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Development of Tongan Materials for Determining Speech Recognition Thresholds

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DEVELOPMENT OF TONGAN MATERIALS FOR DETERMINING SPEECH RECOGNITION THRESHOLDS

by

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ABSTRACT

DEVELOPMENT OF TONGAN MATERIALS FOR DETERMINING SPEECH RECOGNITION THRESHOLD

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Speech recognition threshold (SRT) is an important clinical measure that validates the pure-tone average (PTA), assists in diagnosis and prognosis of hearing and hearing impairment, and helps identify non-organic hearing impairment. Few published, recorded, and standardized materials exist in languages other than English, which results in audiologists testing individuals using materials developed in a non-native language. Research shows that this is problematic, as certain criterion for SRT testing are not met. Thus, performance may reflect test-language deficiency rather than hearing impairment. Currently, there are no known published materials for use in measuring the SRT in individuals whose native language is Tongan. The purpose of this project was to record and develop psychometrically equivalent words in Tongan for measuring the SRT. This study identified 28 trisyllabic words that were relatively homogenous in relation to audibility and psychometric function slope. The intensity of these 28 words was adjusted

to equate 50% threshold performance for each word with the mean PTA (5.92 dB HL) for the twenty normally hearing participants. These materials were digitally recorded onto compact disc for distribution and use for SRT testing in Tongan.

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Introduction

Speech audiometry refers to a battery of testing procedures and protocols aimed at estimating an individual's ability to hear and understand speech. Understanding speech is critical for communication and natural interaction. Knowing an individual's threshold for speech is very beneficial for remediation. Researchers soon recognized the benefits of speech audiometry to identify and diagnose hearing impairment as well as validating pure-tone testing (Hirsh et al., 1952). Primitive forms of speech audiometry involved speaking or whispering to a person from a specified distance (American Speech-Language and Hearing Association; ASHA, 1988). As clinical audiology progressed, more accurate and reliable measures were developed, standardized, and validated, primarily in English. Thus, individuals that did not speak English or were non-native talkers were tested with English materials (Ramkissoon, 2001). Materials in other languages have been produced, but mostly in the last 10-20 years, and represent only a small portion of languages spoken throughout the world or in the United States Research has shown that traditional English materials, although reliable and valid for native English talkers, do not yield reliable results for non-native English talkers (Padilla, 2003; Ramkissoon, 2001). Since few materials have been developed in languages other than English, audiologists are compelled to test in English and interpret compromised test results. Better methods of testing non-native talkers in English have been proposed, but testing in the native language is preferred for the results to be accurate and relevant (McCullough, Wilson, Birck, & Anderson, 1994). The purpose of this project was to develop and digitally record materials in Tongan for measuring the speech recognition (or reception) threshold (SRT) for individuals whose native language is Tongan, and record those materials to compact disc for distribution.

Review of Literature

Development of Speech Audiometry

Early in the 20th century, audiologists realized the significance and importance of testing with speech to more closely resemble natural, real world experiences. Speech audiometry measures were soon found to have diagnostic and prognostic benefits, as well as validating pure-tone testing (Hirsh et al., 1952). The Western Electric 4A (later 4C) test, recorded in 1929, was the first widely-used clinical measure and consisted of recorded digits (ASHA, 1988; Fletcher & Steinberg, 1929). In 1947, Harvard's Psycho-Acoustic Laboratory (PAL) developed a set of spondaic word lists (Hudgins, Hawkins, Karlin, & Stevens, 1947). After complaints of variability and word difficulty on the PAL lists, the Central Institute for the Deaf (CID) modified the lists to create new standardized lists (CID Auditory Tests W-1 and W-2) which could be used for comparison (Hirsh et al., 1952). The PAL and CID lists included sentence and word stimuli and served as the foundation for the continued development of speech audiometry materials.

In 1948, Davis proposed using a combination of measures using speech stimuli to predict an individual's ability to hear speech. These two measures included a threshold of intelligibility and the ability to discriminate speech sounds at intensities well above the threshold (Davis, 1948). Thus, when the CID produced its lists in 1952, it did so with the goal of establishing these two basic measures (Hirsh et al., 1952), commonly known today as speech recognition threshold (SRT) and word recognition score (WRS).

Speech recognition threshold. The purpose of SRT testing is to determine an individual's hearing threshold for speech. Threshold is defined as the lowest intensity level a person can correctly identify at least 50% of the speech stimuli. A closed-set of spondaic words is the recommended stimulus for testing SRT in English (ASHA, 1988).

Closed-set refers to the fact that the listener is familiarized with the words beforehand; the words are thus predictable and possible error due to vocabulary limitations is minimized (Tillman & Olsen, 1973). A spondaic word is bisyllabic with equal stress on each syllable.

The current method of obtaining the SRT was derived from that described by Tillman and Olsen (1973). They proposed a 2-dB method (stimuli presented in 2-dB increments) for obtaining the SRT using an estimate of threshold or pure-tone-average (PTA; the average threshold at 500, 1000, & 2000 Hz). Martin and Stauffer (1975) suggested a slight modification that did not require previous pure-tone testing. Martin and Stauffer found the modification beneficial for hearing aid evaluations, testing children, and differentiating non-organic hearing impairment. Wilson, Morgan, and Dirks (1973) proposed a 5-dB method (stimuli presented in 5-dB increments) to accommodate audiometers incapable of adjusting intensity in 2-dB increments. Although Wilson et al. found statistically significant differences between the 2- and 5-dB methods (1.2 dB difference, $p < 0.01$), these differences were explained by interval size and determined to be clinically insignificant. Both methods have been approved by the American Speech-Language and Hearing Association (ASHA) for clinical use (ASHA, 1988).

The SRT may serve as a validation of the PTA (ASHA, 1988; Tillman & Olsen, 1973; Wilson et al., 1973). Each value can be used to estimate the other. As Martin and Stauffer (1975) suggested, this correlation is useful in identifying non-organic hearing impairment. The SRT is also used as a reference value for WRS and other testing, and in audiological rehabilitation, including hearing aid evaluation and prescription (ASHA, 1988).

Word recognition score. WRS is another form of testing used in speech audiometry to assist in diagnosis as well as provide information about hearing impairment in terms of social adequacy (Tillman & Olsen, 1973). WRS is often referred to as a suprathreshold measurement, because it is measured above threshold, where the individual can better understand speech. A presentation level is chosen at an intensity believed to adequately overcome the hearing impairment, usually 30 to 50 dB above the SRT (Epstein, 1978). Test stimuli typically include monosyllabic, phonetically balanced words which are not familiarized with the patient before testing (i.e. open-set). As words are presented, the patient repeats them back and the audiologist scores each as correct or incorrect, resulting in a percentage of correct words or a WRS. The WRS helps audiologists identify the type and extent of impairment. For example, normal hearing individuals' scores are expected to be between 90% and 100%, but may drop down to 80% (or lower in specific cases) for conductive impairments or to 0% for sensorineural impairments. Extremely low scores may indicate retrocochlear pathology (Gelfand, 2001).

Speech Recognition Threshold Test Materials

When Hudgins et al. (1947) developed the PAL lists, there were several factors they felt were essential for selecting words: familiarity, homogeneity, and phonetic dissimilarity. Recording specifications emerged in the course of additional research as another important factor. Any development of new materials should consider each of these issues before selecting and recording words.

Familiarity. Traditionally, phonetic discrimination was assumed to be the primary factor affecting word recognition testing. However, research has shown that familiarity is also important (Bell & Wilson, 2001; Dirks, Takayana, & Moshfegh, 2001; Kirk, Pisoni, & Miyamoto, 1997; Luce, 1986). Words used more frequently in the language (high-use) are generally more intelligible than words used less frequently (Bell & Wilson, 2001). Dirks et al. (2001) found that several lexical factors—frequency of occurrence, neighborhood density (number of phonemically similar words) and neighborhood frequency (frequency of occurrence of phonemically similar words)—contribute to accurate word recognition. Using these factors, words can be described as "lexically easy" or "lexically hard" (p. 233). Easy words are those that occur frequently and have low neighborhood density and frequency, and hard words occur less frequently and have high neighborhood density and frequency. Dirks et al. found that scores on easy words were, on average, 15% higher than performance on hard words. Kirk et al. (1997) also found the performance was lower for lexically difficult words.

Recommended testing procedures for the SRT require familiarization of the word list in order to account for word difficulty by insuring the patient is familiar with the vocabulary (ASHA, 1988). Strouse and Wilson (1999) found that if the patient is unsure about the test stimuli, performance can diminish. Besides the need for familiar words, stimuli within a list should also have the same degree of difficulty for the test to be maximally sensitive (Dillon, 1983).

Homogeneity. Homogeneity, or equivalence, can refer to individual test items or to the list of items as a whole. Homogeneity is achieved by matching difficulty and intelligibility as a function of intensity (Dillon, 1983). If equivalence is not achieved, individual scores across tests will vary, making it difficult to monitor change or compare performance to a normal distribution (Dillon, 1982). In addition, homogeneity of words increases the accuracy of the SRT and allows the SRT to be determined using fewer test stimuli (Young, Dudley, & Gunter, 1982). Rourke-Cullet, Ninya, and Nerbonne (1995) recommend selecting only items that are homogenous to include on a test list. Also, any background noise during testing will render lists inequivalent (Stockley & Green, 2000). Many researchers are concerned that recordings by male and female talkers would not be homogenous, but several studies have found that the gender of the talker does not contribute to any significant differences for both normal-hearing and hearing-impaired individuals (Cambron, Wilson, & Shanks, 1991; Penrod, 1979; Preece & Fowler, 1992).

A common method for determining homogeneity is by calculating psychometric performance-intensity functions for each word. It is important to know the rate a spondaic word becomes intelligible (psychometric performance-intensity function slope), because the 50% intelligibility level may vary from word to word (Young et al., 1982). Steep slopes on the psychometric performance-intensity function are indicative of homogeneity (Dillon, 1983; Wilson & Carter, 2001). With digital technology, words can be adjusted to equate audibility (threshold), resulting in less variability among words (Wilson & Strouse, 1999).

Phonetic dissimilarity. Ideally, speech testing should determine an individual’s hearing ability in everyday language situations, and therefore it is recommended that stimuli represent a normal distribution of phonemes in the language (Bell & Wilson, 2001; Hirsh et al., 1952). Research has shown that test scores improve when stimuli consist of phonetically dissimilar words (Bell & Wilson, 2001). Dirks et al. (2001) found that steeper slopes of psychometric performance-intensity functions could be achieved by using lexically easy words during testing, which are defined as words with a high frequency of occurrence in the language, but with a low number and frequency of phonemically similar words. The number and frequency of phonemically similar words is important as Luce (1986) found that high word frequency, alone, actually contributed to reduced recognition scores.

Recording procedures. In order to insure accuracy of test results and to compare results from person to person or among facilities, a standard, uniform method of instrument calibration must be used (Tucci, Ruth, Schoeny, Rupp, & Stockdell, 1980). These standards are important in producing digital recordings of test stimuli in order to maintain quality assurance within and across recordings.

Some audiologists feel that presenting the stimuli using monitored live voice (MLV) allows for more flexibility and is quicker, but MLV makes achieving homogeneity, with respect to performance, extremely difficult (ASHA, 1988; Stach, vis-Thaxton, & Jerger, 1995). Not only does MLV limit homogeneity, it is not standardized and requires carefully controlled vocal effort to maintain a consistent signal (Stach et al., 1995). Despite these limitations, approximately 90% of audiologists still use MLV for SRT testing (Martin, Champlin, & Chambers, 1998). Stach et al. (1995) recommend using a computer-based system to allow for more flexibility while taking advantage of the consistency of digital recordings. Using digital materials also reduces test time. ASHA recommends using recorded stimuli during speech audiometry testing (ASHA, 1988).

Speech Audiometry for Non-English Talkers

In 1998, only about 30% of audiologists reported fluently speaking a language other than English, and of those, only half of those conducted audiological testing in a language other than English. Those that only spoke English reported that testing was usually done in English, with a family member translating (Martin et al., 1998). This disparity is currently of concern among audiologists because any errors could be due to phonological limitations, an actual hearing impairment, or both. Thus, there is a great need for development of non-English test materials (McCullough et al., 1994).

Validity in non-native language. Familiarity is a critical element for developing word lists, but even this task has been difficult with regards to targeting native English talkers. Ensuring that a patient who is not a native English talker is familiar with the test stimuli is extremely complicated and not very valuable clinically (Rudmin, 1987), even among non-American English dialects (Wilson & Moodley, 2000). Initially, this obstacle was overcome by using English digits, as it was universally felt that digits would be the most familiar English words for a non-native talker. Several studies show that digits are a viable stimulus for SRT testing (Ramkissoon, Proctor, Lansing, & Bilger, 2002; Rudmin, 1987); digits are both familiar and highly intelligible. However, using digits creates a limited number of response foils for the individual being tested, which decreases the difficulty of the test, and subsequently, the sensitivity (Dillon, 1983). If test items are too familiar, the listener may become biased and have an increased likelihood of guessing correctly (Bell & Wilson, 2001).

Another method adopted, for the benefit of English speaking audiologists, is to use a picture identification response system. Rather than repeating the word, the patient would select a corresponding picture out of a small set. Some researchers found picture identification to be a legitimate alternative (Martin & Hart, 1978; McCullough et al., 1994), while others have not found this option to be promising (Owens, Benedict, & Schubert, 1971).

Non-native English talkers perform poorly on English test materials (Crandell & Smaldino, 1996; Padilla, 2003; Werker, Gilbert, Humphrey, & Tees, 1981), especially in noisy situations (von Hapsburg & Pena, 2002). In quiet situations, non-natives perform better on English tests (Padilla, 2003; von Hapsburg & Bahng, 2006), but significant differences can still be found at the sentence, word, and phonemic level (Padilla, 2003; Werker et al., 1981). However, for some individuals, situation and language use may cause a second language to become dominant over the native language. Research has yet to determine whether testing in the second language would be preferred for such individuals (von Hapsburg & Pena, 2002).

Materials developed in other languages. To date, materials have been developed in other languages, including Brazilian Portuguese (Harris, Goffi, Pedalini, Gygi, & Merrill, 2001; Harris, Goffi, Pedalini, Merrill, & Gygi, 2001), Polish (Harris, Nielson, McPherson, & Skarzynski, 2004a, 2004b), Spanish (Christensen, 1995), Japanese (Mangum, 2005), Korean (Harris, Kim, & Eggett, 2003a, 2003b), French (Nelson, 2004), Italian (Greer, 1997), Russian (Aleksandrovsky, McCullough, & Wilson, 1998; Harris, Nissen, Pola, McPherson, & Tavartkiladze, 2007; Pola, 2003), Arabic (Ashoor & Prochazka, 1985), Mandarin Chinese (Nissen, Harris, Jennings, Eggett, & Buck, 2005a, 2005b), Danish (Elberling, Ludvigsen, & Lyregaard, 1989), Greek (Iliadou, Fourakis, Vakalos, Hawks, & Kaprinis, 2006), and Cantonese (Lau & So, 1988).

Speech Audiometry in Tongan

There are no known published speech audiometry materials in Tongan. However, 130,000 Tongans live in the Kingdom of Tonga and another 28,000 in the United States, one-third of which report they do not speak English very well (Campbell, 2000; U.S. Census Bureau, 2005). Although many Tongans do speak English, the culture is essentially monolingual, as English is often used when talking to foreigners. Tongan is spoken at home and in cultural interactions (Moore, Leslie, & Lavis, 2005; Otsuka, 2007). Tongan culture, and Pacific culture in general, is family oriented. Cultural members feel profound kinship obligations to care and provide for each other, especially for elders and female relatives (Moore et al., 2005). This dynamic can also be seen in Tongan households, as about 50% of households contain one or more attached individuals (persons living in the household other than the spouse and/or children of the head[s] of household), more than 80% of which are relatives (Shulamit & Korn, 1975).

Views toward disabled persons vary greatly across Pacific cultures but generally follow a hierarchical structure. That is, the views and opinions of the people are influenced or determined by Royals, church or government officials, or elder relatives. Historically, cultural views of disability indicate that disabled persons are to be cared for, not (re)habilitated (National Health Committee, 2004). In Tonga, health care has shifted from traditional methods (spiritual intercession, herbal remedies, etc.) to more modern, biomedical treatment. Also, the government is undergoing a shift from monarchy to democracy, which in turn is encouraging more participation by government and the community in public health efforts (McGrath, 1999). The hierarchical view toward disability combined with a government push toward democracy and the associated public services may change views toward disabilities and (re)habilitation. The field of audiology is not well established in Tonga; however, the current trends may very well make it necessary in the future.

Nearly 60,000 Tongans live outside of the Kingdom of Tonga (McGrath, 1999). American culture does support the idea of *enabling the disabled*, as exemplified by many state and federal laws and regulations requiring services for individuals with disabilities and their families. While health services in the Kingdom of Tonga may not have progressed enough to need speech audiometry materials currently, the United States already has an established system of evaluation and treatment for hearing impairment. As native Tongan-talkers immigrate and acculturate to life in America, such materials may be desired and needed.

In a global context, Tongan is considered a minority language and is in danger of extinction due to cultural assimilation and socioeconomic ease of using another language to interact, typically English (Otsuka, 2007). While Tongan is still considered the "language of the home," (p. 464) Otsuka warns that Tongans, both within the homeland and without, need to take action to maintain the language amidst a growing push for globalization. Perhaps availability of materials for any public service, including speech audiometry materials, would aid in those efforts.

Tongan belongs to the Polynesian branch of the Austronesian (Malayo-Polynesian) language family. Other languages in the branch include Maori, Fijian, Hawaiian, and Samoan. It utilizes a standard Roman script and spelling is phonetic. There are 12 consonants and 10 vowels: five vowels with both short and long forms. The difference between short and long vowels is phonemic and, thus, changes the meaning of the word. Consonants include nasals, voiceless stops, liquids, and fricatives. Vowels do not co-occur (i.e. no diphthongs), but are pronounced individually. Words are generally made up of CV or CVV syllables (Anderson & Otsuka, 2006; Campbell, 2000), making the language vocalically rich. Generally, monosyllabic units have functional purposes in the language (e.g., pronouns, possessives, etc.) and are bound morphemes, only occurring attached to other morphemes such as nouns or verbs. Thus, monosyllabic words are rare (Churchward, 1953; Shumway, 1988).

In order for SRT results to accurately reflect an individual's threshold for speech perception, testing should be conducted in the native language. Otherwise, results may be influenced by language deficiency in the test language. As no known published speech audiometry materials exist in Tongan, and many Tongans live outside the Kingdom of Tonga, SRT materials in the native language are needed. In addition to more reliable and valid thresholds, such materials may assist in language maintenance as well as in the shift to increased and improved public health services in the Kingdom of Tonga.

Method

Participants

A total of 20 native talkers of Tongan participated in evaluating the materials developed in this study (8 male and 12 female). The subjects' ages ranged from 19 to 41 years with a mean age of 25.3 years (*SD* = 5.3 years). Participants had lived in the United States on average for 137.9 months, ranging from 14 to 324 months (*SD* = 116.3 months) and self-reported speaking Tongan daily. All of the participants in this study exhibited pure-tone air-conduction thresholds ≤15 dB HL at 125, 250, 500, 750, 1000, 1500, 2000, 3000, 4000, 6000, and 8000 Hz and had static acoustic admittance between 0.3 and 1.4 mmhos with peak pressure between -100 and +50 daPa (ASHA, 1990; Roup, Wiley, Safady, & Stoppenbach, 1998). In addition, each participant passed a screening exam, which included presence of an ipsilateral acoustic reflex of 95 dB HL or better in the test ear at 1000 Hz, and signed an informed consent form approved by the Brigham Young University Institutional Review Board for human subjects (IRB). The mean pure-tone average for the 20 participants was 5.92 dB HL. Descriptive statistics of the audiometric data for the 20 participants can be found in Table 1.

Materials

Word lists. Traditionally, the types of words used for SRT testing in English are bisyllabic; monosyllabic words are used for WRS testing. However, some languages have few, if any, monosyllabic words (e.g., Spanish, Portuguese, Italian, etc.). Materials developed in such languages report less steep psychometric performance-intensity function slopes for bisyllabic words than trisyllabic words (Harris, Goffi, Pedalini, Gygi et al., 2001; Harris, Goffi, Pedalini, Merrill et al., 2001; Nissen et al., 2005a, 2005b). Research involving development of SRT stimuli in these languages has shown

Table 1

Age (in years) and Pure-Tone Threshold (dB HL) Descriptive Statistics for the 20 Tongan Participants

Frequency (Hz)	*M*	*Minimum*	*Maximum*	*SD*
125 Hz	4.8	-5	15	5.0
250 Hz	3.8	-5	15	6.0
500 Hz	5.5	0	15	4.8
750 Hz	5.3	-5	15	6.4
1000 Hz	6.0	0	15	4.5
1500 Hz	7.5	0	15	3.8
2000 Hz	6.3	0	15	4.8
3000 Hz	6.8	0	15	3.7
4000 Hz	7.5	0	15	4.7
6000 Hz	7.5	0	15	4.4
8000 Hz	8.8	-5	15	6.9
PTA[a]	5.9	0.0	11.7	3.5

[a]PTA = arithmetic average of thresholds at 500, 1000, and 2000 Hz

psychometric performance-intensity function slopes on trisyllabic words to be as steep as slopes for English bisyllabic words (Harris & Christensen, 1996; Harris, Goffi, Pedalini, Gygi et al., 2001; Harris & Greer, 1997). As Tongan has very few monosyllabic words and steeper slopes are preferred to improve homogeneity, this project used trisyllabic words for development of SRT materials. A preliminary word corpus of 311 frequently used trisyllabic words was drawn from Shumway's *Intensive Course in Tongan* (1988). These words were rated by three native judges on a scale of 1 to 5 (1 = rarely used, 2 = infrequently used, 3 = somewhat familiar, 4 = very familiar, and 5 = extremely familiar) based on the how familiar a word would be to a native Tongan talker. Of the 311 number original trisyllabic words, 206 words were eliminated from final evaluation for the following reasons: (a) received a familiarity rating of ≤ 3 from the native judges, (b) thought to possibly represent inappropriate content, (c) have the same pronunciation but different meanings, or (d) thought to be culturally insensitive.

Talkers. Initial test recordings were made using seven native talkers of Tongan (three females and four males). All talkers originated from the country of Tonga. After the initial recordings were made, a panel of six native talkers evaluated the pronunciation of each of the seven talkers. The judges were asked to rank order the talkers from best to worst based on vocal quality, standard dialect, and pronunciation. The highest ranked male and female talkers were selected as the talkers for all subsequent recordings.

Recordings. All recordings were made in an 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, positioned approximately 15 cm from the talker at a 0° azimuth and covered by a 7.62 cm windscreen, was utilized for all recordings. The microphone signal was amplified by a Larson-Davis model PRM902 microphone preamp, which was coupled to a Larson-Davis model 2221 microphone preamplifier power supply. The signal was digitized using an Apogee AD-8000 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. The average long term spectrum was calculated for each talker.

During the recording sessions, the talker was asked to use normal vocal effort and to pronounce each trisyllabic word at least four times. The first and last repetitions of each word were excluded to avoid any possible list effects. A native judge then 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 evaluation portion of the study. Any words that were judged to be poorly recorded were rerecorded or eliminated from the study prior to listener evaluation. After the rating process, the intensity of each trisyllabic word to be included in the listener evaluation was edited as a single utterance using Sadie Disk Editor software (Studio Audio & Video Ltd, 2007) to yield the same level equivalent (Leq) as that of a 1 kHz calibration tone. Each word was saved as a 24-bit *wav* file.

Procedures

Custom software was used to control the randomization, presentation, and scoring of the trisyllabic words evaluated in the study. In addition, the custom software was also used to record the performance data. The signal was routed from a computer hard drive to the external input of a Grason Stadler model 1761 audiometer. The stimuli were then routed via a single TDH-50P headphone from the audiometer to the subject, who was seated in a double-walled sound suite meeting ANSI S3.1 standards (American National Standards Institute, 1999) for maximum permissible ambient noise levels for the ears not covered condition using one-third octave-band measurements. Prior to testing each subject, the inputs to the audiometer were calibrated to 0 VU using the 1 kHz calibration tone through customized computer software. In addition, the audiometer was calibrated regularly during and at the conclusion of data collection. Calibration was performed in accordance with ANSI S3.6 standards (American National Standards Institute, 2004). No changes in calibration were necessary throughout the course of data collection.

Each participant attended two test sessions after passing a hearing screening exam and was allowed to have several rest periods during each test session. The 90 trisyllabic words were presented to each listener once at each of 14 different intensity levels, beginning at -10 and ascending to 16 dB HL in 2 dB increments, with at least 2 s of silence between words. The sequence of the 90 trisyllabic words was randomized prior to presentation at each intensity level. Each subject listened to both the male and female talker recordings of the trisyllabic words, in a sequence determined randomly. Subjects repeated words verbally; reproductions were scored as being correct or incorrect by a native judge who spoke Tongan. Thus, the potential influence of learning effects was (a) reduced by the relatively large number of words evaluated by listeners, (b) the stimuli presented from low to high amplitude, and (c) the randomization of the presented stimulus items at each intensity level. Prior to the evaluation of the trisyllabic words, the following instructions were given:

You will hear trisyllabic words, which may become louder or softer in intensity. At the very soft levels it may be difficult for you to hear the words. Please repeat the words that you hear. If you are unsure of a word, you are encouraged to guess. If you have no guess, please be quiet and listen for the next word. Do you have any questions?

Results

After raw data were collected, logistic regression was used to obtain the regression slope and intercept for each of the 90 trisyllabic words. These values were then inserted into a modified logistic regression equation that was designed to calculate the percent correct at each intensity level. The original logistic regression equation is as follows:

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

In Equation 1, *p* is the proportion correct at any given intensity level, *a* is the regression slope, *b* is the regression intercept, and *i* is the intensity level in dB HL. When Equation 1 is solved for *p* and multiplied by 100, Equation 2 can then be calculated:

$$P = (1 - \frac{\exp(a + b \times i)}{1 + \exp(a + b \times i)}) * 100 \qquad (2)$$

In Equation 2, *P* is percentage of correct recognition, *a* is the regression intercept, *b* is the regression slope, and *i* is the presentation intensity in dB HL. By inserting the regression slope, regression intercept, and intensity level into Equation 2, it is possible to predict the percentage of correct recognition at any specified intensity level. Percentage of correct recognition was calculated for each of the trisyllabic words for a range of –10 to 16 dB HL in 1 dB increments.

In order to calculate the intensity level required for a given proportion, Equation 1 was solved for *i* (see Equation 2). By inserting the desired proportions into Equation 2, it is possible to calculate the threshold (the intensity required for 50% intelligibility), the slope (%/dB) at threshold, and the slope (%/dB) from 20 to 80% for each psychometric performance-intensity function. When solving for the threshold, Equation 2 can be simplified to Equation 3.

$$50\% \text{ threshold in } dB = \frac{-a}{b} \qquad (3)$$

Thresholds for the male talker of the 90 trisyllabic words ranged from 4.5 dB HL to 36.3 dB HL (M = 12.0), and for the female talker from 2.3 dB HL to 20.2 dB HL (M = 8.1). Psychometric performance-intensity functions were calculated for each trisyllabic word with Equation 2 using the logistic regression intercept and slope values. The slopes for the male talker at 50% ranged from 3.1 %/dB to 14.9 %/dB (M = 8.6) and from 4.4 %/dB to 14.5 %/dB (M = 8.1) for the female talker. The slopes from 20-80% ranged from 2.7 %/dB to 12.9 %/dB (M = 7.4) for the male talker and from 3.8 %/dB to 12.6 %/dB (M = 7.0) for the female talker. Thus, the slopes at 50% threshold were steeper compared to the slopes at 20-80%. Slopes of the psychometric performance-intensity functions and 50% thresholds for all trisyllabic words are presented in Table 2 (male talker) and Table 3 (female talker).

Because SRT test stimuli need to be relatively homogeneous with steep psychometric performance-intensity function slopes in order to reduce test time and improve reliability (Wilson & Strouse, 1999), only the words with the steepest psychometric performance-intensity function slopes for both the male and female talkers (≥ 7.0 %/dB for both male and female talkers) and with enough available headroom for adjustment (for both male and female talkers) were included in the final list of trisyllabic

Table 2

Mean Performance for 90 Tongan Male Trisyllabic SRT Words

#	Word	a[a]	b[b]	Slope at 50% [c]	Slope 20-80%[d]	Threshold[e]	ΔdB[f]
1	'āngelo	2.82427	-0.32056	8.0	6.9	8.8	2.9
2	'elelo	3.89263	-0.43754	10.9	9.5	8.9	3.0
3	'ikuna	4.91777	-0.37328	9.3	8.1	13.2	7.3
4	'ovava	3.14986	-0.38594	9.6	8.4	8.2	2.2
5	'olunga	4.20431	-0.37317	9.3	8.1	11.3	5.3
6	ako'i	4.28868	-0.35510	8.9	7.7	12.1	6.2
7	fā'ele	3.79424	-0.35297	8.8	7.6	10.7	4.8
8	fafanga	3.97398	-0.28792	7.2	6.2	13.8	7.9
9	faha'i	2.83437	-0.30604	7.7	6.6	9.3	3.3
10	fāhina	7.86004	-0.42712	10.7	9.2	18.4	12.5
11	fāmili	4.88508	-0.40393	10.1	8.7	12.1	6.2
12	fānoa	2.99816	-0.31645	7.9	6.8	9.5	3.6
13	fanongo	3.26777	-0.33002	8.3	7.1	9.9	4.0
14	fefeka	3.14373	-0.35287	8.8	7.6	8.9	3.0
15	fefine	5.09732	-0.36294	9.1	7.9	14.0	8.1
16	fehu'i	3.86366	-0.42430	10.6	9.2	9.1	3.2
17	feinga	6.11794	-0.58169	14.5	12.6	10.5	4.6
18	fepaki	3.46054	-0.35020	8.8	7.6	9.9	4.0
19	fofonu	2.48479	-0.18063	4.5	3.9	13.8	7.8
20	fonua	3.56493	-0.30962	7.7	6.7	11.5	5.6
21	fufulu	4.03527	-0.20889	5.2	4.5	19.3	13.4
22	hahake	2.83185	-0.24544	6.1	5.3	11.5	5.6
23	kakano	2.80446	-0.35316	8.8	7.6	7.9	2.0
24	kalapu	2.61432	-0.29258	7.3	6.3	8.9	3.0
25	kanisā	3.02017	-0.28656	7.2	6.2	10.5	4.6
26	kapusi	3.27364	-0.35463	8.9	7.7	9.2	3.3
27	kavenga	2.50342	-0.34355	8.6	7.4	7.3	1.4
28	kele'a	5.14416	-0.30662	7.7	6.6	16.8	10.9
29	kikite	4.61223	-0.32425	8.1	7.0	14.2	8.3
30	kilimi	5.51020	-0.25589	6.4	5.5	21.5	15.6
31	kolosi	2.98464	-0.33069	8.3	7.2	9.0	3.1
32	kulupu	3.93090	-0.24700	6.2	5.3	15.9	10.0
33	kumete	8.04433	-0.59512	14.9	12.9	13.5	7.6
34	kupenga	6.40606	-0.46104	11.5	10.0	13.9	8.0
35	kupesi	5.52354	-0.35274	8.8	7.6	15.7	9.7
36	lakanga	3.05555	-0.34711	8.7	7.5	8.8	2.9
37	lalanga	3.07776	-0.35402	8.9	7.7	8.7	2.8
38	lavea	2.05096	-0.41314	10.3	8.9	5.0	-1.0
39	loloto	2.28356	-0.34432	8.6	7.5	6.6	0.7
40	mafahi	2.95325	-0.23636	5.9	5.1	12.5	6.6
41	māfana	1.34901	-0.27653	6.9	6.0	4.9	-1.0
42	mahaki	2.90562	-0.37569	9.4	8.1	7.7	1.8

#	Word	a[a]	b[b]	Slope at 50% [c]	Slope 20-80%[d]	Threshold[e]	ΔdB[f]
43	maheu	3.17763	-0.29568	7.4	6.4	10.7	4.8
44	māhina	3.55041	-0.31504	7.9	6.8	11.3	5.3
45	mahino	3.74660	-0.31983	8.0	6.9	11.7	5.8
46	māketi	2.77111	-0.34902	8.7	7.6	7.9	2.0
47	mala'e	1.77078	-0.28550	7.1	6.2	6.2	0.3
48	malala	2.57225	-0.29153	7.3	6.3	8.8	2.9
49	mamafa	1.22017	-0.27157	6.8	5.9	4.5	-1.4
50	mamaha	2.29095	-0.29338	7.3	6.3	7.8	1.9
51	mamahi	2.87028	-0.36622	9.2	7.9	7.8	1.9
52	mātu'a	2.00462	-0.20677	5.2	4.5	9.7	3.8
53	meleni	4.80035	-0.33592	8.4	7.3	14.3	8.4
54	melino	6.29917	-0.47737	11.9	10.3	13.2	7.3
55	miniti	7.58917	-0.41489	10.4	9.0	18.3	12.4
56	mīsini	6.83543	-0.45238	11.3	9.8	15.1	9.2
57	mo'unga	5.25828	-0.39386	9.8	8.5	13.4	7.4
58	mofisi	5.20463	-0.41202	10.3	8.9	12.6	6.7
59	momoko	5.06759	-0.38564	9.6	8.3	13.1	7.2
60	mōtele	4.08528	-0.24983	6.2	5.4	16.4	10.4
61	nanamu	2.62271	-0.32611	8.2	7.1	8.0	2.1
62	ninimo	5.12825	-0.41328	10.3	8.9	12.4	6.5
63	ongo'i	3.28604	-0.37350	9.3	8.1	8.8	2.9
64	pa'anga	3.70986	-0.35226	8.8	7.6	10.5	4.6
65	pipiki	5.06759	-0.38564	9.6	8.3	13.1	7.2
66	polisi	3.80139	-0.32149	8.0	7.0	11.8	5.9
67	pupula	5.50530	-0.38407	9.6	8.3	14.3	8.4
68	sesele	6.34356	-0.40885	10.2	8.8	15.5	9.6
69	sila'i	5.43624	-0.41970	10.5	9.1	13.0	7.0
70	sipi'i	8.03090	-0.49709	12.4	10.8	16.2	10.2
71	sisina	7.14798	-0.45383	11.3	9.8	15.8	9.8
72	tafulu	4.33508	-0.23550	5.9	5.1	18.4	12.5
73	takafi	3.70886	-0.15141	3.8	3.3	24.5	18.6
74	tamatō	1.35902	-0.22561	5.6	4.9	6.0	0.1
75	tapaka	2.44682	-0.23055	5.8	5.0	10.6	4.7
76	tapeva	2.37243	-0.29941	7.5	6.5	7.9	2.0
77	tāpuni	2.64499	-0.25441	6.4	5.5	10.4	4.5
78	tata'o	2.72914	-0.28351	7.1	6.1	9.6	3.7
79	tatala	4.32097	-0.25849	6.5	5.6	16.7	10.8
80	tehina	6.66266	-0.40320	10.1	8.7	16.5	10.6
81	telinga	6.29208	-0.38139	9.5	8.3	16.5	10.6
82	tēpile	3.54628	-0.30121	7.5	6.5	11.8	5.9
83	tokanga	3.23389	-0.40654	10.2	8.8	8.0	2.0
84	tokoto	2.53369	-0.34758	8.7	7.5	7.3	1.4
85	totolo	5.68922	-0.50066	12.5	10.8	11.4	5.4
86	totonu	4.50273	-0.12394	3.1	2.7	36.3	30.4
87	tu'usi	3.76921	-0.36597	9.1	7.9	10.3	4.4
88	tutu'u	5.52975	-0.42737	10.7	9.2	12.9	7.0

#	Word	a[a]	b[b]	Slope at 50% [c]	Slope 20-80%[d]	Threshold[e]	ΔdB[f]
89	tutuku	4.37030	-0.24174	6.0	5.2	18.1	12.2
90	va'inga	4.81243	-0.39758	9.9	8.6	12.1	6.2
	M	4.03992	-0.34251	8.6	7.4	12.0	6.1
	Min	1.22017	-0.59512	3.1	2.7	4.5	-1.4
	Max	8.04433	-0.12394	14.9	12.9	36.3	30.4
	Range	6.82416	0.47118	11.8	10.2	31.8	31.8
	SD	1.57648	0.08334	2.1	1.8	4.6	4.6

[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 the threshold of a word to the mean PTA of the subjects (5.92 dB HL)

Table 3

Mean Performance for 90 Tongan Female Trisyllabic SRT Words

#	Word	a[a]	b[b]	Slope at 50% [c]	Slope 20-80%[d]	Threshold[e]	ΔdB[f]
1	'āngelo	4.08511	-0.39606	9.9	8.6	10.3	4.4
2	'elelo	2.82503	-0.36220	9.1	7.8	7.8	1.9
3	'ikuna	4.58932	-0.58104	14.5	12.6	7.9	2.0
4	'ovava	1.70554	-0.37836	9.5	8.2	4.5	-1.4
5	'olunga	3.63191	-0.42114	10.5	9.1	8.6	2.7
6	ako'i	2.86577	-0.40535	10.1	8.8	7.1	1.1
7	fā'ele	1.17774	-0.38298	9.6	8.3	3.1	-2.8
8	fafanga	2.61996	-0.23829	6.0	5.2	11.0	5.1
9	faha'i	2.47515	-0.42471	10.6	9.2	5.8	-0.1
10	fāhina	3.47532	-0.24637	6.2	5.3	14.1	8.2
11	fāmili	2.67502	-0.37322	9.3	8.1	7.2	1.2
12	fānoa	2.05825	-0.42183	10.5	9.1	4.9	-1.0
13	fanongo	1.46659	-0.43327	10.8	9.4	3.4	-2.5
14	fefeka	1.88828	-0.37439	9.4	8.1	5.0	-0.9
15	fefine	2.28084	-0.38604	9.7	8.4	5.9	0.0
16	fehu'i	2.26505	-0.29849	7.5	6.5	7.6	1.7
17	feinga	2.75435	-0.51481	12.9	11.1	5.4	-0.6
18	fepaki	3.08877	-0.37100	9.3	8.0	8.3	2.4
19	fofonu	1.61034	-0.33761	8.4	7.3	4.8	-1.2
20	fonua	2.34996	-0.36001	9.0	7.8	6.5	0.6
21	fufulu	1.43454	-0.22901	5.7	5.0	6.3	0.3
22	hahake	1.78499	-0.30645	7.7	6.6	5.8	-0.1
23	kakano	2.79700	-0.34903	8.7	7.6	8.0	2.1
24	kalapu	1.87685	-0.29482	7.4	6.4	6.4	0.4
25	kanisā	1.51993	-0.19960	5.0	4.3	7.6	1.7
26	kapusi	2.37923	-0.36436	9.1	7.9	6.5	0.6
27	kavenga	2.22581	-0.26894	6.7	5.8	8.3	2.4
28	kele'a	2.40609	-0.22171	5.5	4.8	10.9	4.9
29	kikite	2.77003	-0.18142	4.5	3.9	15.3	9.3
30	kilimi	3.23377	-0.22148	5.5	4.8	14.6	8.7
31	kolosi	2.30854	-0.34294	8.6	7.4	6.7	0.8
32	kulupu	2.68079	-0.20808	5.2	4.5	12.9	7.0
33	kumete	3.83943	-0.37525	9.4	8.1	10.2	4.3
34	kupenga	2.24764	-0.24268	6.1	5.3	9.3	3.3
35	kupesi	4.58672	-0.33920	8.5	7.3	13.5	7.6
36	lakanga	3.84793	-0.26621	6.7	5.8	14.5	8.5
37	lalanga	2.92240	-0.24107	6.0	5.2	12.1	6.2
38	lavea	1.80752	-0.34607	8.7	7.5	5.2	-0.7
39	loloto	1.39398	-0.31069	7.8	6.7	4.5	-1.4
40	mafahi	2.34468	-0.39636	9.9	8.6	5.9	0.0
41	māfana	0.95396	-0.38174	9.5	8.3	2.5	-3.4
42	mahaki	2.20513	-0.32798	8.2	7.1	6.7	0.8

#	Word	a[a]	b[b]	Slope at 50% [c]	Slope 20-80%[d]	Threshold[e]	ΔdB[f]
43	maheu	3.57934	-0.35247	8.8	7.6	10.2	4.2
44	māhina	1.31296	-0.30194	7.5	6.5	4.3	-1.6
45	mahino	2.22034	-0.37627	9.4	8.1	5.9	0.0
46	māketi	1.83070	-0.31934	8.0	6.9	5.7	-0.2
47	mala'e	1.61534	-0.35295	8.8	7.6	4.6	-1.3
48	malala	2.42766	-0.22095	5.5	4.8	11.0	5.1
49	mamafa	1.22886	-0.34569	8.6	7.5	3.6	-2.4
50	mamaha	1.20741	-0.23328	5.8	5.0	5.2	-0.7
51	mamahi	1.64159	-0.33650	8.4	7.3	4.9	-1.0
52	mātu'a	1.75953	-0.41577	10.4	9.0	4.2	-1.7
53	meleni	3.31390	-0.34029	8.5	7.4	9.7	3.8
54	melino	3.67049	-0.40580	10.1	8.8	9.0	3.1
55	miniti	5.48833	-0.27215	6.8	5.9	20.2	14.2
56	mīsini	4.45165	-0.36001	9.0	7.8	12.4	6.4
57	mo'unga	2.49457	-0.41364	10.3	9.0	6.0	0.1
58	mofisi	2.91719	-0.26934	6.7	5.8	10.8	4.9
59	momoko	2.43043	-0.42465	10.6	9.2	5.7	-0.2
60	mōtele	2.55193	-0.24703	6.2	5.3	10.3	4.4
61	nanamu	2.82262	-0.31330	7.8	6.8	9.0	3.1
62	ninimo	3.30060	-0.33491	8.4	7.2	9.9	3.9
63	ongo'i	2.07150	-0.34630	8.7	7.5	6.0	0.1
64	pa'anga	1.48539	-0.28462	7.1	6.2	5.2	-0.7
65	pipiki	5.12091	-0.39519	9.9	8.6	13.0	7.0
66	polisi	1.95882	-0.27021	6.8	5.8	7.2	1.3
67	pupula	3.43063	-0.22028	5.5	4.8	15.6	9.7
68	sesele	1.64664	-0.22012	5.5	4.8	7.5	1.6
69	sila'i	2.34373	-0.17406	4.4	3.8	13.5	7.5
70	sipi'i	3.93588	-0.23684	5.9	5.1	16.6	10.7
71	sisina	3.68843	-0.24271	6.1	5.3	15.2	9.3
72	tafulu	2.14556	-0.21771	5.4	4.7	9.9	3.9
73	takafi	3.00238	-0.28156	7.0	6.1	10.7	4.7
74	tamatō	1.12354	-0.29183	7.3	6.3	3.8	-2.1
75	tapaka	2.59579	-0.24853	6.2	5.4	10.4	4.5
76	tapeva	1.51818	-0.32732	8.2	7.1	4.6	-1.3
77	tāpuni	2.00403	-0.36670	9.2	7.9	5.5	-0.5
78	tata'o	0.78823	-0.34645	8.7	7.5	2.3	-3.6
79	tatala	2.32658	-0.32037	8.0	6.9	7.3	1.3
80	tehina	2.44370	-0.20757	5.2	4.5	11.8	5.9
81	telinga	3.36519	-0.28756	7.2	6.2	11.7	5.8
82	tēpile	2.06093	-0.40592	10.1	8.8	5.1	-0.8
83	tokanga	2.17008	-0.40245	10.1	8.7	5.4	-0.5
84	tokoto	0.91908	-0.30083	7.5	6.5	3.1	-2.9
85	totolo	1.82083	-0.35516	8.9	7.7	5.1	-0.8
86	totonu	3.07534	-0.32608	8.2	7.1	9.4	3.5
87	tu'usi	2.66557	-0.36136	9.0	7.8	7.4	1.5
88	tutu'u	1.55025	-0.26921	6.7	5.8	5.8	-0.2

#	Word	a[a]	b[b]	Slope at 50% [c]	Slope 20-80%[d]	Threshold[e]	ΔdB[f]
89	tutuku	3.20194	-0.39479	9.9	8.5	8.1	2.2
90	va'inga	1.98359	-0.26940	6.7	5.8	7.4	1.4
	M	2.49070	-0.32366	8.1	7.0	8.1	2.2
	Min	0.78823	-0.58104	4.4	3.8	2.3	-3.6
	Max	5.48833	-0.17406	14.5	12.6	20.2	14.2
	Range	4.70010	0.40698	10.2	8.8	17.9	17.9
	SD	0.95470	0.07554	1.9	1.6	3.6	3.6

[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 the threshold of a word to the mean PTA of the subjects (5.92 dB HL)

words. An additional six words were eliminated after being perceptually rated by four judges as too soft or too loud, resulting in a total of 28 selected words. The threshold, slope at threshold, and the slope from 20% to 80% for the 28 selected trisyllabic words are listed in Table 4 (male talker) and Table 5 (female talker). Figure 1 reveals less variability in the slope of the psychometric performance-intensity functions for the selected words (C-D) when compared to the complete list of 90 words (A-B). Figure 2 (male talker) and Figure 3 (female talker) contain the psychometric performance-intensity functions for each of the 28 words with the logistic regression slopes and intercepts (see Table 4 and Table 5) being used to fit the data. The composite psychometric performance-intensity functions for the selected words are shown in the middle panels (C-D) of Figure 1. The psychometric performance-intensity function slopes for the 28 selected words, at 50% threshold, ranged from 7.1 %/dB to 14.5 %/dB (M = 8.9) for the male talker recording and from 7.1 %/dB to 14.5 %/dB (M = 9.3) for the female talker.

To decrease additional variability existing across the thresholds of the final 28 words, the intensity of each was digitally adjusted so that the 50% threshold of each word was equal to the mean PTA of the subjects (5.92 dB HL). Adjustments for each selected word for the male and female talker recordings are presented in Table 4 (male talker) and Table 5 (female talker). The bottom panels of Figure 1 show predicted psychometric performance-intensity functions for the selected words after adjusting intensity to equate 50% thresholds for the male talker (E) and female talker (F). The mean psychometric performance-intensity functions for the selected words (both male and female talkers) are shown in Figure 4, demonstrating a slightly steeper mean slope for the female talker recordings (9.3 %/dB) compared to the male talker recordings (8.9 %/dB).

Table 4

Mean Performance for 28 Selected Tongan Male Trisyllabic SRT Words

#	Word	a[a]	b[b]	Slope at 50% [c]	Slope 20-80%[d]	Threshold[e]	ΔdB[f]
1	'āngelo	2.82427	-0.32056	8.0	6.9	8.8	2.9
2	'elelo	3.89263	-0.43754	10.9	9.5	8.9	3.0
3	'ikuna	4.91777	-0.37328	9.3	8.1	13.2	7.3
4	'ovava	3.14986	-0.38594	9.6	8.4	8.2	2.2
5	'olunga	4.20431	-0.37317	9.3	8.1	11.3	5.3
6	fā'ele	3.79424	-0.35297	8.8	7.6	10.7	4.8
7	fānoa	2.99816	-0.31645	7.9	6.8	9.5	3.6
8	fanongo	3.26777	-0.33002	8.3	7.1	9.9	4.0
9	fefeka	3.14373	-0.35287	8.8	7.6	8.9	3.0
10	feinga	6.11794	-0.58169	14.5	12.6	10.5	4.6
11	fonua	3.56493	-0.30962	7.7	6.7	11.5	5.6
12	kakano	2.80446	-0.35316	8.8	7.6	7.9	2.0
13	kalapu	2.61432	-0.29258	7.3	6.3	8.9	3.0
14	kolosi	2.98464	-0.33069	8.3	7.2	9.0	3.1
15	loloto	2.28356	-0.34432	8.6	7.5	6.6	0.7
16	mahaki	2.90562	-0.37569	9.4	8.1	7.7	1.8
17	māketi	2.77111	-0.34902	8.7	7.6	7.9	2.0
18	mala'e	1.77078	-0.28550	7.1	6.2	6.2	0.3
19	nanamu	2.62271	-0.32611	8.2	7.1	8.0	2.1
20	ongo'i	3.28604	-0.37350	9.3	8.1	8.8	2.9
21	pa'anga	3.70986	-0.35226	8.8	7.6	10.5	4.6
22	tapeva	2.37243	-0.29941	7.5	6.5	7.9	2.0
23	tata'o	2.72914	-0.28351	7.1	6.1	9.6	3.7
24	tēpile	3.54628	-0.30121	7.5	6.5	11.8	5.9
25	tokanga	3.23389	-0.40654	10.2	8.8	8.0	2.0
26	tokoto	2.53369	-0.34758	8.7	7.5	7.3	1.4
27	totolo	5.68922	-0.50066	12.5	10.8	11.4	5.4
28	tu'usi	3.76921	-0.36597	9.1	7.9	10.3	4.4
	M	3.33938	-0.35792	8.9	7.7	9.3	3.3
	Min	1.77078	-0.58169	7.1	6.1	6.2	0.3
	Max	6.11794	-0.28351	14.5	12.6	13.2	7.3
	Range	4.34716	0.29818	7.5	6.5	7.0	7.0
	SD	0.96953	0.06417	1.6	1.4	1.7	1.7

[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 the threshold of a word to the mean PTA of the subjects (5.92 dB HL)

Table 5

Mean Performance for 28 Selected Tongan Female Trisyllabic SRT Words

#	Word	a[a]	b[b]	Slope at 50% [c]	Slope 20-80%[d]	Threshold[e]	ΔdB[f]
1	'āngelo	4.08511	-0.39606	9.9	8.6	10.3	4.4
2	'elelo	2.82503	-0.36220	9.1	7.8	7.8	1.9
3	'ikuna	4.58932	-0.58104	14.5	12.6	7.9	2.0
4	'ovava	1.70554	-0.37836	9.5	8.2	4.5	-1.4
5	'olunga	3.63191	-0.42114	10.5	9.1	8.6	2.7
6	fā'ele	1.17774	-0.38298	9.6	8.3	3.1	-2.8
7	fānoa	2.05825	-0.42183	10.5	9.1	4.9	-1.0
8	fanongo	1.46659	-0.43327	10.8	9.4	3.4	-2.5
9	fefeka	1.88828	-0.37439	9.4	8.1	5.0	-0.9
10	feinga	2.75435	-0.51481	12.9	11.1	5.4	-0.6
11	fonua	2.34996	-0.36001	9.0	7.8	6.5	0.6
12	kakano	2.79700	-0.34903	8.7	7.6	8.0	2.1
13	kalapu	1.87685	-0.29482	7.4	6.4	6.4	0.4
14	kolosi	2.30854	-0.34294	8.6	7.4	6.7	0.8
15	loloto	1.39398	-0.31069	7.8	6.7	4.5	-1.4
16	mahaki	2.20513	-0.32798	8.2	7.1	6.7	0.8
17	māketi	1.83070	-0.31934	8.0	6.9	5.7	-0.2
18	mala'e	1.61534	-0.35295	8.8	7.6	4.6	-1.3
19	nanamu	2.82262	-0.31330	7.8	6.8	9.0	3.1
20	ongo'i	2.07150	-0.34630	8.7	7.5	6.0	0.1
21	pa'anga	1.48539	-0.28462	7.1	6.2	5.2	-0.7
22	tapeva	1.51818	-0.32732	8.2	7.1	4.6	-1.3
23	tata'o	0.78823	-0.34645	8.7	7.5	2.3	-3.6
24	tēpile	2.06093	-0.40592	10.1	8.8	5.1	-0.8
25	tokanga	2.17008	-0.40245	10.1	8.7	5.4	-0.5
26	tokoto	0.91908	-0.30083	7.5	6.5	3.1	-2.9
27	totolo	1.82083	-0.35516	8.9	7.7	5.1	-0.8
28	tu'usi	2.66557	-0.36136	9.0	7.8	7.4	1.5
	M	2.17436	-0.37027	9.3	8.0	5.8	-0.1
	Min	0.78823	-0.58104	7.1	6.2	2.3	-3.6
	Max	4.58932	-0.28462	14.5	12.6	10.3	4.4
	Range	3.80109	0.29642	7.4	6.4	8.0	8.0
	SD	0.88096	0.06433	1.6	1.4	1.9	1.9

[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 the threshold of a word to the mean PTA of the subjects (5.92 dB HL)

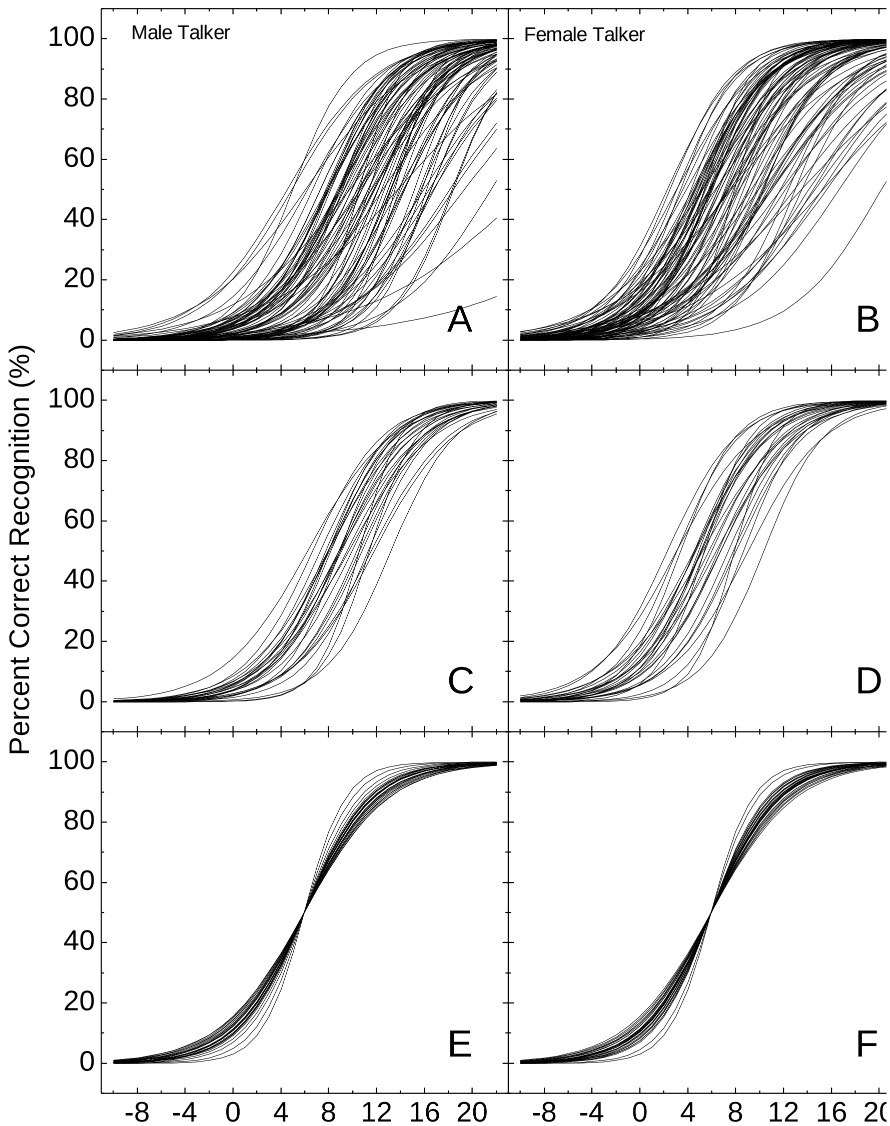

Figure 1. Psychometric functions for Tongan trisyllabic words for male talker (left panels) and female talker (right panels) recordings. All 90 unadjusted words (top panels A-B), 28 selected unadjusted words (middle panels C-D), and 28 selected adjusted words (bottom panels E-F). The 28 selected adjusted words were digitally adjusted to have 50% thresholds equal to the mean PTA (5.92 dB HL) for the 20 normally hearing subjects.

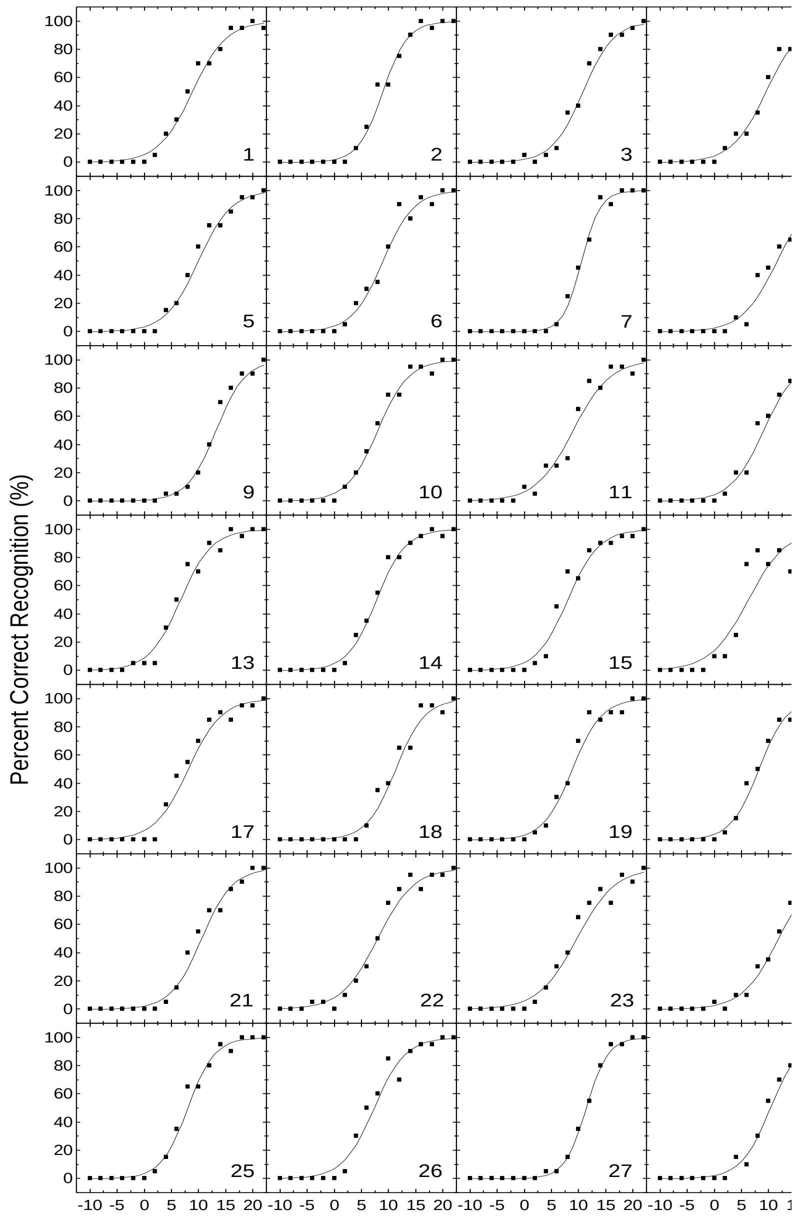

Figure 2. Psychometric functions for the 28 selected unadjusted Tongan trisyllabic words spoken by a male talker. The functions were calculated using logistic regression; the symbols represent mean percentage of correct recognition calculated from the raw data for 20 normally hearing subjects.

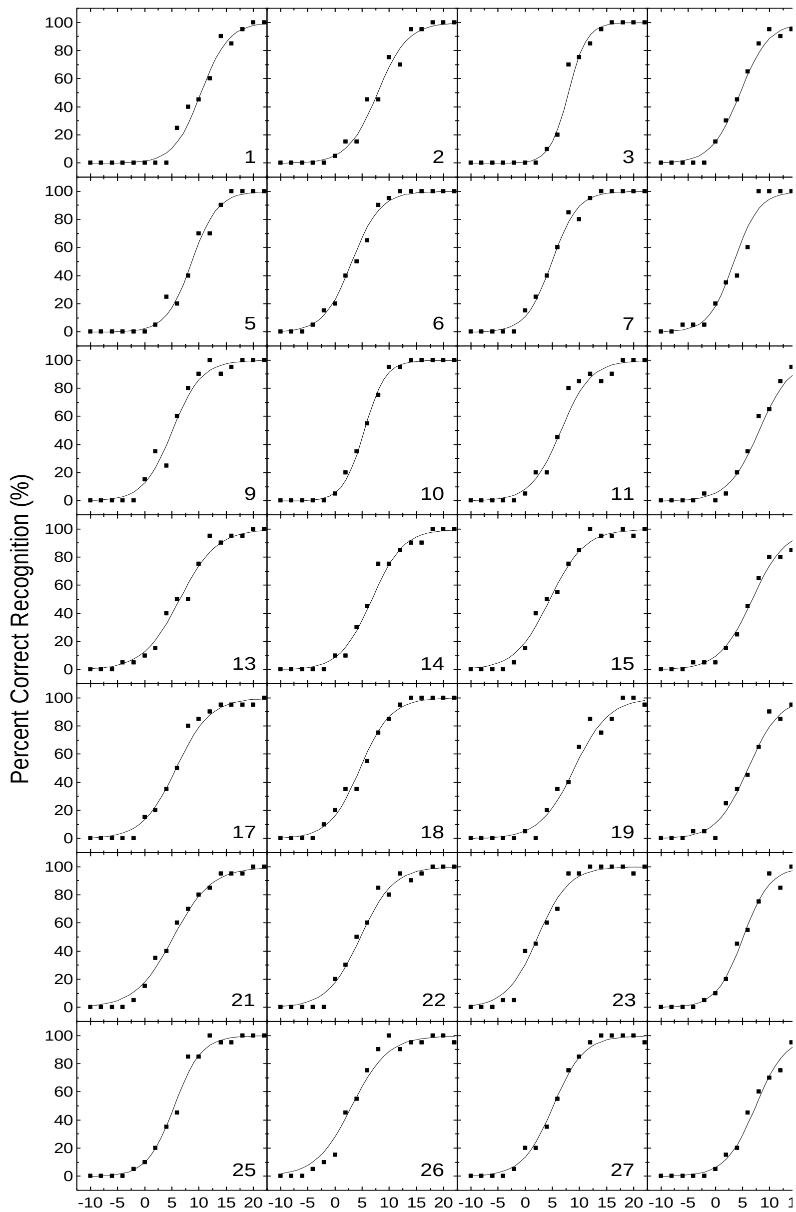

Figure 3. Psychometric functions for the 28 selected unadjusted Tongan trisyllabic words spoken by a female talker. The functions were calculated using logistic regression; the symbols represent mean percentage of correct recognition calculated from the raw data for 20 normally hearing subjects.

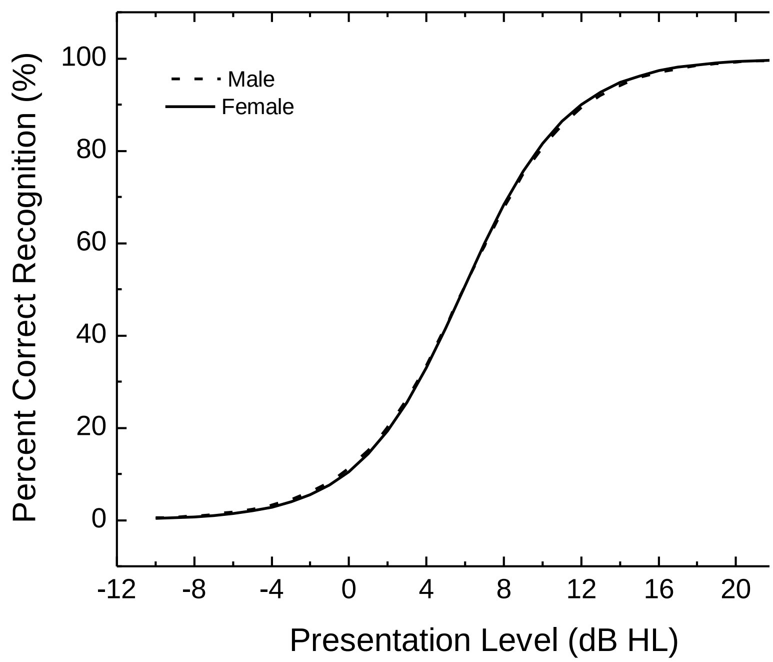

Figure 4. Mean psychometric functions for 28 selected Tongan male and female talker trisyllabic words after intensity adjustment to equate 50% threshold performance to the mean PTA (5.92 dB HL) for the 20 normally hearing subjects.

Discussion

The current study intended to digitally record, evaluate, and psychometrically equate SRT materials so audiologists may obtain more accurate results when testing individuals whose native language is Tongan. Such materials were produced and a final list was generated containing 28 trisyllabic words relatively homogeneous in performance with respect to audibility and psychometric performance-intensity function slope. These words were recorded by a male and a female native Tongan talker. A CD with digital recordings of the selected adjusted words was created for distribution.

The homogeneity of the 28 trisyllabic words, in terms of threshold audibility and psychometric performance-intensity function slope, is much greater after intensity adjustment than the original unadjusted words. The change in homogeneity of slopes after adjustment can be seen in the different panels of Figure 1. The mean slopes from 20 to 80% for the 28 trisyllabic words ranged from 6.1 to 12.6%/dB (M = 7.7) for the male talker and 6.2 to 12.6%/dB (M = 8.0) for the female talker. The mean slopes from 20 to 80% for the trisyllabic psychometric performance-intensity functions for both the male and female talkers are similar to the means reported for SRT materials in other languages. Mean slopes for the spondaic words used in English SRT testing have historically been reported between 7.2%/dB and 10%/dB (Hirsh et al., 1952; Hudgins et al., 1947). Some studies have reported the mean as high as 12%/dB (Beattie, Svihovec, & Edgerton, 1975; Ramkissoon, 2001). Materials developed in other languages also have comparable mean slopes to those in the present study. For example, the mean slopes for Portuguese SRT materials were 9.1 %/dB for a male talker and 8.8 %/dB for a female talker (Harris, Goffi, Pedalini, Gygi et al., 2001)**;** for Mandarin Chinese SRT materials mean slopes were reported to be 9.7%/dB and 10.5%/dB for a male and female talker respectively

(Nissen et al., 2005b); Arabic SRT materials demonstrated mean slopes of 8.0%/dB for the male talker (Ratcliff, 2006). Mean slopes for this project are slightly lower than those reported in several recent studies of similar methodology. A cause is unclear, but further investigation may indicate a direct relationship between perception and a specified factor, such as phonological characteristics of the language. Hoopingarner (2004) states that vowel perception is greatly influenced by context; words in this study were presented in isolation, without contextual cues, so Tongan's vocalic nature may have factored into the participants' performance. If not related to the vowel density, perhaps the decreased slopes are related to the limited number of consonants, which reduces the amount of phonemic dissimilarity within the language.

The process of developing speech audiometry materials is time consuming, but the benefits of standardized speech audiometry materials are worth the time spent identifying, recording, and evaluating materials. By following specified calibration, recording, and testing requirements, developers can adequately describe the physical properties of the stimulus, ensure accurate test results, and make valid inferences regarding an individual's hearing. Standardized materials also allow clinical information to be shared among facilities without compromising the validity of the test results (Tucci et al., 1980). On CD, standardized materials can be easily dispersed for use in many different clinical settings and allow audiologists to select specific test stimuli, randomize the presentation of stimuli, and decrease testing time.

Development of materials in additional languages is an important advance in the practice of audiology, but as these materials are the first created in the Tongan language, some aspects of reliability and validity are unknown. For example, additional research to determine the test-retest reliability of the selected stimuli would be important and beneficial to establish reliability, as well as validity (Ostergard, 1983). If the stimuli were tested again, results should be highly correlated with no significant differences for the test to be considered to have test-retest reliability (Gelfand, 1998).

Because this project was completed in the United States, all participants were bilingual or multilingual, minimally speaking both Tongan and English. It is unclear whether bilingualism has an effect on speech perception in the native language (von Hapsburg & Pena, 2002). Further research is needed to determine the effect of bilingualism. von Hapsburg and Pena suggest that future studies into bilingualism should control for time of second-language acquisition, type of bilingual (circumstantial or elective), language skills learned (reading, writing, speaking, etc.) and language use. If future research indicates that bilingualism does affect native-language speech perception, new materials may need to be developed controlling for bilingualism or using monolingual participants.

Also, it is important to extend the testing from individuals with normal hearing to individuals with hearing impairments to determine validity (i.e. does the measure appropriately distinguish a hearing impairment from normal hearing; Ostergard, 1983). Jerger (2006) points out the flaw of only testing stimuli on a population of normal hearing individuals, when the test is actually intended for use in another population (individuals with hearing impairment). McArdle and Wilson (2006) discovered that materials found to be homogenous when tested on individuals with normal hearing were not homogenous when tested on individuals with sensorineural hearing impairment, but demonstrated significant variability. Since the materials created in the present study are intended for use with the hearing impaired population, further testing on individuals with a hearing impairment whose primary language is Tongan should be conducted. Because Tongan is a heavily vocalic language (Shumway, 1988), and acoustic characteristics of vowels assist in consonant and word recognition (Delaney, 2005), results from a hearing-impaired population, especially with a typical high-frequency loss, may indicate improved scores compared to hearing-impaired individuals in a language that is proportionately less vocalic, such as English.

Especially in the United States, early intervention is considered to be critical in successful remediation of hearing impairment, but adult materials may inadequately reflect a child's receptive and expressive language abilities. Additional research should also address speech stimuli appropriate for testing children so that a child's communication may be related to hearing ability. Due to chronological age and language exposure, some children may be limited in receptive language ability, thus requiring alternate test stimuli appropriate for their language skills, especially vocabulary (Jerger, Jerger, & Abrams, 1983; Meyer & Pisoni, 1999). Also, receptive ability often exceeds expressive ability in young children, thus non-verbal response formats should be considered as an acceptable alternate procedure for SRT (and WRS) testing (Diefendorf, 1983). Pediatric tests utilizing picture identification for responses have been developed in the Spanish language, and subsequently tested for feasibility and reliability (Comstock & Martin, 1984; Martin & Hart, 1978). Materials using a non-verbal response also allow the test to be administered and scored by an audiologist who is not a native talker of the test language. However, if the adult test materials were administered to children to establish a set of pediatric norms, those materials could then be used with children until more appropriate pediatric materials were developed (Palva & Jokinen, 1975).

During data collection for the Tongan words, performance was noted to be better for the female talker recordings than the male talker recordings. It is unclear whether this difference was due to rate of speech, harmonic differences between male and female voices, or to the recording/editing of the words. This difference warrants further study to determine whether talker gender affects speech recognition in Tongan.

These suggestions for future research are in no way considered complete or exhaustive. The topic can be investigated further linguistically, acoustically, audiologically, and socio-perceptively.

In summary, this study resulted in the development of digitally recorded trisyllabic words by both male and female talkers, 28 of which are relatively homogeneous in relation to audibility and psychometric performance-intensity function slope. The threshold variability for the trisyllabic words was significantly reduced after intensity adjustments were made for the individual words. The 28 trisyllabic words can be used to measure SRT in individuals whose native language is Tongan and is available on a CD of digitally recorded materials. The description of the materials contained on the CD can be found in Appendix B.

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Appendix A

Informed Consent

Research Participation Form

Participant:____Age:____________________

You are asked to participate in a research study sponsored by the Department of Communication Disorders at Brigham Young University, Provo, Utah. The faculty directors of this research are Richard W. Harris, Ph.D and Shawn L. Nissen, Ph.D. Students in the Communication Disorders 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 to three 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 you 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, Utah 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

BYU Tongan Compact Disc Contents

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.
Track 4 Word recognition List 1 – 50 bisyllabic words in random order.
Track 5 Word recognition List 2 – 50 bisyllabic words in random order.
Track 6 Word recognition List 3 – 50 bisyllabic words in random order.
Track 7 Word recognition List 4 – 50 bisyllabic words in random order.
Track 8 Word recognition List 1A – 25 bisyllabic words in random order.
Track 9 Word recognition List 1B – 25 bisyllabic words in random order.
Track 10 Word recognition List 2A – 25 bisyllabic words in random order.
Track 11 Word recognition List 2B – 25 bisyllabic words in random order.
Track 12 Word recognition List 3A – 25 bisyllabic words in random order.
Track 13 Word recognition List 3B – 25 bisyllabic words in random order.
Track 14 Word recognition List 4A – 25 bisyllabic words in random order.
Track 15 Word recognition List 4B – 25 bisyllabic words in random order.
Track 16

‘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.

Instructions for speech reception threshold-verbal response: “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

‘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.

Instructions for speech discrimination-verbal response: “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

‘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.

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

‘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.

Instructions for speech audiometry-written response: “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

‘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.

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

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.

Instructions for pure-tone audiometry-hand raising: “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

‘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.

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

‘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.

Instructions for pure-tone audiometry-button pressing: “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

‘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.

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

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.

Instructions for speech discrimination-verbal response: “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

‘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.

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

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.

Instructions for word recognition-written response: “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.”

Appendix C

Selected Trisyllabic Word Definitions

	Word	Definition	Part of Speech
1	'āngelo	angel	noun
2	'elelo	tongue	noun
3	'ikuna	to win, conquer; victory	verb, noun
4	'ovava	tree genus	noun
5	'olunga	up (above)	adjective
6	fā'ele	give birth	verb
7	fānoa	hemorrhage, forty	noun, adjective
8	fanongo	listen, hear	verb
9	fefeka	hard, solid	adjective
10	feinga	try, effort	verb, noun
11	fonua	country	noun
12	kakano	flesh or meat	noun
13	kalapu	club	noun
14	kolosi	cross; to cross	noun, verb
15	loloto	deep	adjective
16	mahaki	sick, ill, illness	adjective, noun
17	māketi	market	noun
18	mala'e	field; open, grassy place	noun, adjective
19	nanamu	smelly, to smell, odor/aura	adjective, verb, noun
20	ongo'i	fell, hear	verb
21	pa'anga	money	noun
22	tapeva	sprain (an ankle)	verb
23	tata'o	touchdown; to press down upon	noun, verb
24	tēpile	table	noun
25	tokanga	to care, pay attention	verb
26	tokoto	to lie down	verb
27	totolo	crawling	verb
28	tu'usi	cut	noun