing will be broken up into 2 or 3 one hour blocks. Each subject will be required to be present for the entire time, unless prior arrangements are made with the tester. You are free to make inquiries at any time during testing and expect those inquiries to be answered.

As the testing will be carried out in standard clinical conditions, there are no known risks involved. Standard clinical test protocol will be followed to ensure that you will not be exposed to any unduly loud signals.

Names of all subjects will be kept confidential to the investigators involved in the study. Participation in the study is a voluntary service and no payment of monetary reward of any kind is possible or implied.

You are free to withdraw from the study at any time without any penalty, including penalty to future care you may desire to receive from this clinic.

If you complete your participation in this research project you will be paid the amount of $_________ for your participation.

If you have any questions regarding this research project you may contact Dr. Richard W. Harris, 131 TLRB, Brigham Young University, Provo, UT 84602; phone (801) 422-6460 or Dr. Shawn L. Nissen, 138 TLRB, Brigham Young University, Provo, UT 84602, phone (801) 422-5056. If you have any questions regarding your rights as a participant in a research project you may contact Dr. Renea Beckstrand, Chair of the Institutional Review Board, 422 SWKT, Brigham Young University, Provo, UT 84602; phone (801) 422-3873, email: renea_beckstrand@byu.edu.

YES: I agree to participate in the Brigham Young University research study mentioned above. I confirm that I have read the preceding information and disclosure. I hereby give my informed consent for participation as described.

____ ____________________

Signature of Participant Date

____ ____________________

Signature of Witness Date

Appendix B

Tongan Words Used in Final Word Lists Listed Alphabetically

Along With English Translation and Part of Speech

Word	English translation	Part of speech
afi	fire	noun
aka	root	noun
ako	to study, learn; school	verb; noun
atu	toward	preposition
ava	to open; opening, hole	verb; noun
a'u	to reach	verb
efu	dust	noun
fahi	to chop, cut	verb
fala	mat	noun
fale	house	noun
fa'a	often, frequently	adverb
fa'ē	mother	noun
fa'u	make	verb
feke	octopus	noun
fesi	to break	verb
fiha	how much	adjective
foha	son	noun
fohi	to peel, scold	verb
foki	to return	verb
fonu	turtle	noun
fo'i	to lose, be defeated	verb
fuhu	to box; boxing	verb; noun
fuka	flag	noun
fusi	to pull	verb
haka	to cook, boil, dance with hands	verb
hele	knife	noun
helu	comb	noun
hia	crime, criminal	noun
hifo	to climb down, descend	verb
hoa	pair or partner	noun
hoka	to poke; billiard game	verb; noun
hola	to run away, escape, elope	verb

Word	English translation	Part of speech
holo	to wipe; hall, fallen tree, objects use to wipe	verb; noun
homo	loose	adjective
hopo	to jump, appear in court; trial	verb; noun
huo	to weed; spade	verb; noun
hu'a	coming in off the tide	verb
ifi	to smoke, blow	verb
ifo	delicious	adjective
ihu	nose	noun
ika	fish	noun
inu	to drink; drink	verb; noun
ipu	a cup	noun
ivi	energy, power, strength	noun
kai	to eat, score; score, point	verb; noun
kaka	to climb; brown fibrous cloth	verb; noun
kākā	to deceive; deception	verb; noun
kalo	to dodge, fake	verb
kato	basket	noun
kehe	different	adjective
keke	cake	noun
keli	to dig, plant yams	verb
kemo	eyebrow	noun
kete	stomach, gut	noun
ketu	lame	verb
kia	neck	noun
kili	skin	noun
koa	soap	noun
koe	you, yourself	pronoun
kofu	dress	noun
kokō	to squeal, bark; the squeal of an adult pig	verb; noun
kole	to ask (for something)	verb
kolo	goal, town, village	noun
konā	to be poisoned, drunk	verb
kote	coat	noun
kovi	bad	adjective
kui	grandparent	noun
kulī	dog	noun
kulo	pot	noun

Word	English translation	Part of speech
kumā	rat	noun
lahi	big, large, vast	adjective
laka	to step, march; pace, stride	verb; noun
laku	to throw, toss, cast off	verb
lalo	under, down, underneath	preposition
lanu	color	noun
lava	to be able	verb
la'ā	sun	noun
la'e	forehead	noun
lea	to talk; speech or language	verb; noun
leka	dwarf; small (term of endearment)	noun; adjective
lele	to run; race	verb; noun
lesi	papaya	noun
le'o	to guard; voice	verb; noun
limu	seaweed	noun
loka	to lock; padlock	verb; noun
loki	to surround; room	verb; noun
lole	candy or lollipop	noun
loli	truck	noun
lolo	to oppress; oil	verb; noun
lose	rose	noun
loto	center, core	noun
lotu	to attend church service; religion	verb; noun
lova	to race	verb
lua	vomit	noun
lue	to walk	verb
lulu	to shake	verb
luma	to mock; mockery	verb; noun
luo	hole	noun
lupe	pigeon, dove	noun
mafu	heart	noun
maka	rock, stone	noun
mali	to get married; wedding, spouse	verb; noun
mālō	thanks, congratulations	interjection; noun
malu	to be safe	verb
mama	to chew; ring	verb; noun
mana	thunder, power, supernatural power, miracle	noun

Word	English translation	Part of speech
manu	animal	noun
masi	match	noun
mata	face; front, front of	noun; preposition
mate	to die, faint; death	verb; noun
ma'a	clean, clear	adjective
misi	to dream; dream	verb; noun
mohe	to sleep	verb
moho	to be cooked, done	verb
moko	lizard	noun
mole	to lose (something)	verb
moli	orange	noun
momo	fine, ground up fine, broken into bits and pieces	adjective
monū	luck	noun
motu	to break in two; island	verb; noun
muli	foreigner, stranger; strange	noun; adjective
mu'a	front, ahead	adjective
namu	mosquito	noun
na'a	to stop crying	verb
nifo	tooth/teeth	noun
niu	coconut	noun
nusi	to wash with hands; a lei of 'kakala'	verb; noun
oli	funny	adjective
olo	to scrub	verb
oma	fast, rapid	adjective
ono	six	noun
paka	crab	noun
palu	to mix kava with water	verb
pamu	to pump; pump	verb; noun
pani	to anoint	verb
papa	wood, timber	noun
pasi	to clap; bus	verb; noun
pata	butter	noun
pato	duck	noun
patō	a tapping noise, thump	noun
pea	and, and then, and also	conjunction
pehē	to think, say	verb
peka	bat (flying fox)	noun

Word	English translation	Part of speech
peku	blunt, dull	adjective
pele	cards, a pet	noun
peni	pen	noun
pepa	paper	noun
pēpē	baby	noun
piki	to hold on to, grasp; scar	verb; noun
piko	bent, crooked	adjective
pīpī	turkey	noun
pito	navel, belly-button; full, over-flowing	noun; adjective
popo	rotten, withered, dried up	adjective
poto	frog, toad; smart	noun; adjective
puha	box	noun
puke	to be sick, hold; illness, small earth mounds	verb; noun
pulu	cow, beef	noun
puna	to jump	verb
pusi	cat	noun
putu	funeral	noun
sea	chair	noun
sino	body; fat	noun; adjective
sipi	blanket, sheep, mutton	noun
sisi	garland of flowers	noun
sivi	to test, examine; test, examination	verb; noun
soka	soccer	noun
sōkē	traditional dance with two sticks	noun
sosa	saucer	noun
sote	shirt	noun
suka	sugar	noun
Sune	June	noun
supo	soup	noun
tafi	to sweep	verb
tahi	ocean, sea	noun
tali	to answer, accept, receive	verb
talo	taro (tropical food plant)	noun
talu	since, ever since	conjunction/preposition
tanu	to bury, cover with earth	verb
tapu	prohibited, forbidden, sacred	adjective
tatā	hat	noun

Word	English translation	Part of speech
ta'o	to bake	verb
ta'u	year	noun
teke	to push away	verb
tele	to peel, take the skin off	verb
tete	to shake, tremble	verb
tohi	book, letter	noun
toli	to pick fruits	verb
tolo	to throw	verb
topu	tub	noun
toto	blood	noun
tufi	to pick up pieces or objects	verb
tuki	to punch, knock	verb
tuku	to quit, stop	verb
tuli	to chase, cast away; deaf	verb; adjective
tunu	to grill, cook on coal, barbeque, or spit	verb
tupu	gain, profit	noun
tu'a	back	noun
tu'o	how many times	adjective
tu'u	to stand	verb
ui	to call	verb
uku	to dive, wash	verb
unu	to dip into liquid	verb
vaka	boat	noun
vala	clothes	noun
vale	dumb, stupid	adjective
vave	rapid, rapidly, quick, quickly, fast	adverb
va'e	leg, foot, feet, wheel	noun
vela	hot, burnt	adjective
veve	rubbish, trash	noun
viku	wet	adjective
vilo	to rotate	verb
'afu	very warm, humid	adjective
'aho	day	noun
'ai	to apply	verb
'alu	to go	verb
'ave	to take	verb
'ea	air	noun

Word	English translation	Part of speech
'eva	to stroll, to visit	verb
'ilo	to find, know; knowledge	verb; noun
'ita	angry	adjective
'ofa	to love; love	verb; noun
'omi	to bring	verb
'osi	to finish	verb
'ota	shellfish, raw fish	noun
'uha	rain	noun
'uli	dirty	adjective
'ulu	head	noun
'uma	to kiss; a kiss	verb; noun
'uta	bush	noun
'uto	brain	noun
'utu	to fill (with liquid)	verb

Appendix C

Description of BYU Tongan Speech Audiometry Materials CD

Track 1 1 kHz calibration tone.

Track 2 Trisyllabic words for use in measuring the SRT in alphabetical order for familiarization purposes.

Track 3 Trisyllabic words for use in measuring the SRT in random order, repeated in blocks for a total duration of 5 minutes.

Track 4 Speech Discrimination List 1 – 50 bisyllabic words in random order.

Track 5 Speech Discrimination List 2 – 50 bisyllabic words in random order.

Track 6 Speech Discrimination List 3 – 50 bisyllabic words in random order.

Track 7 Speech Discrimination List 4 – 50 bisyllabic words in random order.

Track 8 Speech Discrimination List 1A – 25 bisyllabic words in random order.

Track 9 Speech Discrimination List 1B – 25 bisyllabic words in random order.

Track 10 Speech Discrimination List 2A – 25 bisyllabic words in random order.

Track 11 Speech Discrimination List 2B – 25 bisyllabic words in random order.

Track 12 Speech Discrimination List 3A – 25 bisyllabic words in random order.

Track 13 Speech Discrimination List 3B – 25 bisyllabic words in random order.

Track 14 Speech Discrimination List 4A – 25 bisyllabic words in random order.

Track 15 Speech Discrimination List 4B – 25 bisyllabic words in random order.

Tracks 16 – 24 contain Tongan recordings of routine instructions for various audiometric tests.

Track 16 Instructions for speech reception threshold-verbal response:

‘E fakalau atu ‘a e ngaahi fo’i lea taki taha fakale’o si’i pe a mo e fakale’o lahi. Kataki ‘o talamai ‘a e fo’i lea hili ho’o fanongo ki ai. Kapau na’e ‘ikai ke ke mahino’i pe fanongo lelei ki he fo’i lea, fai pe ho’o lelei taha ‘o tali kotoa ‘a e ngaahi fo’i lea.

You are going to hear a series of words that may vary in volume. Please repeat each word as soon as you hear it. If you are not sure of the word that you heard, you may guess.

Track 17 Instructions for speech discrimination-verbal response:

‘E fakalau atu ‘a e ngaahi fo’i lea taki taha. Kataki ‘o talamai ‘a e fo’i lea hili ho’o fanongo ki ai. Kapau na’e ‘ikai ke ke mahino’i pe fanongo lelei ki he fo’i lea, fai pe ho’o lelei taha ‘o tali kotoa ‘a e ngaahi fo’i lea.

You are going to hear a series of words that will be given at a constant volume. Please repeat each word as soon as you hear it. If you are not sure of the word that you heard, you may guess.

Track 18 Instructions for speech audiometry-masking in nontest ear-verbal response:

‘I he sivi ko ‘eni te ke fanongo ki he longoa’a ‘i he telinga ‘e taha pea ‘e fakalau atu ha fo’i lea ‘i he telinga ‘e taha. Kataki ‘o talamai ‘a e fo’i lea hili ho’o fanongo ki ai.

During this part of the test you will hear a noise in one ear and words in the other. Ignore the noise and repeat each word when you hear it.

Track 19 Instructions for speech audiometry-written response:

‘E fakalau atu ‘a e ngaahi fo’i lea taki taha. Kataki ‘o tohi ‘a e fo’i lea hili pe ho’o fanongo ki ai. Kapau na’e ‘ikai ke ke mahino’i pe fanongo lelei ki he fo’i lea fai pe ho’o lelei taha ‘o tali kotoa ‘a e ngaahi fo’i lea.

You are going to hear a series of words that will be given at a constant volume. Please write each word as soon as you hear it. If you are not sure of the word you heard, you may guess.

Track 20 Instructions for speech audiometry-masking in nontest ear-written response:

‘E fakalau atu ‘a e ngaahi fo’i lea fakafo’ituitui. ‘I he sivi ko ‘eni te ke fanongo ki he longoa’a ‘i he telinga ‘e taha pea ‘e fakalau atu ‘a e fo’i lea ‘i he telinga ‘e taha. Kataki ‘o tohi ‘a e fo’i lea hili pe ho’o fanongo ki ai.

During this part of the test you will hear noise in one ear and words in the other. Ignore the noise and write each word when you hear it.

Track 21 Instructions for pure-tone audiometry-hand raising:

Te ke fanongo ki ha ki’i me’a lea. Ko e taimi pe te ke fanongo ki he me’a lea ‘oku fiema’u k e ke hiki ho’o nima ki ‘olunga ‘o tuku ai ke ‘osi ‘a e lea ‘a e ki’i me’a lea pea ke tuku ho’o nima ki lalo. Kapau na’e ‘ikai ke ke mahino’i pe fanongo lelei, fai pe ho’o lelei taha ‘o hiki ho’o nima.

You are going to hear a series of sounds which will vary in pitch. When you hear the tone, immediately raise your hand. Put your hand down as soon as the sound goes off. Raise your hand if you think you hear the tone, even if you are not sure.

Track 22 Instructions for pure-tone audiometry-masking in nontest ear-hand raising:

‘I he sivi ko ‘eni te ke fanongo ki he longoa’a ‘i he telinga ‘e taha pea ‘e fakalea atu ha ki’i me’a lea‘i he telinga ‘e taha. Kataki ‘o hiki ho’o nima ‘i ho’o fanongo ki he ki’i me’a lea.

During this part of the test you will hear noise in one ear and tones in the other. Ignore the noise and raise your hand when you hear the tone.

Track 23 Instructions for pure-tone audiometry-button pressing:

‘I he sivi ko ‘eni te ke fanongo ki he ngaahi fo’i sauni kehe kehe. Hili ho’o fanongo ki he fo’i sauni pea ke lomi ‘a e me’a sivi. To’o ho’o nima mei he me’a sivi hili pe ‘a e ‘osi ‘a e fo’i sauni. Kapau na’e ‘ikai ke ke mahino’i pe fanongo lelei ki he fo’i sauni fai pe ho’o lelei taha ‘o lomi ‘a e ki’i me’a sivi ‘i he fo’i fehu’i taki taha.

You are going to hear a series of tones which will vary in pitch. When you hear a sound, immediately press the button. Stop pushing the button when the tone goes off. Push the button if you think you hear the sound, even if you are not sure.

Track 24 Instructions for pure-tone audiometry-masking in nontest ear-button pressing:

‘I he sivi ko ‘eni te ke fanongo ki he ngaahi fo’i sauni ‘i he telinga ‘e taha pea mo e longoa’a ‘i he telinga ‘e taha. Kataki ‘o lomi ‘a e ki’i me’a sivi hili pe ho’o fanongo ki he fo’i sauni.

During this part of the test you will hear noise in one ear and tones in the other. Ignore the noise and press the button when you hear a tone.

Track 25 Instructions for speech discrimination-verbal response:

Ko e sivi ko ‘eni ‘oku ne fakaha ho’o fanongo he taimi kotoa pe. Kataki ‘o fakalau mai ‘a e fo’i lea hili pe ho’o fanongo ki ai. Kapau na’e ‘ikai ke ke mahino’i pe fanongo lelei ki he fo’i lea, fai pe ho’o lelei taha ‘o tali ‘a e fehu’i.Kapau pe ‘oku ‘ikai ke ke ‘ilo pea ke tali leva ki he fo’i lea hoko.

The purpose of this test is to determine how well you can understand words when they are presented at a constant listening level. Each time you hear a word, just repeat it. If you are unsure of what the word was you may have to guess. If you did not understand the word, and you are not able to guess, please remain silent and wait for the next word.

Track 26 Instructions for speech audiometry-masking in nontest ear-verbal response:

‘I he sivi ko ‘eni te ke fanongo ki he longoa’a ‘i he telinga ‘e taha pea ‘e fakalau atu ‘a e fo’i lea ‘i he telinga ‘e taha. ‘Oua te ke tokanga ki he longoa’a ka ke fanongo fakalelei ki he fo’i lea. Hili pe ho’o fanongo ki he fo’i lea pea ke talamai leva ‘a e fo’i lea. Kapau na’e ‘ikai ke ke mahino’i pe fanongo lelei ki he fo’i lea, fai pe ho’o lelei taha ‘o tali ‘a e fehu’i.Kapau pe ‘oku ‘ikai ke ke ‘ilo pea ke tali leva ki he fo’i lea hoko.

During this part of the test you will hear a noise in one ear and words in the other. Do your best to ignore the noise and listen only to the words. Each time you hear a word, please repeat it. If you are unsure of what the word was you may have to guess. If you did not understand the word, and you are not able to guess, please remain silent and wait for the next word.

Track 27 Instructions for word recognition-written response:

Ko e sivi ko ‘eni ‘oku ne fakaha ho’o fanongo he taimi kotoa pe. Hili pe ho’o fanongo ki he lea taki taha kataki ‘o tohi ‘a e fo’i lea ‘i he pepa kuo ‘osi ‘oatu. Kapau na’e ‘ikai ke ke mahino’i pe fanongo lelei ki he fo’i lea, fai pe ho’o lelei taha.Kapau pe ‘oku ‘ikai ke ke mahino’i kataki ‘o kohi ha fo’i laini hangatonu ‘i he fika ko ia pea tali ki he lea hoko.

The purpose of this test is to determine how well you can understand words when they are presented at a constant listening level. Each time you hear a word, please write it down on the paper provided. If you are unsure of what the word was you may have to guess. If you did not understand the word, and you are not able to guess, please draw a line in the space provided and wait for the next word.