2006-07-06

Speech Reception Threshold Materials for Taiwan Mandarin

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SPEECH RECEPTION THRESHOLD MATERIALS FOR TAIWAN MANDARIN

by

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A thesis submitted to the faculty of

Brigham Young University

in partial fulfillment of the requirements for the degree of

Master of Science

Department of Communication Disorders

Brigham Young University

August 2006

BRIGHAM YOUNG UNIVERSITY

GRADUATE COMMITTEE APPROVAL

of a thesis submitted by

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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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As chair of the candidate's graduate committee, I have read the thesis of Katie Bedke Slade in its final form and have found that (1) its format, citations, and bibliographical style are consistent and acceptable and fulfill university and department style requirements; (2) its illustrative materials including figures, tables, and charts are in place; and (3) the final manuscript is satisfactory to the graduate committee and is ready for submission to the university library.

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ABSTRACT

SPEECH RECEPTION THRESHOLD MATERIALS FOR TAIWAN MANDARIN

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Master of Science

Speech reception threshold (SRT) tools have been developed to assist in the evaluation of hearing. This study was performed to develop, digitally record, evaluate, and equate Taiwan Mandarin trisyllabic words which can be used to measure the SRT. Eighty-nine commonly used trisyllabic words were chosen and digitally recorded by native male and female speakers. The words were then presented to 20 normally hearing subjects at 14 intensity levels (-10 to 16 dB HL) with 2 dB increments. Psychometric function slopes were calculated using logistic regression. Twenty-eight words with steep psychometric function were selected and digitally adjusted to match the mean subject pure-tone average (5.0 dB HL). A list of 28 trisyllabic words which were relatively homogeneous in audibility and slope were developed. The mean slopes for the 28 selected male and female trisyllabic Taiwan Madarin words were 11.3 %/dB (male talker) and 11.7 %/dB (female talker), respectively. Digital recordings of the psychometrically equivalent trisyllabic words are available on compact disc.

ACKNOWLEDGMENTS

Due to the magnitude of this project, there are many people who I wish to thank and acknowledge. First of all, I’d like to thank Father in Heaven for the answers to so many prayers and for allowing me to have and complete my experience at BYU. I’d also like to thank my parents, Doug and Pam Bedke, for being interested in all that I’ve had to say about this project as well as in my education. They have been very supportive throughout my college career and the decisions I’ve made in my life. I’d like to thank Dr. Nissen and Dr. Harris for their editing, patience with me, and all the work that they have put into this project. Without their expertise, this project would not have gone far. I’d also like to thank Sabrina Wu and Alycia Dukes for the hours of work they put into this project and for the fun times we had in doing it. I’d like to thank the other students in the program for the support that they have been to me throughout my time here at BYU to make it a fun and memorable experience. And lastly, I’d like to thank my husband Chris for his support, his patience throughout the process and his encouragement to finish and to do my best.

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Introduction

A comprehensive evaluation of an individual's hearing acuity requires several different types of diagnostic techniques. A commonly utilized procedure is pure-tone testing. This type of testing is designed to assess the thresholds at which a listener is able to detect sinusoidal frequencies. Pure-tone testing is a relatively quick and reliable method to obtain an assessment of an individual's ability to detect specific frequencies. However, to accurately evaluate a listener's ability to comprehend the more complex acoustic signals present in speech, additional auditory tests need to be performed. Speech audiometry is a procedure that can be used to evaluate a listener’s ability to hear, recognize and understand speech communication (American Speech-Language-Hearing Association, 1988; Young, Dudley, & Gunter, 1982). This type of assessment is valuable in the diagnosis of peripheral and central auditory disorders, the evaluation of hearing aid candidacy, the assessment of hearing aid performance, as well as locating possible lesions within the auditory system. In addition, speech audiometry can be used to validate previously obtained pure-tone average (PTA) results.

In order for speech audiometry to be a valid and accurate evaluation, individuals should be tested in their native language (Ramkissoon, 2001). High-quality, standardized speech audiometry materials have been developed and used extensively in English. However, for many of the world's languages such materials are more limited or non-existent. In some cases, speech audiometry materials have been developed in a speaker's native language; however such materials may be inappropriate for a speaker’s specific dialect or regional accent.

Researchers and audiologists have recognized this need and have begun to develop speech audiometry materials in non-English languages such as Arabic, Brazilian Portuguese, Italian, Japanese, Korean, Polish, Russian, and Spanish (Aleksandrovsky, McCullough, & Wilson, 1998; Ashoor & Prochazka, 1985; Christensen, 1995; Greer, 1997; Harris, Goffi, Pedalini, Gygi, & Merrill, 2001; Harris, Kim, & Eggett, 2003; Harris, Nielson, McPherson, Skarzynski, & Eggett, 2004; Mangum, 2005; Ramkissoon, 2001; Ramkissoon, Proctor, Lansing, & Bilger, 2002). Although Mandarin Chinese is spoken by over 1.2 billion people worldwide (Masci, 2000), to date only a limited number of materials have been developed for use in speech audiometry (Fu, Zeng, Shannon, & Soli, 1998; Huang, Wang, & Liu, 1995; Wang, Gu, Han, & Yang, 2003; Wang & Huang, 1988). Materials were recently developed for Standard Mandarin (Pǔtōnghuà), a dialect spoken by approximately 689 million individuals residing in the People's Republic of China (Nissen, Harris, Jennings, Eggett, & Buck, 2005). However, high-quality speech audiometry materials need to be developed for many other dialects of Chinese.

Mandarin spoken by individuals in Taiwan or the Republic of China is dialectically different than many variants of the language spoken by people living in the People's Republic of China or other regions of the world. The cause for these differences can be partially attributed to the geographic isolation and political separation of Taiwan from the People's Republic of China. Dialectal differences may also be due to the historical influence of indigenous speakers (Taiwanese) and a period of Japanese colonization prior to World War II (WWII). Following the re-establishment of a

Nationalist Chinese government in 1949, the national language was changed to Taiwan Mandarin (Lee, 1981).

The purpose of this study is to develop digital speech audiometry materials that can by used to evaluate the speech reception threshold (SRT) of individuals who speak Taiwan Mandarin, a widely spoken dialect of Chinese. Taiwan Mandarin is spoken by over 20 million individuals, residing in regions such as the Republic of China (ROC), Singapore, Canada, Australia, and the United States (Wikipedia, 2005). This project will aim to digitally record, evaluate, and psychometrically equate materials for the testing of speech reception thresholds.

Review of Literature

Speech Audiometry

The purpose of audiometric testing is to accurately assess a person's hearing and quantify the ability, or disability, that person may have to hear. There are many different procedures that audiologists use to assess a person's hearing, such as tympanometry, otoacoustic emissions, and pure-tone audiometry. In pure-tone audiometry a PTA or a listener's average hearing threshold at 500 Hz, 1000 Hz, and 2000 Hz is calculated. Although pure-tone testing is time efficient and effective in assessing frequency-specific hearing loss, it is insufficient to provide an accurate assessment of an individual's ability or disability to comprehend speech. Thus, a comprehensive hearing evaluation will often include additional diagnostic techniques, such as speech audiometry.

Due to the concurrence between PTA and SRT (ASHA, 1988), speech audiometry and PTA are often used jointly to provide a full and more accurate representation of a person's ability to hear (Carhart, 1971). In other words, each diagnostic technique can be used to validate the accuracy of the other. In addition, knowing the patient's PTA can also assist the audiologist in deciding at which frequencies and loudness levels to commence the speech audiometry assessment.

Speech audiometry can not only be used to check the validity of pure-tone results (ASHA, 1988), but is also useful in the quantification of a person's hearing threshold for speech. The SRT has diagnostic and prognostic value to aid the audiologist and individual with a hearing loss in making an educated decision on whether they are candidates for hearing aids and assessing hearing aid performance (Egan, 1979; Hirsh et al., 1952; Mueller & Grimes, 1983). SRT testing is also valuable for assessing progress in auditory training, determining success of otologic surgery, locating the site of lesion causing the hearing problems, diagnosing both peripheral and central auditory disorders, and is valuable in determining suprathreshold intelligibility (Jerger, Speaks, & Trammell, 1968; Rupp & Stockdell, 1980).

There are several different types of diagnostic testing in speech audiometry. Two commonly utilized techniques are word recognition and SRT testing. Word recognition also known as the speech detection threshold, is the minimum hearing level for speech that an individual can hear the presence of sound and identify it as speech, whereas the SRT, is defined as the minimum hearing level for speech at which an individual can recognize 50% of the speech material and be able to repeat or in some way indicate the recognition of the speech material (ASHA, 1988).

Factors that Influence the Quality of Speech Audiometry Materials

In order for speech audiometric testing to be valid and reliable, the audiologist must consider a number of factors, which include the number of words included in the list

(Grubb, 1963; Resnick, 1962), the dialect of the talker (Weisleder & Hodgson, 1989), the word selection (Cambron, Wilson, & Shanks, 1991; Luce, 1986; Wilson & Carter, 2001), the type of recording (Kamm, Carterette, Morgan, & Dirks, 1980; Ridgway, 1986), and the method and level of presentation (Beattie, Svihovec, & Edgerton, 1975; Hood & Poole, 1980; Pisoni, 1985). Therefore, when developing materials for speech audiometry, several issues must be considered. First, words selected for the study should be familiar to the listeners, yet sufficiently difficult to identify (Comstock & Martin, 1984; Weisleder & Hodgson, 1989; Zakrzewski, Jassem, Pruszewicz, & Obrebowski, 1976).

Second, native talkers who exhibit the standard dialect of the intended language should be used in the recordings (Weisleder & Hodgson, 1989). Especially at production levels that are <50 dB SPL, evaluation of hearing ability using recordings in a non-native dialect may significantly reduce the listeners' performance (Wilson & Moodley, 2000).

Third, the materials used should be digitally recorded and archived. ASHA's 1988 guidelines for determining threshold levels for speech suggested that audiometric CDs and tapes be used to standardize the composition and presentation of the speech materials used to increase the consistency of the speech patterns of the recorded talker from one client to another and one clinic to another Digital recordings offer many advantages over tape recordings. For example, digital recordings often have increased channel separation, improved signal-to-noise ratio, increased dynamic range, a reduction in harmonic distortions, and a longer storage life without usage degradation (Kamm et al., 1980; Ridgway, 1986; Sony, 1991). Digital speech recordings are preferred, in part because test words can be presented to listeners in a varied and flexible manner (Harris et al., 2001; Kamm et al., 1980; Ridgway, 1986).

Speech Reception Threshold

As a diagnostic audiological technique, the SRT was utilized as early as 1929. Interestingly, the methods and materials first used to perform SRT testing were developed somewhat earlier. In 1910, researchers at Bell Telephone Laboratories led by Campbell developed a method to evaluate telephone transmitting equipment called *articulation testing*. This type of testing involved a speaker reading out a list of nonsense syllables into a telephone receiver and a listener trying to correctly identify the syllables. In 1929, Fletcher and Steinberg found that the same method and materials used by Campbell could be relevant to the evaluation of hearing. Thus Fletcher and Steinberg created several lists of nonsense syllables that could be used for this type of testing (Markides, 1990).

Since Fletcher and Steinberg's work, a wide variety of speech audiometry materials have been developed that include phonetically-balanced (PB) monosyllabic word lists, bisyllabic word lists, sentences, and continuous discourse. In 1948, the Psycho Acoustic Laboratory (PAL) at Harvard University created the PAL PB-50, twenty word lists comprised of 50 phonetically-balanced words. However, researchers found that many patients had difficulties with the vocabulary used in the PAL PB-50 lists. Therefore, other tests, including tests using sentences as stimulus materials, were developed (Silverman & Hirsh, 1955; Speaks & Jerger, 1965). In 1979, ASHA published guidelines recommending that audiologists use spondaic words (words that have two syllables with equal emphasis) to evaluate the SRT in English. However, it remains unclear if spondaic words are most appropriate for SRT testing in other languages.

Need for Speech Reception Threshold Materials in other Languages

Speech audiometry materials are widely available in English; however, the development of such materials for other languages has received much less attention. Due to the unavailability of multilingual speech audiometry materials, some audiologists have utilized English materials to test non-English populations (Ramkissoon, 2001). A survey performed by Martin and Sides in the US in 1985 showed that 37% of audiologists have performed speech audiometry in languages other than English. Research has found that testing an individual in a language other than their native language will likely result in a less accurate hearing evaluation. Ramkissoon et al. (2002) reported that recognizing words that are unfamiliar is significantly more difficult for listeners than familiar words. Thus, for non-native English speakers, listening to relatively unfamiliar English words will likely reduce the validity of the hearing assessment. This assumption is also supported by research indicating that individuals who are bilingual with normal auditory threshold levels perform significantly poorer than monolingual individuals (Von Hapsberg, Champlin, & Shetty, 2004). Therefore, a listener must be presented with words in their native language in order for speech audiometry tools to be valid.

Speech audiometry materials have begun to be developed by researchers for non-English speakers. Speech audiometry materials have been developed for Brazilian Portuguese, Italian, Korean, Polish, Japanese, and Spanish (Christensen, 1995; Greer, 1997; Harris et al., 2001; Harris et al., 2003; Harris et al., 2004; Mangum, 2005; Nissen, et al., 2005; Ramkissoon, 2001; Ramkissoon et al., 2002). Aleksandrovsky et al. (1998) developed a computerized word recognition test for adults in Russian. The Russian test is comprised of 100 phonetically balanced words (two 50-word lists) which were chosen based on their frequent use in everyday speech. The words were digitally recorded using a female native Russian speaker. The Russian word lists were evaluated using 21 native Russian listeners. After being presented with a stimulus word, listeners were instructed to choose the correct picture from a foil of four rhyming alternative words. The project resulted in the development of SRT materials for native Russian speakers, with accompanying psychometric functions.

Although more limited, speech audiometry materials have also been developed for non-English speaking children. Word recognition and SRT materials were developed for the evaluation of Arabic children (Ashoor & Prochazka, 1985). The Arabic test is comprised of 80 phonetically balanced monosyllabic and bisyllabic words chosen from children's stories and rated for their familiarity by a large group of children listeners (N = 587). The words were recorded using a female speaker with the standard Saudi accent and then administered to 100 normally hearing children, divided into five different groups based on their age. This research resulted in the development of speech audiometric materials for Arabic-speaking children.

Chinese Speech Audiometry

Although Chinese is the most widely spoken language in the world (Weber, 1997), there have been relatively few materials developed for use in speech audiometry (Fu et al., 1998; Huang et al., 1995, Wang et al., 2003; Wang & Huang, 1988). It is estimated that Chinese is spoken by over 1.2 billion people worldwide (Masci, 2000). The term *Mandarin* is often used by linguists to refer to a diverse group of dialects found in many regions of the world. Pǔtōnghuà, translated to mean *ordinary speech*, is considered to be the standard dialect of Chinese in the People's Republic of

China, spoken by approximately 689 million individuals living primarily in Northern and Southwestern regions of China. However, there are many other dialects of Mandarin that exhibit unique linguistic characteristics, such as Hakka, Fujian, and Taiwan Mandarin commonly spoken in the Republic of China or Taiwan.

Chinese is frequently referred to as an *isolated* language, because each character is a free morpheme that carries a unique meaning (Li & Thompson, 1987). Individual characters generally are phonologically represented by a single syllable with a relatively simple and constrained segmental structure. Every syllable has a nuclear vowel that can occur as a monophthong, diphthong, or in some cases a triphthong. Only a limited set of nasals are allowed to occur in a final position syllable and initial consonants are optional. Although each character could stand alone in theory, Taiwan Mandarin vocabulary is generally polysyllabic in form, with the majority of the lexicon being bisyllabic compound words (Zhou & Marslen-Wilson, 1995).

Chinese is considered a tonal language in that the meaning of words within the language is in part determined by the suprasegmental pitch or tone of each syllable. In Taiwan Mandarin, the tone is primarily carried by the vocalic portion of the syllable and has one of four different pitch contours: high-level (first tone), high-rising (second tone), low-falling-rising (third tone), and high-falling (fourth tone). Taiwan Mandarin also has a fifth or neutral tone, which is often used with the unstressed syllables of compound words. Thus, words are formed by combining a relatively simple segmental structure with an over-riding suprasegmental tone. The writing system of Taiwan Mandarin is logographic in nature and has little or no relation to the pronunciation of a word. Therefore, a phonetic transcription system or Romanization has been developed to represent character pronunciation (Katzner, 1986). The Wade-Giles System of Romanization is commonly used by non-native speakers to represent the pronunciation of Taiwan Mandarin. This system represents phonologic segments with a Roman alphabet and tones with diacritic marks above each syllable's nuclear vowel (Li & Thompson, 1987).

Taiwan Mandarin is dialectically different from Standard Mandarin, the dialect commonly promoted by the government of the People's Republic of China. These dialectal differences can be partially attributed to five decades of geographic and political separation from the People's Republic of China. In addition, the influences of indigenous languages (e.g., Taiwanese) and a period of Japanese colonization have had a strong developmental impact on Taiwan Mandarin.

Taiwan is an island located a little over 100 miles off the Eastern coast of the People's Republic of China. This geographical barrier from mainland China has limited the cultural and linguistic interchange between people living in Taiwan and individuals living in mainland China who speak Pǔtōnghuà. The linguistic separation between these two language groups is also due in large part to political factors. At the end of WWII the National government of China relocated to the island of Taiwan following the rise of the Chinese Communist Party (CCP). Due to political disputation between the Nationalist party and the CCP, residents of Taiwan and mainland China have had only limited interaction during the last six decades. Due to these geographic and political barriers, in many ways the people of Taiwan have experienced a linguistic and cultural divergence from the mainland. Since that time, the Nationalist party has had control over Taiwan, thus Mandarin Chinese became Taiwan's official national language (Brown, 2004; Pfeiffer, 2005).

The people living in the southern part of Taiwan consist mainly of people whose ancestors emigrated to Taiwan centuries ago from southern Fujian (a Chinese province located in southeast China), many of whom still speak Southern Min (a dialect of Chinese, also known as Taiwanese). Although the Nationalist party established Mandarin Chinese as Taiwan's official national language, the Southern Min dialect of Chinese or Taiwanese is the native language of a large number of people living in the southern regions of Taiwan (Kubler, 1985; Li & Thompson, 1987). There are also other language varieties which influence the linguistic nature of present day Taiwan Mandarin, such as the Hakka dialect (commonly spoken by immigrants from Guangdong province) and aboriginal people who speak Malayo-Polynesian languages (Kubler, 1985). Taiwan Mandarin has also been heavily influenced by a period of Japanese occupation during the early twentieth century (Brown, 2004).

Although Pǔtōnghuà and Taiwan Mandarin are mutually intelligible, each variant contains marked differences in syntactic, lexical, and phonetic features (Li, 1985). An example of how the two dialects differ syntactically might include a grammatical difference in the use of the verb *you have*. In addition, the two dialects differ lexically, the lexicon used in Pǔtōnghuà often has a different political vernacular in communist mainland China as opposed to Taiwan.

Phonetically, some examples of how Taiwan Mandarin might differ from Pǔtōnghuà are as follows: Taiwan Mandarin replaces retroflex initials with dentals, switches /n/ and /η/ in final position in words having the vowel /ə/, atonic or unstressed syllables are not used, nasals in final word position have emerged into the language, as well as different pitch contours for the lexical tones (Fon & Chiang, 1999; Peng, 1991).

Considering these differences, a linguistically appropriate hearing evaluation for a speaker from Taiwan should involve speech audiometry materials specifically designed and created for native speakers of Taiwan Mandarin. Therefore, the purpose of this study is to develop a high quality digitally recorded trisyllabic word list which can be used to measure the SRT of those whose native language is Taiwan Mandarin. Specifically, this project will: (a) create a list of familiar trisyllabic Mandarin words, (b) identify one native male and one native female speaker of standard Taiwan Mandarin to serve as talkers for the speech audiometry recordings, (c) make high-quality digital recordings of the selected words, (d) collect normative data on the psychometric performance of each word, and (e) select a subset of trisyllabic words that are relatively homogeneous with respect to audibility and psychometric function slope.

Methods

Participants

The participants who participated in this study were native speakers of Mandarin Chinese from different parts of Taiwan. A total of 20 participants, from ages 18 to 39 years (M = 25.8), participated in evaluating 89 Taiwan Mandarin trisyllabic words. All participants had pure-tone thresholds of ≤15 dB HL at all octave and mid-octave frequencies ranging from 125 to 8000 Hz. Each participant had acoustic admittance between 0.3 and 1.4 mmhos with peak pressure between -100 and +50 daPa (ASHA 1990; Roup, Wiley, Safady, & Stoppenback, 1998). Summary statistics of the subject thresholds are listed in Table 1.

Table 1

Age (years) and Pure-tone Threshold (dB HL) Descriptive Statistics for the 20 Normally Hearing Taiwanese Participants

Variable	*M*	*Minimum*	*Maximum*	*SD*
Age	25.8	18	39	6.5
125 Hz	5.8	-5	15	5.9
250 Hz	5.5	-5	15	5.6
500 Hz	5.8	-5	10	4.4
750 Hz	5.8	0	15	5.2
1000 Hz	5.0	0	10	4.0
1500 Hz	6.8	-5	15	5.2
2000 Hz	4.3	-5	15	5.2
3000 Hz	2.0	-5	15	5.5
4000 Hz	2.5	-10	15	6.0
6000 Hz	3.0	-5	15	5.9
8000 Hz	2.3	-5	15	5.0
PTA[a]	5.0	-1.7	10.0	3.5

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

Materials

Word lists. A total of 89 commonly used trisyllabic words (or word phrases) were chosen as stimuli for the development of the SRT test materials. Originally, 130 trisyllabic words were selected from an electronic word corpus (Academia Sinica Computing Center, 1997). These words were then rated by three native judges on a scale of 1 to 5 based on the how familiar a word would be to a Mandarin speaker from Taiwan (1 = extremely familiar, 2 = very familiar, 3 = somewhat familiar, 4 = infrequency used, and 5 = rarely used). Of the 130 original trisyllabic words, 41 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) had the same pronunciation but different meanings, or (d) thought to be culturally insensitive.

Talkers. One male and one female talker were selected from a group of six native Taiwan-accented Mandarin speakers to record the word lists. The group of possible speakers comprised of 3 males and 3 female talkers who were native to Taiwan. Each speaker was recorded initially and evaluated by a panel of Taiwan Mandarin judges comprised of 8 individuals from Taiwan. Each talker was selected based on their voice quality, standard accent and pronunciation. The highest ranked male and female speakers were selected as the talkers for all the recordings that followed.

Recordings. All recordings were made in a double-walled sound suite located on the Brigham Young University campus in Provo, Utah, USA. A Larson-Davis model 2541 microphone was positioned approximately 15 cm from the talker at a 0° azimuth and covered by a 7.62 cm windscreen. The microphone was connected to a Larson-Davis model 900B microphone preamp, which was coupled to a Larson-Davis model 2200C preamp 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 analog-to-digital converter.

During the recording sessions, the talker was asked to produce each trisyllabic word at least four times with a slight pause between each production. Talkers were asked to speak at a normal rate, with natural prosody. To avoid possible list effects, the first and the last words from each word were excluded from the study. Additionally, a native judge (a university student from Taiwan) rated the medial repetitions of each word for the perceived quality of production, and the best production of each word was selected for listener evaluation. Any words that were judged to be a poor recording (peak clipping, extraneous noise, etc.), mispronounced, or produced with an unnatural intonation pattern were rerecorded or eliminated from the study prior to 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., 2004) to yield the same average root mean squared (RMS) power as that of a 1 kHz calibration tone.

Procedures

Custom software was used to control randomization and timing of the presentation of the words. The signal was routed from a computer hard drive to the external input of a Grason Stadler model 1761 audiometer. The stimuli were routed from the audiometer to the single subject via a single TDH-50P headphone. All testing was carried out in a double-walled sound suite that met American National Standards Institute

(ANSI) S3.1 standards for maximum permissible ambient noise levels for the ears not covered condition using one-third octave-bands (ANSI, 1999).

Prior to testing each subject, the external inputs to the audiometer were calibrated to 0 VU using the 1 kHz calibration tone on track 1 of the test CD. The audiometer was calibrated prior to, weekly during, and at the end of the conclusion of the data collection. Audiometric calibration was performed in accordance with ANSI S3.6 (2004) specifications. No changes in calibration were necessary throughout the course of data collection.

Each participant attended two test sessions after passing a hearing screening exam. The 89 trisyllabic words were presented at 14 different intensity levels, beginning at -10 and ascending to 16 dB HL in 2 dB increments. Sequence of the 89 trisyllabic words was randomized prior to presentation at each intensity level. Each subject listened to both the male and female talker recordings of all 89 trisyllabic words, in a sequence determined randomly. Subjects repeated words verbally which were scored as being correct or incorrect by a native judge who spoke Taiwan Mandarin. Each subject was allowed to have several rest periods during each test session. Prior to evaluation of the trisyllabic words, the following instructions were given in Taiwan Mandarin:

> 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 89 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:

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

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

$$i = \frac{\log \frac{p}{1-p} - a}{b} \tag{2}$$

By inserting the regression slope, regression intercept, and intensity level into Equation 2, it is possible to predict the percentage correct 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 dB (see Equation 2). By inserting the desired proportions into Equation 2, it is possible to calculate the threshold (the intensity required for 50% intelligibility), and the slope (%/dB) at 50 % and from 20% to 80% for each psychometric function. When solving for the threshold, Equation 2 can be simplified to Equation 3.

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

Calculations of threshold (intensity required for 50% correct perception), slope at 50%, and slope from 20% to 80% were made for each trisyllabic word using the logistic regression slopes and intercepts. Thresholds for the 89 trisyllabic words ranged from -0.8 dB HL to 10.0 dB HL (*M* = 3.8 dB HL) for the male talker words, and from -3.7 dB HL to 11.3 dB HL (*M* = 2.1 dB HL) for the female talker words. Psychometric functions for each trisyllabic word were calculated with Equation 2 using the logistic regression intercept and slope values. The slopes at 50% ranged from 6.9 %/dB to 19.3 %/dB (*M* = 12.7) for the male talker and from 6.3 %/dB to 15.0 %/dB (*M* = 10.0) for the female talker. The slopes from 20-80% ranged from 6.0 %/dB to 16.7 %/dB (*M* = 11.0) for the male talker and from 5.5 %/dB to 13.0 %/dB (*M* = 8.6) for the female talker. Thus, the slopes at 50% threshold were steeper when compared to the slopes at 20-80%. Slopes of the psychometric functions and 50% thresholds for all trisyllabic words are presented in Table 2 (male talker) and Table 3 (female talker).

Words used to measure SRT should have relatively homogeneous and steep psychometric function slopes (Wilson & Strouse, 1999). In order to reduce test time as well as improve reliability, steeper slopes are used. The 28 words that had the steepest psychometric function slopes for both the male and female talker recordings (≥ 10.0 %/dB for both male and female talkers) were selected for inclusion in the final list of trisyllabic 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). Inspection of Figure 1 reveals much less variability in slope of the psychometric functions for the 28 selected words (C-D) when compared to the slopes of

Table 2

Mean Performance for 89 Taiwanese Mandarin Male Trisyllabic SRT Words

#	Word	Romanization	a[a]	b[b]	Slope at 50%[c]	Slope from 20 to 80%[d]	Threshold[e]	ΔdB[f]
1	為什麼	wèishěnme	1.8950	-0.7314	18.3	15.8	2.6	-2.4
2	這樣子	zhèyàngzi	2.5957	-0.5020	12.5	10.9	5.2	0.2
3	怎麼樣	zěnmeyàng	2.1068	-0.4630	11.6	10.0	4.6	-0.4
4	圖書館	túshūguǎn	0.9664	-0.4382	11.0	9.5	2.2	-2.8
5	有時候	yǒushíhou	0.2297	-0.4704	11.8	10.2	0.5	-4.5
6	在一起	zàiyìqǐ	2.6016	-0.5252	13.1	11.4	5.0	0.0
7	不可能	bùkěnéng	1.8891	-0.6770	16.9	14.7	2.8	-2.2
8	不一定	bùyīdìng	5.7061	-0.7711	19.3	16.7	7.4	2.4
9	父母親	fùmǔqīn	3.2061	-0.5149	12.9	11.1	6.2	1.2
10	怎麼辦	zěnmebàn	1.8314	-0.5236	13.1	11.3	3.5	-1.5
11	會不會	huìbúhuì	0.5812	-0.3890	9.7	8.4	1.5	-3.5
12	差不多	chàbùduō	-0.3244	-0.4177	10.4	9.0	-0.8	-5.8
13	大學生	dàxuéshēng	0.5486	-0.5989	15.0	13.0	0.9	-4.1
14	打電話	dǎdiànhuà	0.1541	-0.5041	12.6	10.9	0.3	-4.7
15	女孩子	nǚháizi	1.9219	-0.4110	10.3	8.9	4.7	-0.3
16	台北市	táiběishì	0.3410	-0.5224	13.1	11.3	0.7	-4.3
17	房地產	fángdìchǎn	1.3770	-0.5814	14.5	12.6	2.4	-2.6
18	能不能	néngbùnéng	2.7323	-0.5185	13.0	11.2	5.3	0.3
19	重要性	zhòngyàoxìng	2.3483	-0.4424	11.1	9.6	5.3	0.3
20	工程師	gōngchéngshī	1.5467	-0.7085	17.7	15.3	2.2	-2.8
21	市政府	shìzhèngfǔ	0.7005	-0.5362	13.4	11.6	1.3	-3.7
22	對不起	duìbuqǐ	2.2135	-0.5813	14.5	12.6	3.8	-1.2
23	不景氣	bùjǐngqì	4.0557	-0.4398	11.0	9.5	9.2	4.2
24	好朋友	hǎopéngyou	0.3734	-0.3712	9.3	8.0	1.0	-4.0
25	美國人	měiguórén	1.6653	-0.5227	13.1	11.3	3.2	-1.8
26	旅行社	lǚxíngshè	1.9657	-0.4765	11.9	10.3	4.1	-0.9
27	停車場	tíngchēchǎng	1.0984	-0.4184	10.5	9.1	2.6	-2.4
28	外國人	wàiguórén	0.0613	-0.5334	13.3	11.5	0.1	-4.9
29	要不要	yàobúyào	0.3213	-0.3659	9.1	7.9	0.9	-4.1
30	沒關係	méiguānxi	1.9532	-0.6997	17.5	15.1	2.8	-2.2
31	總統府	zǒngtǒngfǔ	1.1192	-0.4257	10.6	9.2	2.6	-2.4
32	上班族	shàngbānzú	0.3628	-0.4935	12.3	10.7	0.7	-4.3
33	來不及	láibují	2.2434	-0.4308	10.8	9.3	5.2	0.2
34	男孩子	nánháizi	1.1520	-0.4541	11.4	9.8	2.5	-2.5
35	開玩笑	kāiwánxiào	0.5358	-0.6454	16.1	14.0	0.8	-4.2

#	Word	Romanization	a[a]	b[b]	Slope at 50%[c]	Slope from 20 to 80%[d]	Threshold[e]	ΔdB[f]
36	留學生	liúxuéshēng	0.6903	-0.3621	9.1	7.8	1.9	-3.1
37	要不然	yàoburán	1.0865	-0.5580	13.9	12.1	1.9	-3.1
38	負責任	fùzérèn	2.6529	-0.5999	15.0	13.0	4.4	-0.6
39	補習班	bǔxíbān	2.1575	-0.3553	8.9	7.7	6.1	1.1
40	信用卡	xìnyòngkǎ	2.0141	-0.4529	11.3	9.8	4.4	-0.6
41	記者會	jìzhěhuì	3.0580	-0.6618	16.5	14.3	4.6	-0.4
42	小學生	xiǎoxuéshēng	1.2531	-0.4911	12.3	10.6	2.6	-2.4
43	游泳池	yóuyǒngchí	2.3968	-0.6297	15.7	13.6	3.8	-1.2
44	不見了	bújiànle	2.8824	-0.5369	13.4	11.6	5.4	0.4
45	聽起來	tīngqǐlai	3.3599	-0.4867	12.2	10.5	6.9	1.9
46	辦公室	bàngōngshì	1.8366	-0.5944	14.9	12.9	3.1	-1.9
47	建築物	jiànzhùwù	3.3572	-0.5709	14.3	12.4	5.9	0.9
48	一般人	yībānrén	2.5372	-0.4081	10.2	8.8	6.2	1.2
49	看起來	kànqǐlai	1.1334	-0.4847	12.1	10.5	2.3	-2.7
50	董事長	dǒngshìzhǎng	0.7002	-0.4245	10.6	9.2	1.6	-3.4
51	計程車	jìchéngchē	1.3953	-0.4703	11.8	10.2	3.0	-2.0
52	教科書	jiàokēshū	2.5473	-0.5139	12.8	11.1	5.0	0.0
53	音樂會	yīnyuèhuì	1.7800	-0.4424	11.1	9.6	4.0	-1.0
54	說不定	shuōbudìng	1.7630	-0.4897	12.2	10.6	3.6	-1.4
55	動物園	dòngwùyuán	2.3320	-0.4796	12.0	10.4	4.9	-0.1
56	老百姓	lǎobǎixìng	0.0850	-0.4875	12.2	10.5	0.2	-4.8
57	執政黨	zhízhèngdǎng	1.4701	-0.4089	10.2	8.8	3.6	-1.4
58	比方說	bǐfāngshuō	0.6769	-0.3566	8.9	7.7	1.9	-3.1
59	無線電	wúxiàndiàn	3.3182	-0.4484	11.2	9.7	7.4	2.4
60	做生意	zuòshēngyi	3.1809	-0.4924	12.3	10.7	6.5	1.5
61	老人家	lǎorénjiā	1.0624	-0.4570	11.4	9.9	2.3	-2.7
62	運動會	yùndònghuì	2.3209	-0.4466	11.2	9.7	5.2	0.2
63	立法院	lìfǎyuàn	2.5797	-0.6119	15.3	13.2	4.2	-0.8
64	當事人	dāngshìrén	1.6633	-0.5392	13.5	11.7	3.1	-1.9
65	教育部	jiàoyùbù	3.1183	-0.4821	12.1	10.4	6.5	1.5
66	進一步	jìnyībù	6.2038	-0.6360	15.9	13.8	9.8	4.8
67	小孩子	xiǎoháizi	0.9796	-0.5084	12.7	11.0	1.9	3.1
68	越來越	yuèláiyuè	1.8300	-0.6562	16.4	14.2	2.8	-2.2
69	年輕人	niánqīngrén	2.9480	-0.5496	13.7	11.9	5.4	0.4
70	總經理	zǒngjīnglǐ	3.3761	-0.5154	12.9	11.2	6.6	1.6
71	可能性	kěnéngxìng	3.6621	-0.5815	14.5	12.6	6.3	1.3
72	不見得	bújiànde	2.2814	-0.4386	11.0	9.5	5.2	0.2
73	美術館	měishùguǎn	2.0969	-0.4294	10.7	9.3	4.9	-0.1

#	Word	Romanization	a[a]	b[b]	Slope at 50%[c]	Slope from 20 to 80%[d]	Threshold[e]	ΔdB[f]
74	一下子	yīxiàzi	2.3244	-0.2773	6.9	6.0	8.4	3.4
75	感覺到	gǎnjuédào	1.2106	-0.5373	13.4	11.6	2.3	-2.7
76	了不起	liǎobuqǐ	2.2879	-0.6351	15.9	13.7	3.6	-1.4
77	合唱團	héchàngtuán	1.4326	-0.4664	11.7	10.1	3.1	-1.9
78	不得了	bùdéliǎo	1.5886	-0.4289	10.7	9.3	3.7	-1.3
79	受不了	shòubùliǎo	0.1216	-0.6370	15.9	13.8	0.2	-4.8
80	想像力	xiǎngxiànglì	1.9657	-0.4765	11.9	10.3	4.1	-0.9
81	交通部	jiāotōngbù	0.9993	-0.5439	13.6	11.8	1.8	-3.2
82	大規模	dàguīmó	2.6388	-0.5448	13.6	11.8	4.8	-0.2
83	研究所	yánjiūsuǒ	1.8371	-0.5102	12.8	11.0	3.6	-1.4
84	博物館	bówùguǎn	1.5795	-0.4662	11.7	10.1	3.4	-1.6
85	競爭力	jìngzhēnglì	4.1476	-0.5112	12.8	11.1	8.1	3.1
86	感受到	gǎnshòudaò	1.5896	-0.5159	12.9	11.2	3.1	-1.9
87	注意到	zhùyìdaò	4.4840	-0.4492	11.2	9.7	10.0	5.0
88	俱樂部	jùlèbù	2.6030	-0.4542	11.4	9.8	5.7	0.7
89	現階段	xiànjiēduàn	2.1162	-0.6046	15.1	13.1	3.5	-1.5
		average	1.9190	-0.5081	12.7	11.0	3.8	-1.2
		minimum	-0.3244	-0.7711	6.9	6.0	-0.8	-5.8
		maximum	6.2038	-0.2773	19.3	16.7	10.0	5.0
		range	6.5282	0.4937	12.3	10.7	10.8	10.8
		standard deviation	1.1948	0.0917	2.3	2.0	2.3	2.3

Note. [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 (5.00 dB HL)

Table 3

Mean Performance for 89 Taiwanese Mandarin Female Trisyllabic SRT Words

#	Word	Romanization	a[a]	b[b]	Slope at 50%[c]	Slope from 20 to 80%[d]	Threshold[e]	ΔdB[f]
1	為什麼	wèishěnme	1.0319	-0.5857	14.6	12.7	1.8	-3.2
2	這樣子	zhèyàngzi	0.8524	-0.3963	9.9	8.6	2.2	-2.8
3	怎麼樣	zěnmeyàng	1.4532	-0.4686	11.7	10.1	3.1	-1.9
4	圖書館	túshūguǎn	0.7742	-0.3611	9.0	7.8	2.1	-2.9
5	有時候	yǒushíhou	-0.2230	-0.3752	9.4	8.1	-0.6	-5.6
6	在一起	zàiyìqǐ	2.9525	-0.5279	13.2	11.4	5.6	0.6
7	不可能	bùkěnéng	0.9971	-0.4406	11.0	9.5	2.3	-2.7
8	不一定	bùyīdìng	3.4376	-0.5844	14.6	12.6	5.9	0.9
9	父母親	fùmǔqīn	4.6007	-0.4055	10.1	8.8	11.3	6.3
10	怎麼辦	zěnmebàn	0.5679	-0.3351	8.4	7.3	1.7	-3.3
11	會不會	huìbúhuì	0.1905	-0.3718	9.3	8.0	0.5	-4.5
12	差不多	chàbùduō	-0.9126	-0.3389	8.5	7.3	-2.7	-7.7
13	大學生	dàxuéshēng	0.9807	-0.4541	11.4	9.8	2.2	-2.8
14	打電話	dǎdiànhuà	-0.7242	-0.3593	9.0	7.8	-2.0	-7.0
15	女孩子	nǚháizi	1.2899	-0.3510	8.8	7.6	3.7	-1.3
16	台北市	táiběishì	-0.6118	-0.3791	9.5	8.2	-1.6	-6.6
17	房地產	fángdìchǎn	0.5532	-0.4235	10.6	9.2	1.3	-3.7
18	能不能	néngbùnéng	1.2037	-0.3603	9.0	7.8	3.3	-1.7
19	重要性	zhòngyàoxìng	1.5467	-0.3379	8.4	7.3	4.6	-0.4
20	工程師	gōngchéngshī	0.1757	-0.5712	14.3	12.4	0.3	-4.7
21	市政府	shìzhèngfǔ	0.2193	-0.3597	9.0	7.8	0.6	-4.4
22	對不起	duìbuqǐ	-0.2657	-0.3806	9.5	8.2	-0.7	-5.7
23	不景氣	bùjǐngqì	2.1110	-0.3661	9.2	7.9	5.8	0.8
24	好朋友	hǎopéngyou	0.4555	-0.3588	9.0	7.8	1.3	-3.7
25	美國人	měiguórén	0.3572	-0.5061	12.7	11.0	0.7	-4.3
26	旅行社	lǚxíngshè	0.2356	-0.2586	6.5	5.6	0.9	-4.1
27	停車場	tíngchēchǎng	-0.5790	-0.3946	9.9	8.5	-1.5	-6.5
28	外國人	wàiguórén	-1.3670	-0.3672	9.2	7.9	-3.7	-8.7
29	要不要	yàobúyào	-0.3811	-0.3337	8.3	7.2	-1.1	-6.1
30	沒關係	méiguānxi	1.2476	-0.3872	9.7	8.4	3.2	-1.8
31	總統府	zǒngtǒngfǔ	-0.2233	-0.3650	9.1	7.9	-0.6	-5.6
32	上班族	shàngbānzú	-0.3492	-0.3708	9.3	8.0	-0.9	-5.9
33	來不及	láibují	0.3561	-0.3437	8.6	7.4	1.0	-4.0
34	男孩子	nánháizi	-0.5686	-0.3172	7.9	6.9	-1.8	-6.8
35	開玩笑	kāiwánxiào	-0.7306	-0.4095	10.2	8.9	-1.8	-6.8

#	Word	Romanization	a[a]	b[b]	Slope at 50%[c]	Slope from 20 to 80%[d]	Threshold[e]	ΔdB[f]
36	留學生	liúxuéshēng	1.3159	-0.5311	13.3	11.5	2.5	-2.537
	要不然	yàoburán	-0.7590	-0.3517	8.8	7.6	-2.2	-7.2
38	負責任	fùzérèn	-0.6867	-0.4635	11.6	10.0	-1.5	-6.5
39	補習班	bǔxíbān	0.7158	-0.2524	6.3	5.5	2.8	-2.2
40	信用卡	xìnyòngkǎ	2.3295	-0.3602	9.0	7.8	6.5	1.5
41	記者會	jìzhěhuì	0.0081	-0.4257	10.6	9.2	0.0	-5.0
42	小學生	xiǎoxuéshēng	0.1284	-0.3996	10.0	8.6	0.3	-4.7
43	游泳池	yóuyǒngchí	-0.3193	-0.4309	10.8	9.3	-0.7	-5.7
44	不見了	bújiànle	3.7344	-0.5436	13.6	11.8	6.9	1.9
45	聽起來	tīngqǐlai	1.2725	-0.3046	7.6	6.6	4.2	-0.8
46	辦公室	bàngōngshì	-0.9503	-0.3970	9.9	8.6	-2.4	-7.4
47	建築物	jiànzhùwù	1.8379	-0.4420	11.0	9.6	4.2	-0.8
48	一般人	yībānrén	1.4447	-0.3616	9.0	7.8	4.0	-1.0
49	看起來	kànqǐlai	-0.2643	-0.3553	8.9	7.7	-0.7	-5.7
50	董事長	dǒngshìzhǎng	0.2988	-0.3289	8.2	7.1	0.9	-4.1
51	計程車	jìchéngchē	-0.0475	-0.3095	7.7	6.7	-0.2	-5.2
52	教科書	jiàokēshū	-0.8536	-0.4323	10.8	9.4	-2.0	-7.0
53	音樂會	yīnyuèhuì	0.3885	-0.2939	7.3	6.4	1.3	-3.7
54	說不定	shuōbudìng	1.7538	-0.4992	12.5	10.8	3.5	-1.5
55	動物園	dòngwùyuán	1.6885	-0.4153	10.4	9.0	4.1	-0.9
56	老百姓	lǎobǎixìng	0.2781	-0.2659	6.6	5.8	1.0	-4.0
57	執政黨	zhízhèngdǎng	0.8156	-0.3159	7.9	6.8	2.6	-2.4
58	比方說	bǐfāngshuō	-0.3409	-0.3250	8.1	7.0	-1.0	-6.0
59	無線電	wúxiàndiàn	2.3295	-0.3602	9.0	7.8	6.5	1.5
60	做生意	zuòshēngyi	2.0354	-0.3511	8.8	7.6	5.8	0.8
61	老人家	lǎorénjiā	-0.4267	-0.3524	8.8	7.6	-1.2	-6.2
62	運動會	yùndònghuì	0.3397	-0.4358	10.9	9.4	0.8	-4.2
63	立法院	lìfǎyuàn	0.4595	-0.4209	10.5	9.1	1.1	-3.9
64	當事人	dāngshìrén	-0.0524	-0.3825	9.6	8.3	-0.1	-5.1
65	教育部	jiàoyùbù	1.8745	-0.4281	10.7	9.3	4.4	-0.6
66	進一步	jìnyībù	3.7226	-0.4661	11.7	10.1	8.0	3.0
67	小孩子	xiǎoháizi	0.0454	-0.4079	10.2	8.8	0.1	-4.9
68	越來越	yuèláiyuè	1.0637	-0.4490	11.2	9.7	2.4	-2.6
69	年輕人	niánqīngrén	2.3486	-0.3955	9.9	8.6	5.9	0.9
70	總經理	zǒngjīnglǐ	3.4981	-0.5156	12.9	11.2	6.8	1.8
71	可能性	kěnéngxìng	3.5131	-0.4673	11.7	10.1	7.5	2.5
72	不見得	bújiànde	2.0329	-0.4029	10.1	8.7	5.0	0.0
73	美術館	měishùguǎn	0.4586	-0.3365	8.4	7.3	1.4	-3.6

#	Word	Romanization	a[a]	b[b]	Slope at 50%[c]	Slope from 20 to 80%[d]	Threshold[e]	ΔdB[f]
74	一下子	yīxiàzi	1.5986	-0.2541	6.4	5.5	6.3	1.3
75	感覺到	gǎnjuédào	1.3168	-0.3829	9.6	8.3	3.4	-1.6
76	了不起	liǎobuqǐ	1.1182	-0.5993	15.0	13.0	1.9	-3.1
77	合唱團	héchàngtuán	0.5106	-0.4253	10.6	9.2	1.2	-3.8
78	不得了	bùdéliǎo	-0.1254	-0.4954	12.4	10.7	-0.3	-5.3
79	受不了	shòubùliǎo	-0.3566	-0.3989	10.0	8.6	-0.9	-5.9
80	想像力	xiǎngxiànglì	1.7426	-0.3757	9.4	8.1	4.6	-0.4
81	交通部	jiāotōngbù	0.1846	-0.3260	8.1	7.1	0.6	-4.4
82	大規模	dàguīmó	1.8212	-0.4754	11.9	10.3	3.8	-1.2
83	研究所	yánjiūsuǒ	2.0141	-0.4504	11.3	9.7	4.5	-0.5
84	博物館	bówùguǎn	-0.1145	-0.3226	8.1	7.0	-0.4	-5.4
85	競爭力	jìngzhēnglì	2.7981	-0.3324	8.3	7.2	8.4	3.4
86	感受到	gǎnshòudaò	-0.0405	-0.4179	10.4	9.0	-0.1	-5.1
87	注意到	zhùyìdaò	4.2441	-0.4522	11.3	9.8	9.4	4.4
88	俱樂部	jùlèbù	1.3139	-0.3361	8.4	7.3	3.9	-1.1
89	現階段	xiànjiēduàn	1.4738	-0.5941	14.9	12.9	2.5	-2.5
		average	0.8673	-0.3996	10.0	8.6	2.1	-2.9
		minimum	-1.3670	-0.5993	6.3	5.5	-3.7	-8.7
		maximum	4.6007	-0.2524	15.0	13.0	11.3	6.3
		range	5.9678	0.3469	8.7	7.5	15.1	15.1
		standard deviation	1.2924	0.0774	1.9	1.7	3.1	3.1

Note. [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 (5.00 dB HL)

Table 4

Mean Performance for 28 Selected Taiwanese Mandarin Male Trisyllabic SRT Words

#	Word	Romanization	a[a]	b[b]	Slope at 50%[c]	Slope from 20 to 80%[d]	Threshold[e]	ΔdB[f]
1	為什麼	wèishěnme	1.8950	-0.7314	12.2	10.6	2.6	-2.4
2	怎麼樣	zěnmeyàng	2.1068	-0.4630	10.3	8.9	4.6	-0.4
3	在一起	zàiyìqǐ	2.6016	-0.5252	10.8	9.3	5.0	0.0
4	不可能	bùkěnéng	1.8891	-0.6770	11.8	10.2	2.8	-2.2
5	不一定	bùyīdìng	5.7061	-0.7711	12.0	10.4	7.4	2.4
6	房地產	fángdìchǎn	1.3770	-0.5814	10.3	8.9	2.4	-2.6
7	工程師	gōngchéngshī	1.5467	-0.7085	10.9	9.4	2.2	-2.8
8	美國人	měiguórén	1.6653	-0.5227	13.1	11.3	3.2	-1.8
9	記者會	jìzhěhuì	3.0580	-0.6618	10.5	9.1	4.6	-0.4
10	不見了	bújiànle	2.8824	-0.5369	10.7	9.3	5.4	0.4
11	建築物	jiànzhùwù	3.3572	-0.5709	10.2	8.8	5.9	0.9
12	說不定	shuōbudìng	1.7630	-0.4897	10.7	9.3	3.6	-1.4
13	動物園	dòngwùyuán	2.3320	-0.4797	11.3	9.8	4.9	-0.1
14	運動會	yùndònghuì	2.3209	-0.4466	10.4	9.0	5.2	0.2
15	立法院	lìfǎyuàn	2.5797	-0.6119	12.3	10.7	4.2	-0.8
16	教育部	jiàoyùbù	3.1183	-0.4821	10.6	9.2	6.5	1.5
17	小孩子	xiǎoháizi	0.9796	-0.5084	14.0	12.1	1.9	-3.1
18	越來越	yuèláiyuè	1.8300	-0.6562	12.5	10.8	2.8	-2.2
19	總經理	zǒngjīnglǐ	3.3761	-0.5154	11.1	9.6	6.6	1.6
20	可能性	kěnéngxìng	3.6621	-0.5815	11.2	9.7	6.3	1.3
21	不見得	bújiànde	2.2814	-0.4386	11.0	9.6	5.2	0.2
22	了不起	liǎobuqǐ	2.2879	-0.6351	11.0	9.6	3.6	-1.4
23	合唱團	héchàngtuán	1.4326	-0.4664	11.0	9.6	3.1	-1.9
24	不得了	bùdéliǎo	1.5886	-0.4289	11.0	9.6	3.7	-1.3
25	大規模	dàguīmó	2.6388	-0.5448	11.0	9.6	4.8	-0.2
26	研究所	yánjiūsuǒ	1.8371	-0.5102	11.0	9.6	3.6	-1.4
27	感受到	gǎnshòudaò	1.5896	-0.5159	11.0	9.6	3.1	-1.9
28	現階段	xiànjiēduàn	2.1162	-0.6046	11.0	9.6	3.5	-1.5
		average	2.4918	-0.5695	11.3	9.8	4.4	-0.6
		minimum	0.9796	-0.7711	10.2	8.8	1.9	-3.1
		maximum	5.7061	-0.4386	14.0	12.1	7.4	2.4
		range	4.7266	0.3325	3.8	3.3	5.5	5.5
		standard deviation	1.0286	0.0983	1.0	0.9	1.6	1.6

Note. [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 (5.00 dB HL)

Table 5

Mean Performance for 28 Selected Taiwanese Mandarin Female Trisyllabic SRT Words

#	Word	Romanization	a[a]	b[b]	Slope at 50%[c]	Slope from 20 to 80%[d]	Threshold[e]	ΔdB[f]
1	為什麼	wèishěnme	1.0319	-0.5857	11.5	10.0	-0.6	-3.2
2	怎麼樣	zěnmeyàng	1.4532	-0.4686	15.1	13.1	0.1	-1.9
3	在一起	zàiyìqǐ	2.9525	-0.5279	10.8	9.3	3.0	0.6
4	不可能	bùkěnéng	0.9971	-0.4406	12.5	10.8	-0.9	-2.7
5	不一定	bùyīdìng	3.4376	-0.5844	12.1	10.5	3.5	0.9
6	房地產	fángdìchǎn	0.5532	-0.4235	10.9	9.5	-2.0	-3.7
7	工程師	gōngchéngshī	0.1757	-0.5712	14.9	12.9	-2.1	-4.7
8	美國人	měiguórén	0.3572	-0.5061	12.4	10.7	-2.0	-4.3
9	記者會	jìzhěhuì	0.0081	-0.4257	12.4	10.7	-3.2	-5.0
10	不見了	bújiànle	3.7344	-0.5436	10.3	8.9	4.3	1.9
11	建築物	jiànzhùwù	1.8379	-0.4420	12.0	10.4	1.0	-0.8
12	說不定	shuōbudìng	1.7538	-0.4992	10.6	9.2	0.7	-1.5
13	動物園	dòngwùyuán	1.6885	-0.4153	12.3	10.6	0.7	-0.9
14	運動會	yùndònghuì	0.3397	-0.4358	11.7	10.1	-2.4	-4.2
15	立法院	lìfǎyuàn	0.4595	-0.4209	12.2	10.5	-2.2	-3.9
16	教育部	jiàoyùbù	1.8745	-0.4281	18.1	15.6	1.1	-0.6
17	小孩子	xiǎoháizi	0.0454	-0.4079	11.7	10.1	-3.3	-4.9
18	越來越	yuèláiyuè	1.0637	-0.4490	12.9	11.2	-0.7	-2.6
19	總經理	zǒngjīnglǐ	3.4981	-0.5155	11.4	9.8	4.1	1.8
20	可能性	kěnéngxìng	3.5131	-0.4673	10.0	8.7	4.6	2.5
21	不見得	bújiànde	2.0329	-0.4029	10.0	8.7	1.6	0.0
22	了不起	liǎobuqǐ	1.1182	-0.5993	10.0	8.7	-0.4	-3.1
23	合唱團	héchàngtuán	0.5106	-0.4253	10.0	8.7	-2.1	-3.8
24	不得了	bùdéliǎo	-0.1254	-0.4954	10.0	8.7	-3.1	-5.3
25	大規模	dàguīmó	1.8212	-0.4754	10.0	8.7	0.9	-1.2
26	研究所	yánjiūsuǒ	2.0141	-0.4504	10.0	8.7	1.4	-0.5
27	感受到	gǎnshòudaò	-0.0405	-0.4179	10.0	8.7	-3.4	-5.1
28	現階段	xiànjiēduàn	1.4738	-0.5941	12.1	10.4	0.1	-2.5
		average	1.4136	-0.4793	11.7	10.1	0.0	-2.1
		minimum	-0.1254	-0.5993	10.0	8.7	-3.4	-5.3
		maximum	3.7344	-0.4029	18.1	15.6	4.6	2.5
		range	3.8598	0.1964	8.1	7.0	8.0	7.8
		standard deviation	1.1743	0.0633	1.9	1.6	2.4	2.3

Note. [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 (5.00 dB HL)

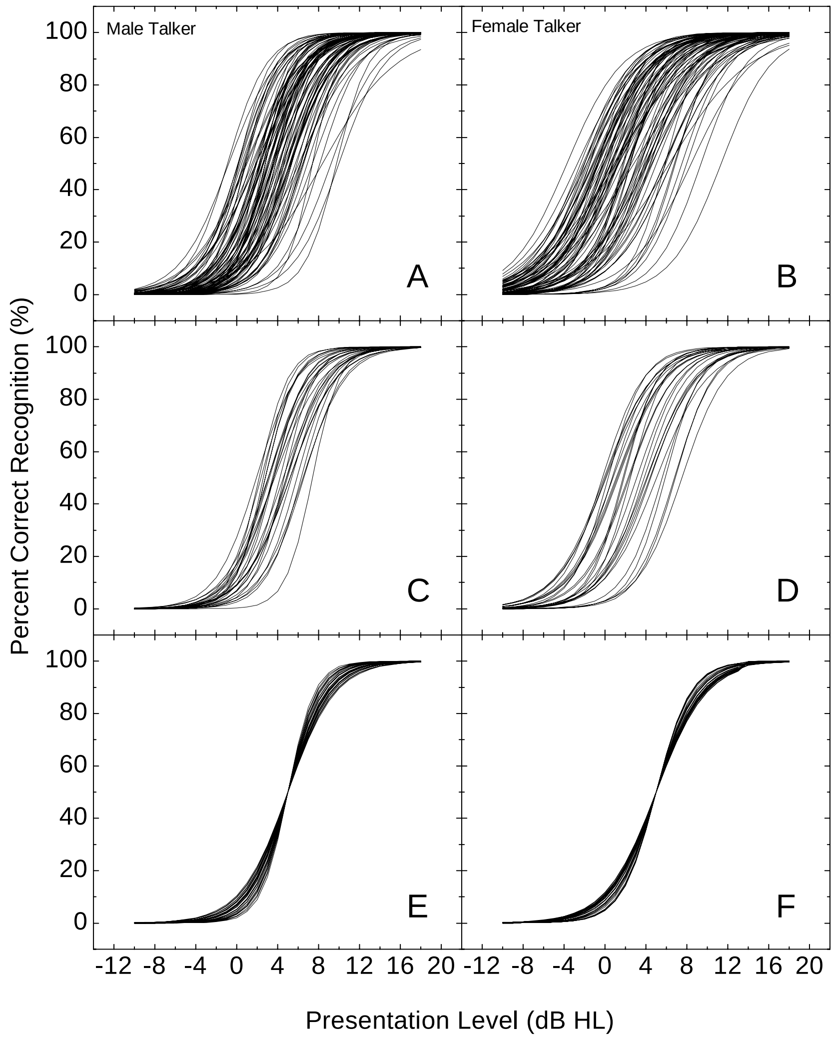

Figure 1. Psychometric functions for Taiwan Mandarin trisyllabic words for male talker (left panels) and female talker (right panels) recordings. All 89 unadjusted words (top panels A-B), 28 selected unadjusted words (middle panels C-D), and 28 selected adjusted words (bottom panels E-F). The 28 selected adjusted words were digitally adjusted to have 50% thresholds equal to the mean PTA (5.0 dB HL) for the 20 normally hearing subjects.

the entire group of 89 words (A-B). Figure 2 (male talker) and Figure 3 (female talker) contain the psychometric 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 functions for the selected 28 words are shown in the middle panels (C-D) of Figure 1. The psychometric function slopes for the 28 selected words, at 50% threshold, ranged from 10.2 %/dB to 14.0 %/dB (M = 11.3 %/dB) for the male talker recording and from 10.0 %/dB to 18.1 %/dB (M = 11.7 %/dB) for the female talker.

To decrease the variability that still existed across the thresholds of the final 28 words, the intensity of each of these words was digitally adjusted so that the 50% threshold of each word was equal to the mean PTA of the subjects (5.0 dB HL). The necessary adjustments for each of the 28 selected words for the male and female talker recordings are presented in Table 4 and Table 5. The bottom panels of Figure 1 contain predicted psychometric functions for the 28 selected words after intensity adjustment to equate 50% thresholds for the male talker (E) and female talker (F). Figure 4 shows the mean psychometric functions for the selected 28 words for both male and female talker, demonstrating the slightly steeper mean slope for the female talker recordings (11.7 %/dB) compared to the male talker recordings (11.3 %/dB).

Discussion

The aims of this study were to develop, digitally record, and adjust speech materials to use for SRT testing with native speakers of Taiwan Mandarin. A list of 28 trisyllabic words were developed that are relatively homogeneous in performance with respect to audibility and psychometric function slope. These words were recorded by a

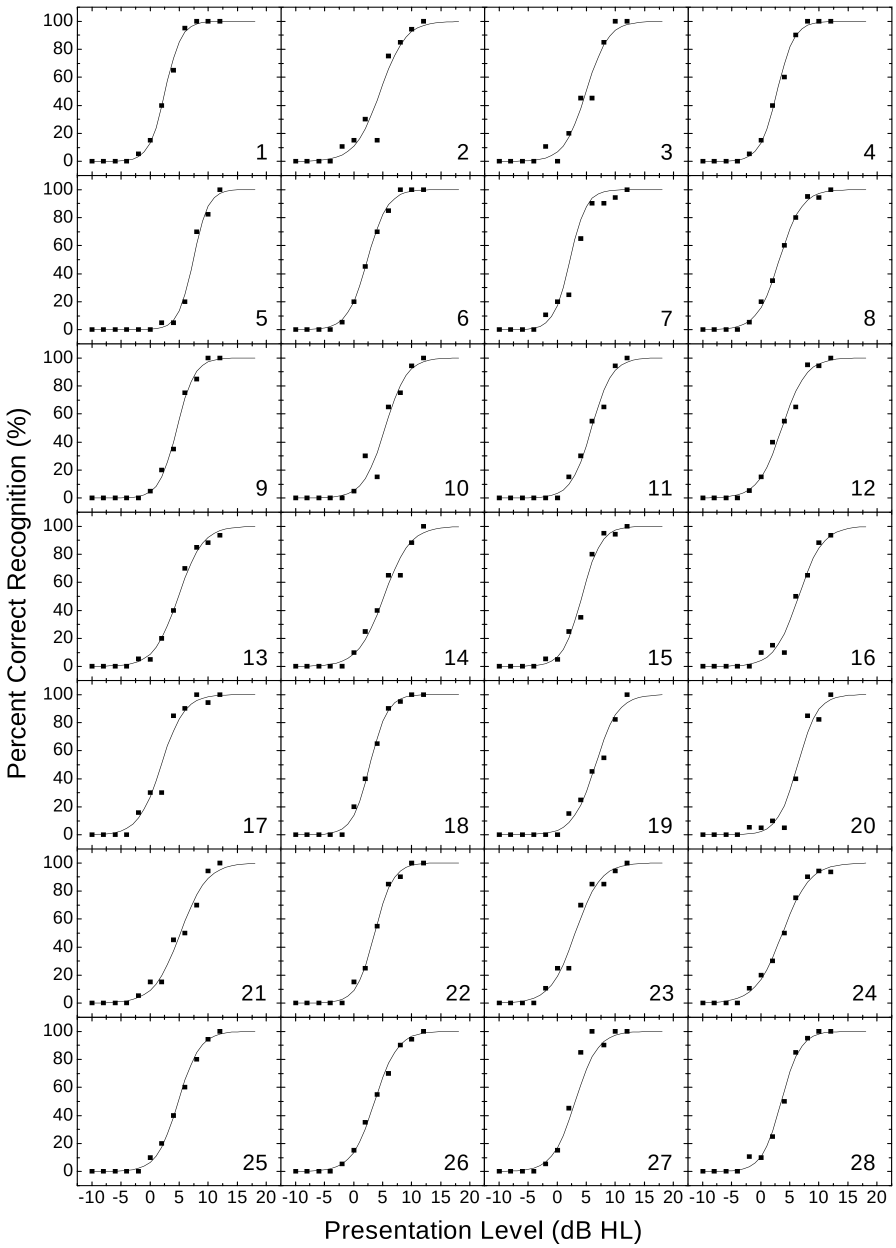

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Figure 2. Psychometric functions for the 28 selected unadjusted Taiwan Mandarin trisyllabic words spoken by a male talker. The functions were calculated using logistic regression; the symbols represent mean percentage of correct recognition calculated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

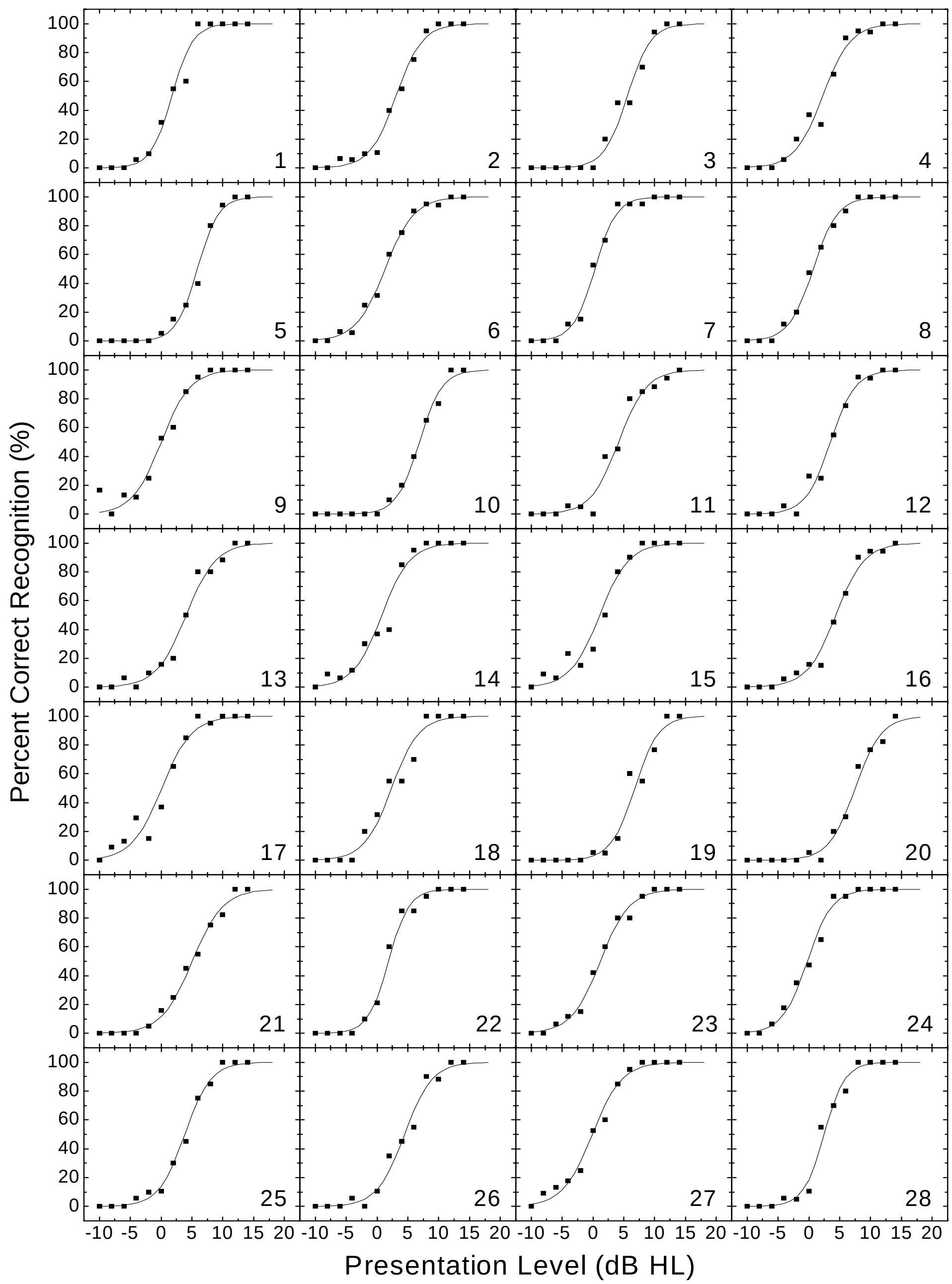

Figure 3. Psychometric functions for the 28 selected unadjusted Taiwan Mandarin trisyllabic words spoken by a female talker. The functions were calculated using logistic regression; the symbols represent mean percentage of correct recognition calculated from the raw data for 20 normally hearing subjects.

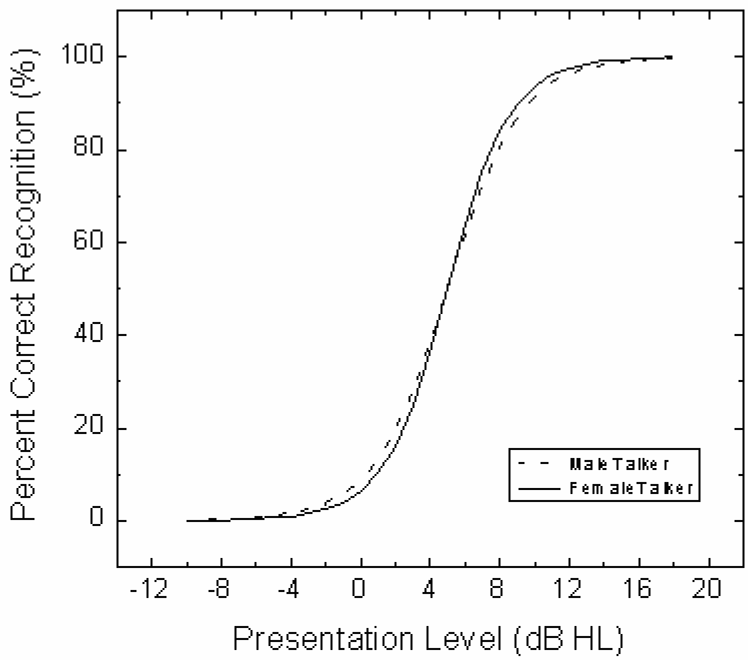

Figure 4. Mean psychometric functions for 28 selected Taiwan Mandarin male and female talker trisyllabic words after intensity adjustment to equate 50% threshold performance to the mean PTA (5.0 dB HL) for the 20 normally hearing subjects.

male and a female native Taiwan Mandarin talker. A CD with digital recordings of the selected adjusted words was then created and included with this project.

The 28 trisyllabic words are much more homogeneous with respect to audibility and psychometric function slope than the original unadjusted trisyllabic words. This difference can be seen in the different panels of Figure 1. The means for the slopes in the trisyllabic psychometric functions are similar with the means for SRT materials that have been reported in other languages. The mean slope for spondaic words in English has generally been reported between 7.2 %/dB and 10.0 %/dB (Hirsh et al., 1952; Hudgins, Hawkins, Karlin, & Stevens, 1947; Wilson & Strouse, 1999; Young et al., 1982), but has been as high as 12.0 %/dB (Beattie, Edgerton, & Svihovec, 1977; Ramkissoon, 2001). Materials developed for Spanish speakers, have been reported to have slope values of 11.1 %/dB for a male talker and 9.7 %/dB for a female talker (Christensen, 1995). In Japanese, the mean slope for trisyllabic words developed for SRT measurement had a slope of 8.9 %/dB for a male talker and 7.6 %/dB for a female talker recording (Mangum, 2005).

The means for the slopes from 20 to 80% for both the male and female talker in the trisyllabic psychometric functions are also in close agreement with the means for SRT materials developed in Pǔtōnghuà (Nissen et al., 2005). The mean slopes from 20 to 80% in Pǔtōnghuà were reported as 9.7 %/dB for the male talker and 10.5 %/dB for the female talker, reflecting a concurrence between Taiwan Mandarin and Pǔtōnghuà. At 50%, the mean in Pǔtōnghuà was reported as 11.3 %/dB (with a minimum of 9.2 %/dB and maximum of 17.6 %/dB) for the male talker and 12.1 %/dB (with a minimum of 9.4 %/dB and maximum of 18.1 %/dB) for the female talker. In Taiwan Mandarin, it is

11.3 %/dB (ranging from 10.2 %/dB to 14.0 %/dB) for the male talker and is 11.7 %/dB (ranging from 10.0 %/dB to 18.1 %/dB) for the female talker. These findings show that although the 50% mean is quite similar, there was a greater degree of variability between the words in Pǔtōnghuà than the materials developed in Taiwan Mandarin.

Although the development of these materials is an important first step, there remains a need for further extension of our knowledge in the area of Taiwan Mandarin speech audiometry. It is unclear whether these same words, if given to be tested a second time would provide the same results. As this is the first test developed in Taiwan Mandarin, a possible next step would be to examine the test-retest reliability of the words. According to Gelfand (1998), the test and retest scores should be highly correlated and not show a significant difference in order for the test to be reliable.

Another possible area to study would be to look at how dialectical differences might affect the performance of a list of words. For instance, it would be of interest to investigate how native speakers from the mainland would perceive the materials spoken by a native of Taiwan. Weisleder & Hodgson (1989) found when testing native Spanish speakers in Spanish presented by a talker of Mexican origin that although all the participants reported that the talker's speech intelligibility was very clear, the participants of Mexican origin obtained better scores than the participants of other nationalities. Interestingly, differences were only found at the low presentation levels. These findings suggest that perhaps a listener with a different dialect may perceive a talker's intelligibility to be clear, but the results of the hearing test reflect a lower score than the listener has.

In this study, the materials were tested on normally hearing individuals. A logical and important next step would be to test the materials on individuals who have hearing impairments, as eventually the materials created are to be used with individuals with possible hearing impairments. McArdle and Wilson (2006) found in a recent study that there is a significant difference in the performance of individuals with normal hearing and those with hearing impairment. It has been suggested that the lists, in order to establish a more accurate test, need to be tested on the population for which the test is intended (Jerger, 2006). Therefore, further testing on the population of individuals whose primary language is Taiwan Mandarin and who have a hearing impairment should be conducted.

Another possible area of study specific to Taiwan Mandarin speech audiometry may be to develop a test appropriate to use with children. In Arabic, a test for children has been developed using pictures. These materials also use words that are more familiar to the juvenile listener, which are norm referenced for children (Ashoor & Prochazka, 1985). Since the materials developed in this study were not created with the intention of testing children, the words chosen and used may not be age appropriate for younger listeners.

Other areas that may be of interest for further study include, but are not limited to, the evaluation of the influence of the talker's gender, examining the effect of word list length on listener performance, and other dialects of Chinese (i.e., Cantonese). In addition, there is a need for further testing using the speech audiometric materials developed and audiometric masking on normal hearing individuals and individuals with hearing impairments should be done in order to ensure comparable results from different test measures and to help determine the appropriate intervention strategy with amplification (Wagener & Brand, 2005; Wilson & McArdle, 2005).

Conclusion

In summary, this study resulted in the development of digitally recorded male and female talker recordings of 28 trisyllabic words that are relatively homogeneous in relation to audibility and psychometric function slope. These 28 trisyllabic words can be used to measure SRT in individuals whose native language is Taiwan Mandarin. The threshold variability for the trisyllabic words is significantly reduced by the adjustments in intensity of individual words which were part of this study. The results from this experiment were used to produce a CD of digitally recorded materials to use in Taiwan Mandarin SRT testing, a description of which 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 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 our 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 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. 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, Utah 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 TAIWAN MANDARIN CD 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	您將聽到一系列音量大小變化的單詞. 當您一聽到單詞時，請重複一遍. 如果您不確定您聽到的單詞是什麼，請盡量猜. 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	您將聽到一系列音量大小不變的單詞. 當您聽到單詞時，請重複一遍. 如果您不確定您聽的單詞是什麼，請盡量猜. Instructions for word recognition-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	這一部分您會在一耳聽到噪音，在另外一耳聽到單詞. 請忽略噪音並重複您聽到的單詞. 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

您將聽到一系列音量大小不變的單詞. 當您聽到單詞時，請把它寫下來. 如果不確定您聽的單詞是什麼請盡量猜.

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:

這一部分您會在一耳聽到噪音，在另一耳聽到一個單詞. 請忽略噪音並寫下你聽到的單詞.

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:

您將聽到一系列音調高低變化的哨音. 只要您聽到哨音，請馬上舉手.

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:

這一部分您會在一耳聽到哨音，在另一耳聽到噪音. 請忽略噪音，聽到哨音後馬上舉手.

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:

您將聽到一系列音調高低變化的哨音. 當您一聽到哨音，請馬上按鈕. 當哨音停止時，請停止按鈕. 即使不確定，您覺得聽到了一個哨音還是要按鈕.

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:

這一部分您會在一耳聽到哨音，在另一耳聽到噪音. 請忽略噪音並且一聽到哨音，請馬上按鈕.

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:

這個部分是測試您在聽到一系列音量大小不變的單詞時的聽力水平. 每聽到一個單詞, 請重複一遍. 如果您不確定這個單詞是什麼, 請盡量猜.
如果您聽不到任何單詞也無法猜出它, 請安靜地等到下一個單詞.
Instructions for word recognition-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:

這個部分您會在一耳聽到噪音，在另一耳聽到單詞. 請忽略噪音，而只注意聽單詞. 每聽到單詞時，請重複那個單詞一遍. 如果不確定您聽的單詞是什麼，請盡量猜. 如果不確定您聽的單詞也無法猜，請安靜地等到下一個單詞.
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:

這個部分是測試你在聽到一些音量大小不變的單詞時的聽力水平. 每聽到一個單詞，請您在我們給您的紙上寫下那個單詞. 如果不確定您聽的單詞是什麼，請盡量猜. 如果您也無法猜，請在空格裡劃一條線. 劃完後以後請安靜地等到下一個單詞.
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."