Psychometrically Equivalent Thai Monosyllabic Word Recognition Materials Spoken by Male and Female Talkers

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PSYCHOMETRICALLY EQUIVALENT THAI MONOSYLLABIC WORD
RECOGNITION MATERIALS SPOKEN BY MALE AND
FEMALE TALKERS

by
Chela Williams

A thesis submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of

Master of Science

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GRADUATE COMMITTEE APPROVAL

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This thesis has been read by each member of the following graduate committee and by majority vote has been found to be satisfactory.

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ABSTRACT

PSYCHOMETRICALLY EQUIVALENT THAI MONOSYLLABIC WORD RECOGNITION MATERIALS SPOKEN BY MALE AND FEMALE TALKERS

Chela Williams

Department of Communication Disorders

Master of Science

The purpose of this study was to develop, digitally record, evaluate, and psychometrically equate a set of Thai monosyllabic word lists to use in the measurement of word recognition ability. A native male and female talker from Thailand, who were judged to have a standard Thai dialect, participated as talkers in digitally recording familiar Thai monosyllabic words. Twenty native Thai participants were used as subjects to determine the percentage of correct word recognition for each word at 10 intensity levels ranging from –5 to 40 dB HL in 5 dB increments. The 200 words with the highest raw scores were included in the final word lists. Four lists of 50 words each were created and eight half-lists (25 words each) were created from the four lists. A chi-square analysis was performed, revealing no statistical differences among the lists and half-lists. The monosyllabic word data were analyzed using logistic regression to calculate threshold and slope for each list and half-list.
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I would like to express my great appreciation to all those who played a role in the process of this thesis. Dr. Harris and Dr. Nissen, thanks for all the guidance and patience. Lauren, thanks for working hard all the way to the end. Tan, thanks for staying sane while listening to the same words over and over again. Kris, thanks for putting up with a stressed out wife and for putting things in perspective for me. This thesis was definitely a team effort, and I had great support throughout the entirety of it.
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Review of Literature

*Review of Speech Audiometry*

Audiologic evaluations are comprised of a series of tests, which typically include pure-tone audiometry, acoustic immittance, and speech audiometry. Speech audiometry is a unique aspect of an audiologic evaluation, as it tests the listener’s responses to speech. This provides meaningful information concerning the impact a hearing impairment may have on the listener’s daily interactions. While pure-tone audiometry is important, “a test in which the subject strains to listen, against an absolutely silent background, for the least sign of a meaningless tone, is one which submits his auditory apparatus to a situation that has no obvious relevance to his ability to ‘hear’, using the term in its social sense” (Robinson, 1971, p. 2). In actuality we are not only concerned with our ability to hear tones, but with our ability to hear words and conversations. A test that provides information concerning the ability to receive and understand speech is a more practical measure of hearing and will be more meaningful to the patient (Robinson, 1971). Researchers have reported that 99% of audiologists use speech audiometry during an audiologic evaluation, further adding to the importance of these tests (Gelfand, 1998). Speech audiometry also aids in an audiologic evaluation by providing a means of cross checking the validity of the pure-tone thresholds (Smoski, 2005). Furthermore, speech audiometry can be used to rule out pseudohypoacusis (Cahart, 1965) and can be useful when selecting and programming hearing aids (Beattie & Zipp, 1990).

Two widely used tests of speech audiometry are speech reception threshold (SRT) testing and word recognition testing. Other names for SRT include speech recognition threshold or spondee recognition threshold. The SRT consists of a list of equivalent words that are either bisyllabic or trisyllabic, depending on the language being tested.
The intensity at which these words can be correctly identified 50% of the time determines the SRT (Ramkissoon, Proctor, Lansing, & Bilger, 2002). Research has found that there is a high correlation between the SRT and the PTA scores at 500, 1000, and 2000 Hz (Smoski, 2005). Comparing the SRT score to the PTA score is a way to double check the two scores. If the SRT and PTA are within 6 dB of each other, then there is good agreement. If the SRT and PTA vary by 13 dB or more, then Brandy (2002) recommends that one or both of the tests be repeated.

Finding the SRT involves specific procedures, however the examiner may need to adapt the procedures or the test stimuli in order to compensate for certain variables. Under normal circumstances, the patient repeats back the word to the examiner in order for the examiner to determine whether or not the word was heard correctly. Exceptions to this procedure occur when the patient has poor speech intelligibility, if the examiner has poor hearing, or if the talkback circuit is distorted. In such cases, alternatives include “(a) having the patient point to pictures representing the words, (b) having the patient write the word responses, or (c) obtaining speech detection threshold (SDT) in lieu of the SRT” (Brandy, 2002, p. 100). The SRT test is typically administered before the word recognition test, as it helps to determine the appropriate presentation levels for later suprathreshold word recognition tests.

Word recognition scores are also called word identification scores or speech discrimination scores. Word recognition scores are different from a listener’s SRT in several ways. The purpose of the word recognition test is to estimate the listener’s ability to understand and to “repeat single-syllable words presented at conversational or another suprathreshold level” (Smoski, 2005). While SRT stimuli typically utilize bisyllabic or
trisyllabic words, word recognition materials typically utilize monosyllabic or bisyllabic words. If a language contains monosyllabic words, like English, then monosyllabic words are commonly used. When a language does not contain monosyllabic words, bisyllabic words are used. Also, while the purpose of SRT is to find the lowest intensity level at which words can be repeated with 50% accuracy; the purpose of word recognition testing is to find a suprathreshold at which words can be repeated with maximum accuracy.

Word recognition testing typically consists of lists of 25 or 50 words, which are presented to the listener at an intensity level that is 30-40 dB above the SRT (Berger, 1971). In English, word recognition lists are made up of monosyllabic words, which are presented to the listener, who must then correctly repeat the words back. The test materials that are commonly used for the assessment of word recognition ability in the English language are the Central Institute for the Deaf (CID) W-22 and the Northwestern University Test No. 6 (NU-6) recordings (Wiley, Stoppenbach, Feldhake, Moss, & Thordardottir, 1995). The W-22 word lists were first developed as a means of assessing persons with hearing impairments (Hirsh et al., 1952). Four lists of 50 monosyllabic words make up the W-22 word lists. Initially, these word lists were reported to be inhomogeneous in terms of difficulty and familiarity. Researchers questioned the value of the test scores (Brewer & Resnick, 1983). Over the years, adjustments have been made to the W-22 word lists to increase accuracy and reliability. Currently, the W-22 is one of the most widely used tests of word recognition in English (Wiley et al., 1995). The NU-6 was first developed in 1963 in order to improve on the phonetic balance of current word lists and to create an overall more homogeneous set of word lists. The NU-6 at first only had 95 words, but was then expanded to include 200
words in 1966 (Tillman & Carhart, 1966). Currently, the NU-6 is composed of four monosyllabic word lists with 50 words in each list. Research has reported high reliability for the NU-6 (Brewer & Resnick, 1983).

Word recognition tests are important in an audiolologic evaluation because they can aid in the diagnosis of lesions within the central auditory system and are of rehabilitative value (Smoski, 2005). Word recognition tests can be used to provide useful information to patients who have or may need hearing aids. Word recognition tests can discern whether or not speech intelligibility is affected adversely when a hearing aid is used. It is possible that an intensity gain may not improve hearing because it results in a loss in discrimination (Cahart, 1965). Another advantage of word recognition tests is that they may help identify the specific phonemes a patient has difficulty hearing. Knowing the phonemes a patient has trouble hearing provides valuable information that may help with auditory rehabilitation. Thus, word recognition testing plays an important role in the assessment of normal and impaired hearing patients.

A third type of hearing screening test is called speech detection threshold (SDT) or speech awareness threshold (SAT). While this is a distinct test from word recognition testing, the same monosyllabic lists may be used. SDT determines the lowest intensity level at which the presence of speech can be identified. The listener does not repeat back the words, but will signal to the audiologist that speech has been perceived. The raising of a hand or clicking a button are the most common signals used to indicate perception of a word by a listener (Brandy, 2002).

Historically testing a patient’s ability to hear words consisted of speaking or whispering messages across measured distances (ASHA, 1990). Later, a test named the
Western Electric 4A was created and was the first widely used recorded auditory test. It consisted of a phonographic recording of spoken digits (ASHA, 1990). Campbell, in the 1920’s created a test that was used to calculate the efficiency of telephone sound-transmitting equipment. Campbell created 174 different lists, containing 50 nonsense syllables in each, which were used in the testing. These lists were known as the Standard Articulation Test and were used to evaluate hearing (Berger, 1971).

During World War II, another speech test was created and used for a similar purpose: to test various types of military communications equipment. These tests were developed at the Psycho-Acoustic Laboratory (PAL) at Harvard University and are known as the PAL Auditory Tests No. 9 and No. 12. The PAL Auditory Test No. 9 is made up of 50 words that measure the intelligibility threshold of spondaic words. The PAL Auditory Test No. 12 measures the intelligibility threshold of sentences. These tests were first clinically used in military rehabilitation centers and were later available in general clinical settings (Hirsh et al., 1952). While these tests contributed to the development of current speech audiometry materials, they lacked the consideration of specific variables which researchers now know are important when considering the development and use of speech materials for testing hearing ability. These variables include the number of test items, the type of response, the presentation mode, the use of a carrier phrase, the word selection, and the linguistic background of the patient.

Development of Speech Audiometry Materials

Word recognition tests typically consist of 50-word lists. However, recent investigations have found that the majority of audiologists presented only half of the list to the patient. In a study completed in 1978, Martin and Forbis found 16.6% of audiologists presented 50 words to all patients, 32.3% presented 25 words to all patients,
and 40.8% presented 25 words if the first 25 responses were correct. Martin and Morris completed a follow up survey in 1989 and found that only 5.9% of audiologists presented 50 words to all patients, 56.9% presented 25 words to all patients, and 24.8% presented 25 words if the first 25 responses were correct. These studies (Martin & Forbis, 1978; Martin & Morris, 1989) show a considerable decrease in the percent of audiologists who continued to use 50-word lists with all of their patients. The decreasing percentage of audiologists using the full 50-word lists has caused concern among the professional world, as audiologists were doing this to reduce clinic time and to avoid patient fatigue, but had not considered the clinical implications of that choice (Penrod, 1980).

Ramkissoon et al. (2002) reported that word lists should not be reduced for convenience. The number of words presented to a patient is important because the variability of scores is inversely related to the number of items in the test (Wiley et al., 1995). As the number of test items decrease, the variability of the score increases, leading to a lower reliability and confidence level.

There have been several studies over the years, which have addressed the growing trend of using half-lists in place of the full-lists. In 1961, Elpern reported high correlations between half vs. full-list word recognition scores. Elpern concluded that shortened lists appeared to be as accurate as the complete 50-item lists. In 1980, Penrod carried out a study in which he found that the half-list scores he obtained from elderly patients appeared to be within 6 to 10 percentage points of the full-list scores. A study by Runge and Hosford-Dunn (1985) suggested that if the 25 words used are more difficult and if strict screening criteria were used to determine whether or not additional items should be administered, then it is appropriate to use 25-word lists. However, the choice of
using a half- or full-list still relies heavily on the individual and variable judgments of each audiologist. In order to follow these two guidelines, a standard would need to be agreed upon by audiologists, in order to provide consistency and greater inter-judge reliability. Hagerman (1976) addresses the issue of whether or not additional items should be administered. Hagerman suggests that 25-word lists may be used if the patient has a maximum of one error. Otherwise, the 50-word lists should be used. From the many studies that have been conducted on this subject, there is now a general consensus that using 25-word lists can be substituted for the 50-item lists (Resnick, 1962).

A second variable to consider is the type of list set that is presented to the listener. The lists can be an open set or a closed set. An open set does not provide the listener with any possible responses. The listener must depend solely on his or her own familiarity with the test words. Well-known open set tests include the CID W-22 word lists and the NU-6 word lists. A closed set test is a multiple-choice test where the listener is given a finite number of response alternatives. These responses can be either written words or pictures. If the responses are in written form, it is important to ensure that the listener has adequate reading and spelling skills. Commonly used closed set tests include the Rhyme Test (Fairbanks, 1958), the Modified Rhyme Test (House, Williams, Hecker, Kryter, 1965), Rhyming Minimal Contrast Lists (Griffiths, 1967), and the Multiple Choice Discrimination Test (Schultz & Schubert, 1969). Closed set tests promote better discrimination scores, as it allows for more accurate guessing than an open response test allows.

A third variable that must be considered is the presentation mode to be used. The two common options available to audiologists are monitored live voice (MLV) and
recorded presentation of stimuli. In 1988, the American Speech-Language and Hearing Association stated that the preferred presentation mode is a recorded presentation of the test material. However, a 1989 survey by Martin and Morris found that 70.3% of audiologists surveyed continued to use MLV. The advantages of MLV include greater flexibility and reduced testing time (Brandy, 2002). Audiologists have greater flexibility to control the rate of presentation, to change the rate of presentation, to randomize the lists, and to randomize the words within a list (Stach, Davis-Thaxton, & Jerger, 1995).

Several articles discuss the limitations of MLV and the advantages of recorded test materials (Brandy, 1966; Brandy, 2002; Wiley et al., 1995). The main limitation of MLV is that the speech signal will be variable in its acoustic composition each time that it is presented. MLV is not standardized. Speakers will not be able to produce the words in the same manner to each patient. This leads to greater variability in the vocal intensity, pitch, articulation, individual dialect, and speaking rate. A common error made among audiologists who use MLV is using a strong upward inflection on the second syllable of bisyllabic words (Brandy, 2002). The words from the word lists need to be presented in the same manner in order to ensure accuracy and reliability of testing.

In 1966, Brandy assessed the impact of multiple readings of specific word lists on the consistency of a speaker’s acoustic signal. Brandy’s question was whether or not a talker could produce the same acoustic signal when given time to practice reading and saying the test words. Brandy found that talkers were not able to produce the same acoustic signal on successive readings of a given printed word. Thus, practice of the words read may not ensure consistency.
Using recorded test materials ensures that the presentation of the acoustic signal is the same for every patient. This mode of presentation also allows for editing of the words, in order to provide the best recording possible. The ability to control the acoustic presentation of the test materials allows for greater validity and reliability. Standardized presentation of speech audiometry materials is only possible if recorded materials are used (Wiley et al., 1995).

If using MLV, the use of a carrier phrase is another variable that may affect test results. A carrier phrase is a phrase that is spoken before the test word and is supposed to serve two purposes: to alert the patient to the task and to ensure the speaker uses the proper intensity. Some common carrier phrases are say the word and you will say, followed by the test word (Gladstone & Siegenthaler, 1971). The specific content of the carrier phrase is not important. When presenting word lists via MLV, an audiologist can monitor the VU meter during the carrier phrase in order to speak the word at the proper intensity. Martin, Hawkins, and Bailey (1962) found no significant difference in test scores if a carrier phrase was or was not used. However, other studies have found differences. Gladstone and Siegenthaler (1971) and Gelfand (1975) found that patients had poorer word recognition scores when a carrier phrase was not used, compared to when a carrier phrase was used. However, the use of a carrier phrase can also worsen the scores by affecting the phonemic interaction with the test word (Gladstone & Siegenthaler, 1971). Saying the test word in a phrase causes phonemic interaction of the phrase and the test word, resulting in different degrees of intelligibility. The phonemic interactions may vary depending on what carrier phrase is used. Recorded test materials eliminate the need for a carrier phrase and provide for greater consistency among tests.
Word selection is an additional variable of great importance to the construction of word lists for word recognition tests. Other than the number of syllables, specific criteria are involved for word selection. One of these criteria is that the words should be familiar. Conn, Dancer, & Ventry (1975) found that there are significantly more correct responses and significantly fewer error responses to familiar words. Conn et al. suggested that nonsense syllables should be used in such tests, meaning none of the words would be familiar to the listener. The PAL Auditory Test No. 9 word lists, developed at Harvard during World War II, contained many unfamiliar words and therefore confused many patients (Conn et al., 1975). The PAL Auditory Test No. 9 word lists were later changed so that they would be more suitable for the general population. Another important factor of word selection is that the word lists should be a representative sample of the language’s phonetic makeup. This means that all the sounds used in a language should be included in the word lists.

It is important to consider the linguistic background of the patient so that the test results will be better suited for the specific client. As stated previously, unfamiliar test items will make the test more difficult and familiar test items will make the test easier. Cahart (1965) reported that a clinician must be aware of when words become nonsense items for the patient. Cahart affirms that this sometimes happens with children. When testing children, audiologists should use specific word lists that are familiar to children. If such a list is not readily available, an audiologist may hand select easier words from SRT and word recognition word lists if no suitable word lists are available (Brandy, 2002). A clinician should also be alert to when words become nonsense items for a patient who speaks English as a second language. Unfamiliar words to a non-native speaker of
English will have the same negative effect seen with native speakers of English and nonsense syllables. Instead of solely testing the patient’s ability to perceive speech, the audiologist would also be testing the patient’s knowledge of familiar words in the English language. A patient who has limited mastery of the English language will have significantly worse word recognition scores if the administered tests are in English. In order to ensure accuracy and reliability, a word recognition test should be administered to the patient in their native language.

Speech Audiometry in Thai

While many English speech audiometry materials are readily available to audiologists, materials in foreign languages are more difficult to come by. In recent years, speech audiometry materials have been developed in many different languages. However, an extensive review has found limited information on Thai speech audiometry materials and no published recorded materials. The U.S. Census Bureau (2000) reported 150,283 native Thai people living in the United States. The World Fact Book (2006) reports that approximately 65 million people live in Thailand as of July 2006, ranking Thailand 21st in the world’s population. These numbers indicate that there is a need for Thai speech audiometry materials to evaluate the hearing abilities of individuals within the United States and throughout the world.

The Thai Language

Thai is the official language of Thailand and is the most important member of the Tai language family (Smyth, 2002, p.1). Standard Thai is considered to be “the language used by the educated, middle class population in the central region of Thailand, particularly in Bangkok” (Iwasaki & Ingkaphirom, 2005, p. 1). However, there are a total of four main dialects of Thai that all differ in tone and phonological aspects (Campbell,
1991). Standard Thai, one of the four main dialects, is the native language of approximately 19.5% of the population of Thailand. However, Standard Thai is nevertheless widely understood and used due to its use in school and in the media (Iwasaki & Ingkaphirom, 2005). Government affairs, political activity, cultural activity, and public speeches are also conducted in Standard Thai (Smalley, 1994). While only 19.5% of the population of Thailand claims Standard Thai as their native language, the majority of the population is exposed to Standard Thai and can understand it.

Thai is a tonal language, meaning it uses different tones to distinguish between words. Tone is a key element of the Thai language, as the same sequence of phonemes can have different meanings, if produced with different tones. The tones may differ on some words depending on the social setting: formal or conversational (Smalley, 1994). Every syllable in Thai has one of five phonemic tones (Comrie, 1987). These tones are defined as middle, low, falling, high, and rising. The tones are labeled to describe the characteristics of their fundamental frequency shape. These tones can be divided into two groups: level or static tones and contour or dynamic tones (Teeranon, 2002). The middle, low, and high tones make up the level tone category. The falling and rising tones make up the contour tones. The five Thai tones can also be divided into two additional groups, based on the rising or falling pattern of the fundamental frequency. The high tone and the rising tone belong to the upward trend group. The mid tone, low tone, and falling tone belong to the downward trend group (Chomphan & Kobayashi, 2008). For typical Thai morphemes, C1VC2, the tones are determined by the following factors: class of C1 consonant, presence or absence of a tone marker, vowel length, and the nature of C2 (Campbell, 1991).
The morphology and phonology of Thai is also worth noting. Standard Thai, as described in English, is comprised of 21 single consonants: b, c, cʰ, d, f, h, j, k, kʰ, l, m, n, ɳ, p, pʰ, r, s, t, tʰ, w, ʔ; and 12 double consonants: kʰl, kʰr, kʰw, kl, kr, kw, pʰl, pʰr, pl, pr, tʰr, tr (Iwasaki & Ingkaphirom, 2005; Kasuriya, Kanokphara, Thatphithakkul, Cotsomrong, & Sunpethniyom, 2004). All 21 consonants can appear in initial position, but only a limited few may appear in final position. No consonant clusters appear in the final position. Standard Thai also contains 24 vowels: a, aː, i, iː, iː, ia, iaː, iː, iaː, e, eː, o, oː, u, uː, ua, uaː, æ, æː, ɔ, ɔː, ɔː (Iwasaki & Ingkaphirom, 2005; Kasuriya, Kanokphara, Thatphithakkul, Cotsomrong, & Sunpethniyom, 2004). The vowels used in Standard Thai have great flexibility. All of the vowels can appear alone, with an initial consonant, with a final consonant, or with an initial and final consonant (Comrie, 1987). Vowels can be short, long, or combined with other vowels to form a diphthong.

The basic syllabic structure in Thai includes a vowel, a consonant, and a suprasegmental tone. However, the only required elements of a syllable are a vowel and a tone. Syllables can be divided into two types: live syllables and dead syllables (Iwasaki & Ingkaphirom, 2005). Live syllables end in vowels, glides, or nasals, and dead syllables end with a stop consonant. These two types of syllables influence the tone that is used.

Concerning syntax, the basic word order of a Thai sentence is subject-verb-object. Nouns are one of the largest classes of words in the vocabulary, other than verbs. Thai nouns can be either monosyllabic or polysyllabic. Verbs can also be both monosyllabic and polysyllabic. Adjectives usually follow a noun. Pronouns in Thai are complex because acceptable forms depend upon sex, age, social position, kinship terms, and the attitude of the speaker toward the addressee (Comrie, 1987).
The current practice of testing speech perception for non-native speakers of English is to use the most familiar words in a word recognition word list or to use digits instead of words (Ramkissoon et al., 2002). Modifying the test is an unreliable way to test and is not based on research and data. Using digits presents many drawbacks, as it incorporates a limited amount of phonemes and it does not represent the range of phonemes in a non-English speaker’s native phonology. It also does not ensure familiarity with the words, even though digits are more commonly used than other vocabulary words. Using digits as test stimuli may also have the capability to inflate the word recognition scores as it creates a closed response test. Hapsburg & Peña (2002) state that results in the area of multilingual speech audiometry do not agree on what the most accurate method of testing is and audiologists are still unsure of how to provide services to non-English speakers. ASHA (1988) gives the guidelines that the specific wording of the instructions must be given in the language appropriate for the client. Following this guideline, it is important to give instructions to a client in the language that is most familiar to them. Speech audiometry materials need to be created for non-English speakers in order to provide more standardized results.

Purpose of Study

The goal of the present study is to create psychometrically equivalent Thai monosyllabic word lists that will follow the specific criteria aforementioned. The word lists have been comprised of familiar Thai words. A male and female from Thailand were selected to be talkers for the study. Word recognition materials were recorded onto a CD that is available for audiologists upon request. The development of these materials has taken into account the specific characteristics of the Thai language to produce lists for accurate word recognition testing for patients whose native language is Thai. Word
recognition tests produced specifically for the Thai population will help to accurately test word recognition ability of a Thai speaker.

Method

Participants

A total of 20 native speakers of Thai, who were born in Thailand, participated in evaluating the monosyllabic words for this study. All of the participants exhibited pure-tone air-conduction thresholds ≤15 dB HL at octave and mid-octave frequencies from 125 to 8000 Hz and had a static acoustic admittance between 0.3 and 1.4 mmhos with peak pressure between -100 and +50 daPa (ASHA, 1990). Table 1 displays a summary of the participant thresholds.

Materials

Word lists. Monosyllabic Thai words were selected as the stimuli for word recognition testing. Words were selected from an electronic word corpus of Thai. Initially, 500 words were selected for recording, avoiding words with the same pronunciation but different meanings. From the 500 monosyllabic words that were initially selected, 250 words were selected for evaluation in this study. Any words that were judged to be culturally insensitive, considered to be unfamiliar by native judges, or thought to possibly represent inappropriate content were eliminated from the study prior to listener evaluation. This was completed using three native speakers who rated all the words on a scale of 1 to 5 based on the how familiar a word would be to a Thai speaker from Thailand (1 = extremely familiar, 2 = very familiar, 3 = somewhat familiar, 4 = infrequently used, and 5 = rarely used). Only those words which received a ranking of 1 or 2 were used in the study.
Table 1
*Age (years) and Pure Tone Threshold (dB HL) Descriptive Statistics for 20 Normally Hearing Thai Subjects*

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<th>SD</th>
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<td>5.5</td>
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<td>6.6</td>
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</tr>
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<td>-5</td>
<td>15</td>
<td>5.9</td>
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<td>6.3</td>
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</tr>
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</table>

| PTA\(^a\) | 6.3 | -3.3 | 13.3 | 4.3 |

\(^a\)PTA = arithmetic average of thresholds at 0.5, 1.0, and 2.0 kHz
Talkers. Initial test recordings were made using eight native talkers of Thai (five females and three males). All talkers originated from the country of Thailand, who self-reported speaking a standard accent of Thai. After the initial recordings were made, a panel of three native speakers evaluated the performance of each of the eight talkers. The judges rank ordered the talkers from best to worst based on vocal quality, standard dialect, and pronunciation. The highest ranked male and female Thai speakers were selected as the talkers for all subsequent recordings.

Recordings. All recordings were made in an anechoic chamber located on the Brigham Young University campus in Provo, Utah, USA. A Larson-Davis model 377B41 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 902B microphone preamp, which was coupled to a Larson-Davis model 2221 microphone preamp power supply. The signal was digitized using an Apogee AD-8000 analog-to-digital converter and was then 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.

During the recording sessions, the talker pronounced each monosyllabic word at least four times. The first and last repetition of each word was excluded to avoid any possible list effects. A native judge then rated the medial repetitions of each word for perceived quality of production. 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 (e.g., peak clipping, extraneous noise) was re-recorded or eliminated from the
study prior to listener evaluation. After the rating process, the intensity of each monosyllabic word to be included in the listener evaluation was edited as a single utterance using Sadie Disk Editor software (Studio Audio & Video Ltd., 2004) to yield the same average root mean square power as that of a 1 kHz calibration tone.

*Calibration*

The audiometer was calibrated weekly and prior to each data collection session in accordance to the American National Standards Institute (ANSI) 2004 standards. No changes in audiometric calibration were necessary during the course of data collection.

*Procedures*

Custom software was used to control randomization and timing of the presentation of the words. In addition, the custom software was also used to record and store all of the scoring. 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 (ANSI, 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 weekly during and at the conclusion of data collection. Calibration was performed in accordance with ANSI S3.6 standards (ANSI, 2004).

The subjects were not familiarized with the monosyllabic words prior to testing. The 250 monosyllabic words were randomly grouped into ten lists of 25 words each. These ten lists were used for presentation to the first ten subjects. The 250 words were
then randomly combined in a second group of ten different lists for presentation to the
next group of ten subjects. Ten presentation levels were selected for the lists: -5 to
40 dB HL in 5 dB steps. One list was presented at each intensity level. The word lists
were presented to each patient in a different order and the words within the list were
randomized. Each word was presented an equal number of times at each intensity level
across the entire subject population. Prior to administration of the word recognition test,
the following instructions were given to the participants in Thai:

You will hear monosyllabic words at several different loudness levels. At
the very soft levels it may be difficult for you to hear the words. Please listen
carefully and repeat the words you hear. If you are unsure of the word, you are
encouraged to guess. If you have no guess, please remain quiet until the next word
is presented. Do you have any questions?

Results
The 250 monosyllabic Thai words were ranked from difficult to easy to perceive. Each
word was given a ranking based on the number of times it was identified correctly. The
more often a word was identified correctly, the higher or easier the ranking given. Once
the words were ranked, the 50 most difficult words were eliminated and the 200
remaining words were then divided into four lists of 50 words each. Each list was
counterbalanced using an s-curve distribution. These lists can be found in character form
in Table 2 and Table 3. These lists are also available in char Thai Romanization in Table
4 and Table 5. The four word lists were then converted into eight half-lists using the same
process. These lists can be found in character form in Table 6 and Table 7. These lists are
also available in Thai Romanization in Table 8 and Table 9. The same 200 words were
then assigned into four different lists of 50 words each using an s-curve distribution.
Table 2

*Thai Male Monosyllabic Lists in Rank Order from Most Difficult to Easiest*

<table>
<thead>
<tr>
<th>List 1</th>
<th>List 2</th>
<th>List 3</th>
<th>List 4</th>
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<td>น้ำ</td>
<td>ฝาก</td>
<td>จบ</td>
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<td>นะ</td>
<td>แสง</td>
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<td>ปิด</td>
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<td>มะ</td>
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Table 3

*Thai Female Monosyllabic Lists in Rank Order from Most Difficult to Easiest*

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Table 4

*Thai Male Monosyllabic Lists (Romanized) in Rank Order from Most Difficult to Easiest*

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Table 5

*Thai Female Monosyllabic Lists (Romanized) in Rank Order from Most Difficult to Easiest*

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*Thai Male Monosyllabic Half-lists (Romanized) in Rank Order from Most Difficult to Easiest*

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<td>luem</td>
<td>bài</td>
<td>nãng</td>
</tr>
<tr>
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<td>cham</td>
<td>khun</td>
<td>kôt</td>
<td>nông</td>
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</tr>
<tr>
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<td>tô</td>
<td>wâng</td>
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<td>sâo</td>
<td>wâi</td>
<td>khon</td>
<td>wîng</td>
<td>rôi</td>
</tr>
</tbody>
</table>
Table 9

Thai Female Monosyllabic Half-lists (Romanized) in Rank Order from Most Difficult to Easiest

<table>
<thead>
<tr>
<th>1A</th>
<th>1B</th>
<th>2A</th>
<th>2B</th>
<th>3A</th>
<th>3B</th>
<th>4A</th>
<th>4B</th>
</tr>
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<tbody>
<tr>
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<td>ðêk</td>
<td>chîng</td>
<td>chût</td>
<td>thîng</td>
<td>yût</td>
<td>trûng</td>
</tr>
<tr>
<td>tû</td>
<td>chîp</td>
<td>thaen</td>
<td>thon</td>
<td>rong</td>
<td>phîw</td>
<td>sâng</td>
<td>rôp</td>
</tr>
<tr>
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<td>raeng</td>
<td>phák</td>
<td>cha</td>
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<td>hîn</td>
<td>lâng</td>
<td>nîw</td>
</tr>
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<td>lênn</td>
<td>nûek</td>
<td>than</td>
<td>pu</td>
<td>dûi</td>
<td>nû</td>
</tr>
<tr>
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<td>wân</td>
<td>klang</td>
<td>ngan</td>
<td>hâ</td>
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<td>rán</td>
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<tr>
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<td>khâ</td>
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<tr>
<td>phànn</td>
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<td>klàî</td>
<td>kîn</td>
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<td>khâo</td>
<td>rôi</td>
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<td>náp</td>
<td>lông</td>
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<td>hâng</td>
<td>bôk</td>
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<td>rûp</td>
<td>thôt</td>
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<tr>
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<td>tô</td>
<td>sân</td>
<td>chîôp</td>
<td>châng</td>
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</tr>
<tr>
<td>lûi</td>
<td>thâm</td>
<td>rû</td>
<td>done</td>
<td>lûp</td>
<td>reo</td>
<td>tam</td>
<td>khûen</td>
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<tr>
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<td>phî</td>
<td>châm</td>
<td>tô</td>
<td>khamm</td>
<td>mô</td>
<td>ngâi</td>
<td>kài</td>
</tr>
<tr>
<td>eng</td>
<td>wâng</td>
<td>ya</td>
<td>ràp</td>
<td>wâi</td>
<td>ro</td>
<td>khôn</td>
<td>wâng</td>
</tr>
<tr>
<td>yô</td>
<td>pôet</td>
<td>chêp</td>
<td>sông</td>
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<td>wîng</td>
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<td>rôn</td>
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<td>tô</td>
<td>yû</td>
<td>phût</td>
<td>sôm</td>
</tr>
<tr>
<td>khô</td>
<td>pâk</td>
<td>pàng</td>
<td>chôn</td>
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<tr>
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<td>wân</td>
<td>fôñ</td>
<td>chák</td>
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<td>ao</td>
<td>chài</td>
</tr>
<tr>
<td>khûn</td>
<td>yao</td>
<td>thang</td>
<td>lûn</td>
<td>nôi</td>
<td>chàô</td>
<td>ma</td>
<td>sûng</td>
</tr>
<tr>
<td>yài</td>
<td>fà</td>
<td>sài</td>
<td>kàew</td>
<td>yom</td>
<td>dao</td>
<td>chûe</td>
<td>nào</td>
</tr>
</tbody>
</table>
These lists were then divided into half-lists using s-curve distribution as well. No significant differences were found between the complete lists or between the half-lists. Logistic regression was used to calculate regression slopes and intercepts for each of the monosyllabic lists and half-lists. The regression slopes and intercepts values were then inserted into a modified logistic regression equation that was designed to calculate percentage of correct performance for any given intensity level. Percent correct values were then used to construct psychometric functions. Percentage of correct word recognition was predicted for each of the monosyllabic lists and half-lists. Psychometric functions were then produced using the predicted percentages. These percentages are displayed in Figure 1. The threshold, the slope at the threshold, and the slope from 20 to 80% were calculated for the monosyllabic lists and half-lists and are displayed in Table 10 and Table 11. Finally, a chi-square analysis was utilized to compare the completed lists and half-lists in order to assess whether or not there was a significant difference among the completed lists and the half-lists. This analysis found there were no significant differences among the completed word lists for the male and female talkers, $\chi^2(3, N = 20) = 0.37, p = 0.95$ and $\chi^2(3, N = 20) = 1.06, p = 0.79$. There were no significant differences found among the half-lists for male and female talkers, $\chi^2(7, N = 20) = 1.57, p = 0.98$ and $\chi^2(7, N = 20) = 5.37, p = 0.62$ respectively. Even though significant differences were not found among the completed lists or half-lists, digital intensity adjustments were made to each word list in order to increase the psychometric equivalency of the lists. The intensity adjustments made all lists and half-lists produce 50% correct performance at 10.89 dB HL, the average of the male and female list thresholds. The adjustments needed were 1.5 dB to the male lists and –1.5 dB
Figure 1.

Psychometric functions for the four Thai monosyllabic lists and eight half-lists for male talker and female talker recordings before intensity adjustments.
Table 10

*Mean Performance of Thai Male Monosyllabic Lists and Half-lists*

<table>
<thead>
<tr>
<th>List</th>
<th>a&lt;sup&gt;a&lt;/sup&gt;</th>
<th>b&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Slope at 50%&lt;sup&gt;c&lt;/sup&gt;</th>
<th>Slope 20-80%&lt;sup&gt;d&lt;/sup&gt;</th>
<th>Threshold&lt;sup&gt;e&lt;/sup&gt;</th>
<th>ΔdB&lt;sup&gt;f&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.63109</td>
<td>-0.21232</td>
<td>5.3</td>
<td>4.6</td>
<td>12.4</td>
<td>1.50</td>
</tr>
<tr>
<td>2</td>
<td>2.77647</td>
<td>-0.22470</td>
<td>5.6</td>
<td>4.9</td>
<td>12.4</td>
<td>1.47</td>
</tr>
<tr>
<td>3</td>
<td>2.71598</td>
<td>-0.21990</td>
<td>5.5</td>
<td>4.8</td>
<td>12.4</td>
<td>1.46</td>
</tr>
<tr>
<td>4</td>
<td>2.78191</td>
<td>-0.22423</td>
<td>5.6</td>
<td>4.9</td>
<td>12.4</td>
<td>1.51</td>
</tr>
</tbody>
</table>

| M    | 2.72636       | -0.22029       | 5.5                      | 4.8                    | 12.4              | 1.49           |
| Minimum | 2.63109        | -0.22470       | 5.6                      | 4.9                    | 12.4              | 1.46           |
| Maximum | 2.78191        | -0.21232       | 5.6                      | 4.9                    | 12.4              | 1.51           |
| Range | 0.15082       | 0.01238        | 0.3                      | 0.3                    | 0.1               | 0.05           |
| SD   | 0.07019       | 0.00573        | 0.1                      | 0.1                    | 0.0               | 0.03           |

| 1A   | 2.52335       | -0.20303       | 5.1                      | 4.4                    | 12.4              | 1.54           |
| 1B   | 2.75189       | -0.22275       | 5.6                      | 4.8                    | 12.4              | 1.46           |
| 2A   | 2.78746       | -0.22377       | 5.6                      | 4.8                    | 12.5              | 1.57           |
| 2B   | 2.76592       | -0.22567       | 5.6                      | 4.9                    | 12.3              | 1.37           |
| 3A   | 2.68116       | -0.21714       | 5.4                      | 4.7                    | 12.3              | 1.46           |
| 3B   | 2.75189       | -0.22275       | 5.6                      | 4.8                    | 12.4              | 1.46           |
| 4A   | 2.98593       | -0.23755       | 5.9                      | 5.1                    | 12.6              | 1.68           |
| 4B   | 2.60338       | -0.21269       | 5.3                      | 4.6                    | 12.2              | 1.35           |

| M    | 2.73137       | -0.22067       | 5.5                      | 4.8                    | 12.4              | 1.49           |
| Minimum | 2.52335        | -0.23755       | 5.1                      | 4.4                    | 12.2              | 1.35           |
| Maximum | 2.98593        | -0.20303       | 5.9                      | 5.1                    | 12.6              | 1.68           |
| Range | 0.46258       | 0.03452        | 0.9                      | 0.7                    | 0.3               | 0.33           |
| SD   | 0.13740       | 0.01011        | 0.3                      | 0.2                    | 0.1               | 0.11           |

<sup>a</sup>a = regression intercept. <sup>b</sup>b = regression slope. <sup>c</sup>Psychometric function slope (%/dB) at 50% was calculated from 49.999 to 50.001%. <sup>d</sup>Psychometric function slope (%/dB) from 20-80%. <sup>e</sup>Intensity required for 50% intelligibility. <sup>f</sup>Change in intensity required to adjust threshold to the mean threshold for male and female lists (10.89 dB HL).
Table 11

Mean Performance of Thai Female Monosyllabic Lists and Half-lists

<table>
<thead>
<tr>
<th>List</th>
<th>Slope at 50%</th>
<th>Slope 20-80%</th>
<th>Threshold</th>
<th>∆dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.8</td>
<td>5.0</td>
<td>9.4</td>
<td>-1.52</td>
</tr>
<tr>
<td>2</td>
<td>5.9</td>
<td>5.1</td>
<td>9.4</td>
<td>-1.52</td>
</tr>
<tr>
<td>3</td>
<td>5.8</td>
<td>5.0</td>
<td>9.5</td>
<td>-1.42</td>
</tr>
<tr>
<td>4</td>
<td>5.5</td>
<td>4.7</td>
<td>9.4</td>
<td>-1.49</td>
</tr>
</tbody>
</table>

| M    | 5.7         | 5.0          | 9.4       | -1.49|
| Minimum | 5.5         | 4.7          | 9.4       | -1.52|
| Maximum | 5.9         | 5.1          | 9.5       | -1.42|
| Range | 0.5         | 0.4          | 0.1       | 0.10 |
| SD   | 0.2         | 0.2          | 0.0       | 0.05 |

| 1A   | 5.7         | 5.0          | 9.5       | -1.37|
| 1B   | 5.8         | 5.1          | 9.2       | -1.67|
| 2A   | 5.4         | 4.6          | 9.2       | -1.71|
| 2B   | 6.6         | 5.7          | 9.6       | -1.33|
| 3A   | 5.7         | 4.9          | 9.6       | -1.27|
| 3B   | 6.0         | 5.2          | 9.3       | -1.56|
| 4A   | 5.5         | 4.7          | 9.4       | -1.49|
| 4B   | 5.5         | 4.7          | 9.4       | -1.49|

| M    | 5.8         | 5.0          | 9.4       | -1.49|
| Minimum | 5.4         | 4.6          | 9.2       | -1.71|
| Maximum | 6.6         | 5.7          | 9.6       | -1.27|
| Range | 1.3         | 1.1          | 0.4       | 0.43 |
| SD   | 0.4         | 0.4          | 0.2       | 0.16 |

*a = regression intercept. 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 (10.89 dB HL).
to the female lists. These adjustments can be found in Figure 2 and Figure 3. Figure 2 displays the psychometric functions for the male and female talker lists and half-lists after the intensity adjustments. Figure 3 displays the mean psychometric functions for the combined male and female lists and half-lists, both before and after intensity adjustments.

Discussion

The purpose of this study was to create a set of four lists, comprised of 50 monosyllabic words each in the Thai language, to be used for word recognition testing. These four word lists were created using both male and female talkers. The monosyllabic word lists were comprised of familiar words and the lists can be divided into 25-word half-lists. A chi-square analysis of the complete lists and of the half-lists found no significant differences among lists.

In order to ensure statistical equivalency, the male and female thresholds were adjusted by 1.5 and –1.5 dB respectively. Figure 3 displays the change and shows the homogeneity of word lists because of that change. The homogeneity of the word lists is of the utmost importance in creating reliable and valid word lists. Also of importance are the slopes of the word lists. The average psychometric function slopes at 50% were 5.5 %/dB for the male word lists and 5.7 %/dB for the female word lists. The female word lists have a slightly steeper slope than the male word lists at the psychometric function slopes at 50%. The average function slopes from 20-80% were 4.8 %/dB for the male word lists and 5.0 %/dB for the female word lists. This analysis indicates the female word lists have a slightly steeper slope than the male word lists. The slopes for the male and female monosyllabic word lists are displayed in Table 10 and Table 11. The average slope for all male and female lists psychometric function slopes at 50% is 5.6 %/dB.
Figure 2.

Psychometric functions for the four Thai monosyllabic lists and eight half-lists for male talker and female talker recordings after intensity adjustments to produce 50% performance at 10.89 dB HL.
Figure 3.

Mean psychometric functions for male and female Thai talker monosyllabic word lists before and after intensity adjustment. Intensity adjustments were made to each list and half-list to produce 50% correct performance at 10.89 dB HL.
The average slope for all male and female lists psychometric function slopes at 20-80% is 4.9 %/dB.

In comparison to other studies that used tonal languages, the Thai monosyllabic word lists generally have lower psychometric function slopes at both 50% and 20-80%. However, this difference is likely due to the fact that many of the studies that used tonal languages used bisyllabic words instead of monosyllabic words. Bisyllabic words were used if the language did not contain monosyllabic words. Nevertheless, the comparison is still worth noting. A Taiwan Mandarin study, which used bisyllabic words, found the average psychometric function slopes to be 8.75 %/dB and 7.55 %/dB for the psychometric function slopes at 50% and 20-80% respectively (Nissen, Harris, Jennings, Eggett, & Buck, 2005). A Cantonese study, using bisyllabic words, found the average psychometric function slopes to be 7.55 %/dB and 6.55 %/dB for the psychometric function slopes at 50% and 20-80% respectively (Conklin, 2007).

In comparison to other language word lists that used monosyllabic words, the results were fairly similar. Robertson (2006) completed a study to produce Arabic monosyllabic word recognition materials. While Arabic is not a tonal language, the results were based on the use of monosyllabic words. This study found the average psychometric function slopes to be 4.8 %/dB and 4.2 %/dB for the psychometric function slopes at 50% and 20-80% respectively. This study only created male word lists and so the slopes represent the psychometric function slopes for male word lists only. When these results are compared to the Thai male word lists, the results are similar. Another study produced Polish monosyllabic word lists and found the psychometric function slopes to be 5.85%.dB and 5.25%/dB for the psychometric function slopes at 50% and
20-80% respectively (Harris, Nielson, McPherson, & Skarzynski, 2004). A third study produced Korean monosyllabic word lists and found the psychometric function slopes to be 4.95%/dB and 4.4%.dB for the psychometric function slopes at 50% and 20-80% respectively (Harris, Kim, & Eggett, 2003). Finally, a study which produced Russian monosyllabic word lists and found the psychometric function slopes to be 5.7%/dB and 4.95%/dB for the psychometric function slopes at 50% and 20-80% respectively (Harris, Nissen, Pola, McPherson, Tavartkiladze, & Eggett, 2007). The results of these studies are all similar to the results of Thai word lists used in the current study. Differences that did occur may be due to the fact that Thai is a tonal language, while the other languages mentioned are not tonal languages. Differences may also have been caused by a difference in complexity of the languages. Language containing more difficult words will likely have different psychometric function slopes. Finally, unique characteristics of the Thai language may have affected the psychometric function slopes.

When compared to the English speech recognition tests, the Thai psychometric function slopes are very similar. According to Beattie, Edgerton, and Svihovec (1977), the mean psychometric slopes at 20-80% for the NU-6 and CID W-22 speech recognition tests are 4.2 %/dB and 4.6 %/dB respectively. These slopes are slightly lower than the 4.9 %/dB mean slope obtained for the Thai word recognition lists. The NU-6 and CID W-22 speech recognition tests both used monosyllabic words for the speech recognition word lists, which may partially be responsible for the similar scores when compared to the Thai word lists. While the exact reason for the slight differences in slopes is unclear, the differences may have been caused by words in one language being more difficult than words in another language. Differences may also have been caused by the use of tones in
the Thai language and the lack of tone usage in the English language. However, while there is a slight difference, the Thai word lists and the English word lists produce similar results.

This current study yielded similar results to the English speech recognition tests; however, this does not imply a flawless study. While the end product is statistically equivalent word lists, these word lists cannot necessarily be generalized to the entire Thai population because of limitations concerning the selection of Thai participants. According to the data on Table 1, the mean age of participant was 24.2 years. The range was from 19 to 33 years. This is an acceptable mean age and age range of participants. However, because of the age range used to create the monosyllabic word lists, this test is not standardized for the pediatric population. Words that are familiar to adults may not be familiar to a child, which indicates the need for specialized word lists for the pediatric population. In a future study it would be beneficial to include a greater age range among participants in order to create a test that can be generalized to a greater amount of ages. It would also be beneficial to create word lists specifically for the pediatric population. Word lists would need to use a more simple vocabulary in order to accommodate a younger age group.

A further limitation caused by the participant selection is the extent of education for each participant. Many of the participants who volunteered for this study had some degree of higher education. This may indicate that they also had a larger or different vocabulary compared to other Thai people with little or no higher education. This may potentially have created more difficult word lists, as they were standardized with a population of a higher educational level. A future study may try to include a more
diversified and larger participant group that included participants of different education levels and employments.

A final limitation that is worth mention concerns Thai dialects. Standard Thai was used in this study and is widely used in Thailand. However, it is the more educated and wealthy people who are exposed to Standard Thai. Standard Thai is taught in schools and is used in the public media. Those people who do not attend school or do not have access to public media, will have limited exposure to Standard Thai. Weisleder and Hodgson (1989) and Garlick (2008) studied whether or not different dialects caused differences in the results of speech recognition materials. Weisleder and Hodgson found that participants of Mexican origin obtained higher word recognition scores than participants of other Spanish speaking nationalities. Garlick found a difference among the word recognition scores of mainland China participants and Taiwan participants on Mandarin word recognition tests. Both studies indicate that different dialects have an effect on the word recognition scores. Word recognition tests of several Thai dialects would be useful and would result in more accurate hearing tests for those who speak the other Thai dialects.

The creation of Thai monosyllabic word recognition lists will benefit both native Thai speakers and audiologists. These word lists are created such that audiologists in Thailand and audiologists in the United States can use them to test the hearing of patients whose primary language is Thai. It is important to test the hearing of a patient in their native language, in order to eliminate lower scores due to reasons other than a hearing loss. Testing a patient in their primary language will solely test their ability to hear the words, while testing a patient in a different language will not only be testing their ability
to hear the words but also their familiarity of the words and knowledge of the language. It is also an expectation and a hope that this study will promote future studies to improve upon these word lists and to create new ones that focus on different dialects and age ranges.

This study was successful in creating lists of psychometrically equivalent monosyllabic words in the Thai language. Specifically, four complete lists and eight half-lists, using both male and female talkers, were created. Results indicated no significant differences among the lists. These lists can now be used for speech recognition testing of patients who speak Standard Thai and will produce more accurate and meaningful results. The monosyllabic complete lists and half-lists can be found on the CD entitled Brigham Young University Thai Speech Audiometry Materials (Disc 1.0). The CD’s contents are included in Appendix C.
References


Appendix A

Informed Consent

RESEARCH PARTICIPATION 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 ____________

APPROVED EXPIRES
SEP 2 1 2007 - SEP 2 0 2008
## Appendix B

Selected Monosyllabic Word Definitions

<table>
<thead>
<tr>
<th>No.</th>
<th>Word</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>chăng</td>
<td>to employ, hire</td>
</tr>
<tr>
<td>2</td>
<td>chàk</td>
<td>From</td>
</tr>
<tr>
<td>3</td>
<td>chèp</td>
<td>to be hurt, injured</td>
</tr>
<tr>
<td>4</td>
<td>yâk</td>
<td>to be hard, difficult</td>
</tr>
<tr>
<td>5</td>
<td>phîw</td>
<td>Skin</td>
</tr>
<tr>
<td>6</td>
<td>phàn</td>
<td>to pass</td>
</tr>
<tr>
<td>7</td>
<td>klâi</td>
<td>near, close</td>
</tr>
<tr>
<td>8</td>
<td>din</td>
<td>earth, dirt, ground</td>
</tr>
<tr>
<td>9</td>
<td>chòt</td>
<td>to write down</td>
</tr>
<tr>
<td>10</td>
<td>pu</td>
<td>Crab</td>
</tr>
<tr>
<td>11</td>
<td>phâ</td>
<td>fabric, clothing</td>
</tr>
<tr>
<td>12</td>
<td>nôk</td>
<td>Outside</td>
</tr>
<tr>
<td>13</td>
<td>yô</td>
<td>brief; abbreviation</td>
</tr>
<tr>
<td>14</td>
<td>thang</td>
<td>way, path</td>
</tr>
<tr>
<td>15</td>
<td>khâng</td>
<td>next to, beside</td>
</tr>
<tr>
<td>16</td>
<td>reo</td>
<td>fast, quick</td>
</tr>
<tr>
<td>17</td>
<td>ráp</td>
<td>to receive, get</td>
</tr>
<tr>
<td>18</td>
<td>man</td>
<td>It</td>
</tr>
<tr>
<td>19</td>
<td>ngan</td>
<td>work, job</td>
</tr>
<tr>
<td>20</td>
<td>tàeng</td>
<td>to decorate</td>
</tr>
<tr>
<td>21</td>
<td>khâo</td>
<td>Rice</td>
</tr>
<tr>
<td>22</td>
<td>hàeng</td>
<td>to be dry</td>
</tr>
<tr>
<td>23</td>
<td>không</td>
<td>probably, most likely</td>
</tr>
<tr>
<td>24</td>
<td>yêng</td>
<td>Female</td>
</tr>
<tr>
<td>25</td>
<td>ngoen</td>
<td>money; silver</td>
</tr>
<tr>
<td>26</td>
<td>náp</td>
<td>to count</td>
</tr>
<tr>
<td>27</td>
<td>nói</td>
<td>small amount, very little</td>
</tr>
<tr>
<td>28</td>
<td>bàn</td>
<td>house, home</td>
</tr>
<tr>
<td>29</td>
<td>rú</td>
<td>to know, understand</td>
</tr>
<tr>
<td>30</td>
<td>sôn</td>
<td>to teach</td>
</tr>
<tr>
<td>31</td>
<td>yen</td>
<td>cold, cool</td>
</tr>
<tr>
<td>32</td>
<td>lôek</td>
<td>to discontinue, cancel</td>
</tr>
<tr>
<td>33</td>
<td>chai</td>
<td>Male</td>
</tr>
<tr>
<td>34</td>
<td>chái</td>
<td>to use</td>
</tr>
<tr>
<td>35</td>
<td>chüet</td>
<td>bland, tasteless</td>
</tr>
<tr>
<td>36</td>
<td>khrai</td>
<td>who; anyone</td>
</tr>
<tr>
<td>37</td>
<td>rón</td>
<td>hot</td>
</tr>
<tr>
<td>38</td>
<td>phrôm</td>
<td>to be ready, prepared</td>
</tr>
<tr>
<td>39</td>
<td>trong</td>
<td>direct, straight</td>
</tr>
<tr>
<td>40</td>
<td>cham</td>
<td>to remember</td>
</tr>
<tr>
<td>41</td>
<td>rúp</td>
<td>picture</td>
</tr>
<tr>
<td>42</td>
<td>yom</td>
<td>to allow; to accept</td>
</tr>
</tbody>
</table>
43 ao to take, get
44 rák to love
45 hến to see
46 khái to sell
47 kåew glass, cup
48 yài big, large
49 náo to be/feel cold
50 phút to speak, talk, say
51 fák to deposit, leave something
52 pák mouth
53 pi to close; to turn off
54 phák vegetable
55 phát to blow, fan
56 mít knife
57 hõm fragrant, pleasant-smelling
58 ro to wait
59 lãi several, many
60 bàep style, type, model
61 thäen instead of
62 tám low; inferior
63 wát common cold
64 mõ doctor
65 sák to wash, launder
66 bàeng to share, divide
67 chí to indicate, point
68 to to grow up; to be big
69 doen to walk
70 thing to throw away, discard
71 kài chicken
72 yù to be located
73 sòng to send
74 mượt dark
75 súng to be tall
76 chôp to end, finish
77 sâeng light
78 ya medicine
79 tham to do
80 kwát to sweep
81 sài to put/add in; to put on (clothing)
82 fõn rain
83 chon to collide, crash
84 mái new
85 ỏn soft, tender
86 kho to ask for, request
87 wan day
88 chôp to like
<p>| 89 | kòet | to happen, occur |
| 90 | khun | you |
| 91 | tò | to, towards; against |
| 92 | wăng | to hope, wish |
| 93 | kâe | old, aged |
| 94 | mâk | much; very |
| 95 | lom | wind, air |
| 96 | láeo | already |
| 97 | wang | to place, set down |
| 98 | yûng | busy, occupied |
| 99 | ròng | to sing; to cry out |
| 100 | sâo | young woman |
| 101 | mòt | to be empty, all used up |
| 102 | tòp | to answer, respond |
| 103 | tam | to follow |
| 104 | lõng | to be lost, go astray |
| 105 | thuebasng | to arrive |
| 106 | phleng | song |
| 107 | núek | to consider, think |
| 108 | tem | complete, full |
| 109 | bôk | to say, tell |
| 110 | nũ | rat, mouse |
| 111 | tông | must |
| 112 | nãk | heavy |
| 113 | mën | to be foul-smelling, stinky |
| 114 | sín | to end, to terminate |
| 115 | raeng | strong, powerful |
| 116 | nan | for a long time |
| 117 | khấu | couple, pair |
| 118 | tàe | but, however |
| 119 | ân | to read |
| 120 | khêm | needle, pin |
| 121 | niw | finger; toe |
| 122 | chon | until, till |
| 123 | khoei | once; ever |
| 124 | tâng | to establish, set up |
| 125 | hông | room, chamber |
| 126 | mũ | pig, pork |
| 127 | chûc | name |
| 128 | khít | to think |
| 129 | thûe | to hold, carry |
| 130 | lân | grandchild |
| 131 | pla | fish |
| 132 | sù | to contend, fight |
| 133 | klang | center, middle |
| 134 | nók | bird |</p>
<table>
<thead>
<tr>
<th>Number</th>
<th>Vietnamese</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>181</td>
<td>phàen</td>
<td>sheet</td>
</tr>
<tr>
<td>182</td>
<td>fâ</td>
<td>blue; sky</td>
</tr>
<tr>
<td>183</td>
<td>non</td>
<td>to lie down, sleep</td>
</tr>
<tr>
<td>184</td>
<td>lék</td>
<td>small amount, very little</td>
</tr>
<tr>
<td>185</td>
<td>kòn</td>
<td>before</td>
</tr>
<tr>
<td>186</td>
<td>khượn</td>
<td>to ascend, increase, go up</td>
</tr>
<tr>
<td>187</td>
<td>bài</td>
<td>afternoon</td>
</tr>
<tr>
<td>188</td>
<td>năng</td>
<td>to sit</td>
</tr>
<tr>
<td>189</td>
<td>bon</td>
<td>on, over, above</td>
</tr>
<tr>
<td>190</td>
<td>im</td>
<td>to be full, satisfied</td>
</tr>
<tr>
<td>191</td>
<td>chài</td>
<td>to spend, pay</td>
</tr>
<tr>
<td>192</td>
<td>lên</td>
<td>to play</td>
</tr>
<tr>
<td>193</td>
<td>koen</td>
<td>to exceed, surpass</td>
</tr>
<tr>
<td>194</td>
<td>du</td>
<td>to look, watch; to appear, seem</td>
</tr>
<tr>
<td>195</td>
<td>fân</td>
<td>to dream</td>
</tr>
<tr>
<td>196</td>
<td>klâ</td>
<td>brave</td>
</tr>
<tr>
<td>197</td>
<td>sàng</td>
<td>to create, build</td>
</tr>
<tr>
<td>198</td>
<td>wân</td>
<td>sweet</td>
</tr>
<tr>
<td>199</td>
<td>wîng</td>
<td>to run</td>
</tr>
<tr>
<td>200</td>
<td>rói</td>
<td>hundred, 100</td>
</tr>
</tbody>
</table>
## Appendix C

### Brigham Young University

**Thai Speech Audiometry Compact Disc Track Contents**

<table>
<thead>
<tr>
<th>Track Contents</th>
<th>1 kHz sinusoid</th>
</tr>
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<tbody>
<tr>
<td>2-3 Equivalent words for SRT evaluation</td>
<td></td>
</tr>
<tr>
<td>2 Monosyllabic word lists 1-4 with words in random order (easy to difficult)</td>
<td></td>
</tr>
<tr>
<td>3 Monosyllabic word lists 1-4 with words in random order</td>
<td></td>
</tr>
<tr>
<td>4-7 Monosyllabic word half-lists 1A-4B with words in random order</td>
<td></td>
</tr>
<tr>
<td>8-11 Monosyllabic word lists 1-4 with words in random order</td>
<td></td>
</tr>
<tr>
<td>12-19 Monosyllabic word half-lists 1A-4B with words in random order</td>
<td></td>
</tr>
<tr>
<td>20-27 Monosyllabic word half-lists 1A-4B with words in random order</td>
<td></td>
</tr>
</tbody>
</table>

### 28-38 Patient instructions for routine audiometric tests recorded in Tongan

<table>
<thead>
<tr>
<th>Track 1: 1 kHz Calibration Tone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Track 2: Bisyllable SRT words for Familiarization</td>
</tr>
<tr>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>1 บันชัก</td>
</tr>
<tr>
<td>2 จำกับ</td>
</tr>
<tr>
<td>3 จิตระ</td>
</tr>
<tr>
<td>4 จิตระ</td>
</tr>
<tr>
<td>5 ยิ้ม</td>
</tr>
<tr>
<td>6 กล้า</td>
</tr>
<tr>
<td>7 กล้า</td>
</tr>
<tr>
<td>8 ครั้ง</td>
</tr>
<tr>
<td>9 กระแส</td>
</tr>
<tr>
<td>10 กระแส</td>
</tr>
<tr>
<td>11 กระแส</td>
</tr>
<tr>
<td>12 กระแส</td>
</tr>
<tr>
<td>13 กระแส</td>
</tr>
<tr>
<td>14 กระแส</td>
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<td>15 กระแส</td>
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<td>16 กระแส</td>
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<td>18 กระแส</td>
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<td>19 กระแส</td>
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<td>20 กระแส</td>
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<td>21 กระแส</td>
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<td>22 กระแส</td>
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<td>23 กระแส</td>
</tr>
<tr>
<td>24 กระแส</td>
</tr>
<tr>
<td>25 กระแส</td>
</tr>
<tr>
<td>26 กระแส</td>
</tr>
<tr>
<td>27 กระแส</td>
</tr>
<tr>
<td>28 กระแส</td>
</tr>
</tbody>
</table>

Note: The Thai and English words are paired to demonstrate bilingual usage in the audiometry test.
<table>
<thead>
<tr>
<th>Male Monosyllabic Lists in Ranked Order (difficult to easy)</th>
<th>Male Lists Romanized (Ranked Order - difficult to easy)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Track 4</strong></td>
<td><strong>Track 5</strong></td>
</tr>
<tr>
<td>List 1 List 2 List 3 List 4</td>
<td>List 1 List 2 List 3 List 4</td>
</tr>
<tr>
<td>1 จ้อง นัก หมอก ด่าง</td>
<td>1 châng fâk mît láng</td>
</tr>
<tr>
<td>2 ชาว ปาก ตอบ คิด</td>
<td>2 châk pâk tâp tât</td>
</tr>
<tr>
<td>3 เข่า พื้น คาระ พ้อ</td>
<td>3 chêp pit tam pho</td>
</tr>
<tr>
<td>4 ยาก พื้น หลอด ภัย</td>
<td>4 yâk phâk lâng yîm</td>
</tr>
<tr>
<td>5 ผี พล ดี ซี่</td>
<td>5 phiw phât thuang sue</td>
</tr>
<tr>
<td>6 ผ่าน พื้น เหลือง ขิว</td>
<td>6 phiâm mît phuang mue</td>
</tr>
<tr>
<td>7 ใกล้ หมอ บิด สี</td>
<td>7 klâi hîm niek sán</td>
</tr>
<tr>
<td>8 ดิน ราม เดิม มัน</td>
<td>8 din ro tem yût</td>
</tr>
<tr>
<td>9 กล หมอ บอก ข้า</td>
<td>9 chôt lâi bôk châo</td>
</tr>
<tr>
<td>10 มุ่น แถบ หนู แต่</td>
<td>10 pu bâep nû râek</td>
</tr>
<tr>
<td>11 ผ่า แน่น ต้อง ตัน</td>
<td>11 phâ thaen tông tôn</td>
</tr>
<tr>
<td>12 มาก ดา หน้า สัง</td>
<td>12 nök tâm nák sang</td>
</tr>
<tr>
<td>13 ย่อ หวั่น เหม็น มา</td>
<td>13 yö wât men ma</td>
</tr>
<tr>
<td>14 ทาง หมอ ฝั่ง ร่อง</td>
<td>14 thang mî phîn wâng</td>
</tr>
<tr>
<td>15 ข้าง แซก แรก กิน</td>
<td>15 khâng sâk raeng kin</td>
</tr>
<tr>
<td>16 เร็ว แรง นาน ข้า</td>
<td>16 reo biâng nan khâm</td>
</tr>
<tr>
<td>17 ป้าย ซี่ ตู ข้า</td>
<td>17 râp chi khâ khâ</td>
</tr>
<tr>
<td>18 บ้าน โลก ตัด ต้อง</td>
<td>18 man to tâc ling</td>
</tr>
<tr>
<td>19 งาม เส้น ถ่าน ฟาก</td>
<td>19 ngân doen ân phák</td>
</tr>
<tr>
<td>20 แผง ชั้น ชั้น ชั้น</td>
<td>20 tâng thîng khâm klâp</td>
</tr>
<tr>
<td>21 ร่าง นิด งาม โปร</td>
<td>21 khâo kâi nîw ngâî</td>
</tr>
<tr>
<td>22 แห่ง ดอง จม บุก</td>
<td>22 hâeng yû chon bun</td>
</tr>
<tr>
<td>23 คลอง สง เล่น ราย</td>
<td>23 không sîng khoi râi</td>
</tr>
<tr>
<td>24 หนง นึก นึก ข้า</td>
<td>24 yîng mît tâng cha</td>
</tr>
<tr>
<td>25 เบน คุ้ง ฮอง ลอง</td>
<td>25 ngôn sîng hông long</td>
</tr>
<tr>
<td>26 บัก นะ หมุน ช้าง</td>
<td>26 nû thîp mû châng</td>
</tr>
<tr>
<td>27 บ่าน แผง บุ้น เล่น</td>
<td>27 noî sâng chûc sên</td>
</tr>
<tr>
<td>28 บ้าน ยา ครั้ง อบ</td>
<td>28 bán ya khî thâm</td>
</tr>
<tr>
<td>29 รู้ ทำ ถูก เล็ก</td>
<td>29 rû tham thû dêk</td>
</tr>
<tr>
<td>30 สอบถาม ทราบ ทหาร เลย</td>
<td>30 sûn kwât lân loei</td>
</tr>
<tr>
<td>31 เขียน โต ปลา แผ่น</td>
<td>31 yen sî plâ phûan</td>
</tr>
<tr>
<td>32 เลิก ผ่าน สู่ ฟ้า</td>
<td>32 kâek fûn sî fû</td>
</tr>
<tr>
<td>33 ชาว ชน กลาง นาม</td>
<td>33 châi chon klang non</td>
</tr>
<tr>
<td>34 ปุ่ม ไหม บาน เล็ก</td>
<td>34 pûm mîi bân lék</td>
</tr>
<tr>
<td>35 ชิล ฉัน ลอ ถัด</td>
<td>35 chîl ân lô tiân</td>
</tr>
<tr>
<td>36 ใคร ย่อ นิย์ ชั่น</td>
<td>36 khîi hôi doî khûên</td>
</tr>
<tr>
<td>37 ร้าน ร้าน บาง บาง</td>
<td>37 rûn wâng nâm bâî</td>
</tr>
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### Female Half-lists Romanized Random Order

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<td><strong>Speech reception threshold - verbal response</strong>&lt;br&gt;คุณกำลังจะได้ยินกลุ่มคำที่มีระดับความดังของเสียงต่างกัน หัวที่คุณได้ยินเสียงค่าพุค ครูจะพูดตามคำนำง ถ้าคุณไม่แน่ใจคำนำง คุณสามารถคาดคะเนได้&lt;br&gt;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.</td>
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<td><strong>Word recognition testing - verbal response</strong>&lt;br&gt;จุดประสงค์ของการทดสอบส่วนนี้จะช่วยในการตัดสินว่าคุณมีความเข้าใจมากแค่ไหนในค่าพุคที่มีระดับความดังของเสียงทางเทียมกัน หัวที่คุณได้ยินเสียงค่าพุค ครูจะฟังค่าคำนำง ถ้าคุณไม่แน่ใจคำนำง คุณสามารถคาดคะเนได้ แต่ถ้าคุณไม่สามารถคาดคะเนคำนำงได้ ครูอาจลองให้ แล้วรอคำนำงไป&lt;br&gt;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.</td>
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<td><strong>Speech audiometry - masking in nontest ear - verbal response</strong>&lt;br&gt;ในการทดสอบส่วนนี้ คุณจะได้ยินเสียงรถขวางในหูข้างหนึ่ง สำหรับหูข้างหนึ่งคุณจะได้ยินค่าพุค หัวที่คุณได้ยินเสียงค่าพุค ครูจะฟังค่าคำนำง แล้วพยายามอย่าใช้กับเสียงรถขวาง&lt;br&gt;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.</td>
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<td><strong>Speech audiometry - written response</strong>&lt;br&gt;คุณกำลังจะได้ยินกลุ่มคำที่มีระดับความดังของเสียงทางเทียมกัน หัวที่คุณได้ยินเสียงค่าพุค ครูจะเขียนคำนำง ถ้าคุณไม่แน่ใจคำนำง คุณสามารถคาดคะเนได้&lt;br&gt;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.</td>
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<td><strong>Speech audiometry - masking in nontest ear - written response</strong>&lt;br&gt;ในการทดสอบส่วนนี้ คุณจะได้ยินเสียงรถขวางในหูข้างหนึ่ง สำหรับหูข้างหนึ่งคุณจะได้ยินค่าพุค หัวที่คุณได้ยินเสียงค่าพุค ครูจะเขียนคำนำง แล้วพยายามอย่าใช้กับเสียงรถขวาง&lt;br&gt;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.</td>
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<td><strong>Pure-tone audiometry - hand raising response</strong>&lt;br&gt;คุณกำลังจะได้ยินกลุ่มเสียงที่มีระดับเสียงต่างกัน หัวที่คุณได้ยินเสียงครูอาจมี ซึ่งจะให้คุณไม่แน่ใจว่าคุณได้ยินเสียงดังหรือไม่ เมื่อเสียงที่ฟังครูจะพิจารณาเห็นว่าคุณได้ยินเสียงดังหรือไม่ แล้วให้คุณนั่งตั้งตัว&lt;br&gt;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.</td>
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<td>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.</td>
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