

PSYCHOMETRICALLY EQUIVALENT BISYLLABIC WORDS FOR SPEECH
RECEPTION THRESHOLD TESTING IN MONGOLIAN

by

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ABSTRACT

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Speech audiometry is an important aspect of audiological testing. One aspect of speech audiometry is the measurement of an individual's speech reception threshold (SRT). Materials needed to measure the SRT are available in many languages; however, recorded materials for the Mongolian Language are not widely available. The purpose of this study was to develop a list of psychometrically equivalent words for evaluating the hearing abilities of native Mongolian speaking individuals. A set of 90 commonly used bisyllabic Mongolian words were digitally recorded by a male and female talker of Mongolian and then evaluated by 20 native Mongolian listeners. A final list of 28 words with relatively steep psychometric function slopes were selected and digitally adjusted to reduce intensity threshold variability among words. Digital recordings of the 28 psychometrically equivalent bisyllabic words are available on compact disc to facilitate SRT testing of native Mongolian speakers.

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Introduction

The purpose of an audiological evaluation is to detect the presence of hearing loss, and if so, the type and severity of the hearing impairment. To accurately establish an individual's hearing ability and if necessary the appropriate intervention, it is important that a hearing evaluation consists of a variety of diagnostic procedures. Such procedures may include but are not limited to pure-tone audiometry, otoscopy, tympanometry, acoustic reflex testing, and otoacoustic emissions.

The most commonly used diagnostic test in evaluating an individual's hearing acuity is pure-tone audiometry. Pure-tone audiometry is the measurement of an individual's hearing sensitivity for calibrated sinusoidal tones at different intensities and frequencies. However as discussed by Egan (1979), the pure-tone average (PTA) provides minimal information toward determining the effect of hearing impairment on an individual's communication abilities.

Otosopic examination can be used to examine the health and function of the external auditory meatus and the tympanic membrane. Tympanometry is often performed to evaluate the function of the middle ear and can also be helpful in distinguishing between sensorineural and conductive hearing loss. Acoustic reflexes measure the stapedius and tensor tympani reflex generated eardrum movement in response to intense sound. An evaluation of these reflexes can be helpful in corroborating hearing loss in situations where patient reliability is questionable, as well as indicating the possible presence of central nervous system pathology. In addition, the status of an individual's cochlear status can be examined through otoacoustic emission testing.

Despite the diagnostic value of these types of hearing procedures, to more completely understand the potential communicative impact of a patient's hearing

impairment, diagnostic measures which evaluate the ability to perceive and understand speech are needed. A type of hearing testing whereby an individual's hearing is examined through their ability to perceive words or sentences is speech audiometry. It is important that individuals be evaluated with materials in their native language for speech audiometry testing to be a valid and accurate measure (Ramkissoon, 2001). Speech audiometry materials have been developed in English and many other languages, however, high-quality digital materials do not currently exist for the Mongolian language. Thus, this study intended to develop, evaluate, and digitally record materials for evaluating the hearing of native speakers of Mongolian.

Review of Literature

Speech Reception Threshold Testing

Beyond basic pure-tone testing, speech audiometry further evaluates a listener's ability to hear, recognize, and understand the speech communication that is encountered in our everyday environment (Young, Dudley, & Gunter, 1982). Instead of only using pure-tone stimuli to evaluate an individual's degree of hearing loss, it is paramount to evaluate an individual's ability to process the more complex acoustic signals characteristic of speech (Martin, Champlin, & Perez, 2000; Ramkissoon, 2001; Weisleder & Hodgson, 1989). Thibodeau (2007) pointed out that two patients with the same degree of hearing loss may demonstrate very different speech processing difficulties, which may in part lead to a difference in recommended clinical intervention (e.g., hearing aid selection and setting). Therefore, properly conducted speech audiometry is an important step in lessening the disabling effect of an individual's hearing impairment.

One type of speech audiometry commonly used to evaluate the speech perception abilities of an individual is speech reception threshold (SRT) testing. The SRT has been defined as the minimum hearing level at which an individual can recognize 50% of the speech material presented. SRT testing can be used to validate pure tone air-conduction threshold results, provide an index of hearing sensitivity for speech, and serve as the baseline for determining the presentation levels for subsequent suprathreshold speech recognition tests.

Before the 20th century, SRT values were measured by having the patient repeat words or sentences that were whispered or spoken (Brandy, 2002). Although the procedure of repeating sentences was an attempt at making hearing tests more functional, it only provided a gross estimate of an individual's ability to hear speech.

In the mid 1900s, scientists at Bell Telephone Laboratories began studying speech as an auditory signal to test new telephone equipment. It became obvious to these early investigators that the process of speech perception was far more complex than simply perceiving a set of sinusoidal tones. In addition to the acoustic characteristics of conversational speech, linguistic and psychological factors also had to be considered when evaluating an individual's ability to communicate effectively (Brandy, 2002).

In 1926, Bell Telephone Laboratories developed the Western Electric 4A, an SRT test which utilized a phonographic recording of spoken digits (ASHA, 1988). The rationale for using digits as stimuli was their high familiarity and ease in testing very young children (ASHA, 1988; Hudgins, Hawkins, Karlin, & Stevens, 1947).

Today the basic model used for the clinical measurement of speech thresholds is a relatively limited number of familiar words. An early set of SRT words was developed at the Psycho-Acoustic Laboratory (PAL) at Harvard (Hudgins et al., 1947). Initially this set of SRT materials contained two lists of 42 spondaic words (bisyllabic words with approximately equal stress on each syllable) recorded by a male talker. Subsequent analysis indicated that some of the words were not highly familiar to many individuals. Thus the lists were later reduced to 36 of the most familiar spondees by the Central Institute for the Deaf as Auditory Tests W-1 and W-2 (Hirsh et al., 1952). More recently, an examination of the words' homogeneity of audibility has led to an additional reduction to 20 spondees, with the easiest and most difficult to perceive words being eliminated from the lists (Brandy, 2002).

Development of valid and reliable SRT materials. Considerable research has addressed the validity and reliability of SRT testing. In an effort to standardize testing

across audiological settings, it is recommended that audiologists conducting SRT tests adhere to the guidelines set forth by ASHA in 1988. In addition, SRT materials should be developed in a manner that results in stimuli that can be used to evaluate an individual's speech perception abilities in an accurate and reliable manner. When developing speech audiometric materials the following criteria should be taken into consideration: (a) mode of presentation, (b) phonetic dissimilarity, (c) homogeneity of audibility, (d) word familiarity, and (e) dialect of the talker (Harris, Nielson, McPherson, & Skarzynski, 2004; Hudgins et al., 1947).

Mode of presentation. In obtaining SRT measures, audiologists often use either a monitored-live-voice technique or recorded materials. Recorded materials are the mode of presentation that has been endorsed by the ASHA Committee on Audiologic Evaluation (ASHA, 1988). Using recorded materials ensures that the test is standardized across different test administrators, diagnostic sessions, and clinical settings. Digital recordings are preferred over tape recordings due to increased sound quality, presentation versatility, and storage durability (Kamm, Carterette, Morgan, & Dirks, 1980; Ridgway, 1986).

Phonetic dissimilarity. Test items need to be phonetically dissimilar to avoid negative effects on spoken word recognition. Phonetic dissimilarity ensures that the words do not provide additional auditory cues like those found in rhyming words (Ramkisson, 2001). Research has indicated that lexical items may be organized in an individual's mental lexicon according to semantic or phonologic properties, thereby creating a series of similarity neighborhoods (Dirks, Takayanagi, & Moshfegh, 2001). Bradlow and Pisoni (1999) found that lexical characteristics of particular words in a

stimulus set exert a strong influence on overall intelligibility. Dirks et al. (2001) performed an investigation to examine the effects of lexical difficulty on spoken word recognition. Results from this investigation revealed that easy words produced more favorable performance levels than difficult words at an equal intelligibility. Lexically easy words are defined as being words that occur frequently in the language, and have few phonetically similar neighbors with which they could be confused. In contrast, lexically difficult words have many neighbors, making them highly confusable during threshold testing.

Homogenous audibility. It is also important that SRT words are homogeneous with respect to audibility. The audibility of a test word can be measured in terms of psychometric threshold and slope. The psychometric slope relates to the percentage of correct recognition as a function of intensity, with the psychometric threshold being related to the intensity intercept of the psychometric function. As speech audiometry stimuli increase in homogeneity, the results of the SRT evaluation become more precise (Wilson & Carter, 2001).

Word familiarity. The objective of SRT testing is to measure an individual's threshold for perceiving a stimulus word. To arrive at this objective, the words presented during the test should be highly familiar to the listener. Familiarity helps to eliminate the possibility that an individual's perception of a test word was not influenced by their receptive vocabulary or education level. It is also recommended that an individual is briefly familiarized with the presentation words prior to testing (ASHA, 1988).

A factor to consider when evaluating an individual's hearing is that not all clients are proficient speakers of English. For non-native English speakers, listening to words

that are unfamiliar reduces the value of SRT measurements obtained under non-native testing conditions (Ramkissoon, 2001). The problem of non-native stimuli has been addressed in several ways. Some audiologists have attempted to mitigate this problem by utilizing English digit pairs as test stimuli. Ramkissoon, Proctor, Lansing, and Bilger (2002) indicated that the use of digit pairs as alternative stimuli has some cross-linguistic appeal in multilingual patient communities. An additional method to address the problem of conducting SRT testing with non-English speaking listeners is to develop language or dialect specific test materials.

Talker native dialect. If possible, native talkers of the intended language should be used to develop SRT materials. A study by Weisleder and Hodgson (1989) found that individuals' performance on SRT tasks was negatively affected when listening to recordings from a talker with a different dialectal background. Recent research has indicated that although the regional dialect of the materials talker is associated with a statistical change in listener performance, such differences may not be clinically significant (Richardson, 2008). According to these findings, it may be sufficient to have recordings from talkers of the same native language without matching the regional dialect of the listener, considering that the two dialects are mutually intelligible and are commonly used in the listener's linguistic community at large.

Talker gender. The gender of the talker may also be a factor to consider when developing SRT materials. In a study done by Wilson and Strouse (1999) recordings from a female talker had to be raised by 10 to 13 dB in quiet and 12 to 16 dB in noise to produce psychometric audibility functions that were similar to recordings from a male talker. The authors attributed the differences in performance to spectral differences

between the two talkers. The possible influence of talker gender on a listener's speech perception may increase the need to develop materials produced by both male and female talkers. However it is important to note that such differences in performance may also have been due to intra-talker factors such as voice quality, pronunciation, speech rate, or regional dialect.

Need for native SRT materials in Mongolian. Historically, many researchers have focused on improving the quality of SRT materials available in English. Due to materials in other languages being absent or only minimally developed, researchers have recently aimed at developing and improving materials for non-English speaking individuals. To date there has been successful development of materials in languages such as Arabic, Spanish, Italian, Russian, Portuguese, Polish, Japanese, Mandarin, and Korean (Aleksandrovsky, McCullough, & Wilson, 1998; Ashoor & Prochazka, 1985; Christensen, 1995; Greer, 1997; Harris, Goffi, Pedalini, Gygi, & Merrill, 2001; Harris, Kim, & Eggett, 2003; Harris et al., 2004; Mangum, 2005; Nissen, Harris, Jennings, Eggett, & Buck, 2005). However the availability of high-quality SRT materials for native speakers of Mongolian is limited or non-existent. The development of such materials would assist in the evaluation and treatment of hearing loss for Mongolian speakers, thereby helping to reduce the disabling effects of hearing impairment.

The Effect of Hearing Disability in Mongolia

In Mongolia and many other developing countries, children and adults with disabilities are among the poorest and most vulnerable societal groups. Individuals with significant hearing loss are no exception. The ability to adequately hear speech is critical to an individual's success in mainstream culture. For children, hearing loss can delay language acquisition and lead to social isolation. Hearing impairments also act as barriers

to educational opportunities. Individuals who lose their hearing later in life are also likely to face challenges socially and in the workforce.

Mongolia is among the poorest of nations in the world with a per capita gross national product of \$400 (Sharma & Deepak, 2002). Recently, the country has encountered frequent changes in government, high levels of poverty (as high as 40% live below poverty line), budget cuts for education and healthcare (as high as 50% since 1990), an increase in school dropouts and non-enrollments (as high as 25% since 1990), rising unemployment, and the growth of street children in the capital city of Ulaanbaatar (Sharma & Deepak, 2002). Considering the burden of meeting these societal challenges, it stands to reason that the needs of persons with disabilities are often unmet.

Due to geographical and social constraints, an accurate collection of statistical data on the incidence of disability in Mongolia is difficult to obtain. In 1999, the Office of Mongolian National Statistics estimated that there were 45,000 persons with disability, of which 20% had speech and hearing difficulties, with 75% being school-aged children. The Mongolian State Social Welfare Office more currently estimates that there are 120,000 persons with disabilities in Mongolia (Johnstone, 2002). These statistics do not account for Mongolian speakers living outside of Mongolia, such as the large population of native Mongolians living in China.

Defining disability in Mongolia is both complicated and controversial (Johnstone, 2002). The Mongolian Social Security Law for People with Disabilities has legally defined persons with disabilities as those individuals with limited physical or mental abilities, either genetically inherited or acquired during life, persons born with deformations or disability caused by illness or accident which limits full ability to work,

mute persons or persons officially diagnosed with sight, hearing, or body or mental disabilities. Often to the detriment of the disabled individual, disability in Mongolia is regularly assessed and treated based on a purely medical model, with little support for rehabilitation or special education (Johnstone, 2002).

In Mongolia, the integration of disabled students into the mainstream educational system is not widespread. There is still a common attitude within the Mongolian educational system that children with disabilities should be educated at special schools that only enroll disabled students (Asia-Pacific Development Center on Disability, 2008). However, there are only a few such schools in Mongolia for children with disabilities. This lack of educational support likely contributes to 88% of persons with disabilities in Mongolia living below the poverty line (Asia-Pacific Development Center on Disability, 2008).

Efforts are being made in Mongolia to more actively address the needs of individuals with disabilities. The restrictive medical definitions for disability used in the past are starting to give way to definitions that incorporate the extent of people's participation in society and social life, and the role of adaptive technologies (Filmer, 2008). In 1991, the Government of Mongolia solicited the assistance of the World Health Organization for initiation of community-based rehabilitation services for its disabled population (Sharma & Deepak, 2002). The Government of Mongolia also declared 2001 as the year for the Promotion of Employment of the Disabled Person and adopted a national disability program to be implemented with funding from the state budget. The main objective of this national program was to improve the quality of life of persons with

disabilities and build an environment to increase participation and integration of persons with disabilities into society (Johnstone, 2002).

The Mongolian Language

As a member of the Altaic language group, language relatives of Mongolian include Turkic, Korean, and the Manchu-Tungus languages. The Altaic languages are agglutinative, meaning that word formation and inflection are carried out by adding suffixes to otherwise unchanging word stems. Another feature held in common within Altaic languages is the nominal character of the verb, where the verbal forms originate from nouns (Poppe, 1970). A considerable portion of root words are monosyllabic. Similar to Russian, many common words are polysyllabic due to the agglutinative morphology of Mongolian (Janhunen, 2003).

The most commonly used writing system for Mongolian is Cyrillic, which was introduced into the Mongolian People's Republic in 1941 (Poppe, 1970). Mongolic languages are spoken over a wide span of the Eurasian continent, extending from the Caspian region in the west to southern and central Manchuria in the east. In the south, the Mongolic territory extends to northern Afghanistan as well as to the Gans-Qinghai region (Amdo) in northern Tibet, while in the north it comprises the Baikal region and part of the Amur basin (Janhunen, 2003). A large population of Mongolian speakers is found in the Mongolian People's Republic and in the adjacent parts of Manchuria and Inner Mongolia.

The Khalkha dialect serves as the official state language of the Mongolian People's Republic and closely similar dialectal forms are used by Mongols living in the Chinese region of Inner Mongolia. Khalkha, often identified as Modern Mongolian, is used in both oral and in written communication in multiple social domains

(e.g., administration, education, broadcast media, literature, and in everyday conversations). Although there are many regional Mongolian dialects, the Khalkha dialect and the literary language on which it is based is highly intelligible among Mongolian speakers (Janhunen, 2003).

Currently the number of Mongolian speakers is estimated to be approximately 7 million, with more Mongolian speakers in China than in the Mongolian People's Republic (Janhunen, 2003). Approximately two million individuals consider Khalkha as their native regional dialect; however, many additional speakers in the Mongolian People's Republic also consider Khalkha to be their second dialect (Janhunen, 2003). About a third of the population lives in the capital city of Ulaanbaatar, a third in 21 towns or *Aimag centres*, and another third live as nomads roaming from one place to another.

Purpose of the Study

The aim of this study is to address the need for speech audiometry materials specifically designed and created for native speakers of Mongolian. The objectives of this study are to (a) identify one male and one female from Mongolia who are native speakers of the Khalkha dialect to serve as talkers for the recordings, (b) compile a list of familiar bisyllabic Mongolian words to be used in measurement of the SRT, (c) create high-quality digital recordings of the selected bisyllabic Mongolian words, (d) collect normative data on the bisyllabic words, and (e) construct psychometrically equivalent lists of bisyllabic Mongolian words using both the male and female talkers. It is hoped that the development of these materials will improve audiologists' ability to accurately assess and treat hearing impairments for native Mongolian speakers, thereby increasing their ability to access additional educational and employment opportunities.

Methods

Participants

A total of 20 native speakers of Mongolian (11 male and 9 female) participated in this study. All subjects indicated that they have continued to speak Mongolian on a daily basis at home and/or at work while residing in the United States. All participants underwent a hearing screening and exhibited pure-tone air-conduction thresholds ≤ 15 dB HL at octave and midoctave frequencies from 125 to 8000 Hz and static acoustic admittance between 0.3 and 1.4 mmhos with peak pressure between -10 and +50 daPa (ASHA, 1990; Roup, Wiley, Safady, & Stoppenbach, 1998). Summary statistics describing the hearing acuity of the participants are presented in Table 1.

Materials

Words. Bisyllabic Mongolian words were chosen as stimuli for the construction of the SRT materials. Originally, 200 bisyllabic words were selected from electronic sources obtained from Scanell (2008). These words were then rated by three native speakers of Mongolian on a scale of 1 to 5 in order to ensure word familiarity (1 = extremely, 2 = very, 3 = average, 4 = seldom used, 5 = rarely used). Words with the same pronunciation but multiple meanings were eliminated as well as words considered by the native judges to be culturally insensitive, unfamiliar, and/or representative of inappropriate content. Only those words which received a ranking of 1 or 2 were used in this study. Based on these rankings, the list was reduced to 120 bisyllabic words. A pilot study was then administered at 15 dB HL to a native Mongolian speaker used in the project as an interpreter. Any words that were judged to be unintelligible were taken out. The original list of 120 words was reduced to 90 words for subsequent evaluation.

Table 1

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

Mongolian Subjects

kHz	<i>M</i>	<i>Minimum</i>	<i>Maximum</i>	<i>SD</i>
0.125	1.0	-10	10	5.8
0.25	-1.8	-10	10	5.4
0.5	-1.3	-10	5	4.8
0.75	0.3	-10	10	5.7
1.0	1.0	-5	10	4.5
1.5	2.5	-5	15	6.6
2.0	2.0	-5	10	4.4
3.0	1.0	-10	15	6.2
4.0	0.5	-5	10	4.6
6.0	-0.3	-10	15	5.7
8.0	-0.5	-10	15	6.5
PTA ^a	0.58	-6.67	6.67	3.65

^aPTA = arithmetic average of thresholds at 0.5, 1.0, and 2.0 kHz

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

Recordings. All recordings were made in a double-walled sound suite designed for audiological testing 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 was 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 by an Apogee AD-8000 24-bit analog-to-digital converter and subsequently stored on a hard drive for later editing. A 44.1 kHz sampling rate with 24-bit quantization was used for all recordings, and every effort was made to utilize the full range of the 24-bit analog-to-digital converter.

During the recording sessions, the talkers were asked to pronounce each bisyllabic word at least four times with a slight pause between each production. Talkers were asked to speak at a natural rate with normal intonation patterns. To avoid possible list effects, the first and last repetitions of each word were excluded from the study, unless either token was judged to be the best pronunciation of the word by a native Mongolian judge. Any word that was judged to be a poor recording (peak clipping, extraneous noise, etc.), mispronounced, or produced with unnatural intonation was rerecorded. Repetitions of

each word were then rated by a native judge for perceived quality of the production. The best perceived production was then selected for inclusion in the set of bisyllabic words to be evaluated by the native Mongolian listeners.

After the word selection process, the intensity of each bisyllabic word included in the test materials was edited as a single utterance using Sadie Disk Editor software (Studio Audio & Video Ltd., 2006) to yield the same average root mean square power as that of a 1000 Hz calibration tone in an initial attempt to equate test word threshold audibility (Harris et al., 2004; Wilson & Strouse, 1999). Each of the individually recorded and edited words was then saved as 24-bit wav files.

Procedure

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

Prior to testing each participant, the external inputs to the audiometer were calibrated to 0 VU using a 1000 Hz calibration tone. The audiometer was calibrated prior to, during, and at the conclusion of data collection. Audiometric calibration was performed in accordance with ANSI S3.6 specifications (American National Standards Institute, 2004).

Each participant attended two to three sessions after passing a hearing screening. Participants were familiarized with the list of words by listening to the words at 50

dB HL while also reading a printed list of the words. After word familiarization, the 90 bisyllabic words were then presented at 14 different intensity levels, beginning at 6 dB below the subject's pure tone average. The test ascended in 2 dB increments and was completed upon the basis of one of the following criteria: (a) the subject heard 100% of the stimuli correctly or (b) the presentation level reached 16 dB HL. The sequence of the 90 bisyllabic words was randomized prior to presentation at each intensity level. Each subject listened to both the male and female talker recordings of all 90 bisyllabic words. Subjects repeated words verbally which were scored as being correct or incorrect by a native Mongolian judge. Each subject was allowed to have several rest periods during each test session. Prior to evaluation of the bisyllabic words, the following instructions were given by a translator in Mongolian:

You will hear Mongolian words at a number of different loudness levels. Each word is two syllables in length. At the very softest loudness levels, it may be difficult for you to hear the words. For each word, listen carefully to the word, and then repeat what you think the word was. If you are not sure, you may guess. If you have no guess, simply wait silently for the next word. Do you have any questions?

Results

After the raw data were collected, psychometric functions (regression slope and intercept) for each of the 90 bisyllabic words were calculated using logistic regression. 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 follows:

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

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

$$p = \left(1 - \frac{\exp(a + b \times i)}{1 + \exp(a + b \times i)}\right) * 100 \quad (2)$$

By inserting the regression slope, regression intercept, and presentation 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 bisyllabic words for a range of -10 to 18 dB HL in 1 dB increments.

In order to calculate the intensity level required for a given proportion of correct identifications, Equation 1 was solved for i (see Equation 3). By inserting the desired proportions into Equation 3, it is possible to calculate the threshold (intensity required for 50% intelligibility), the slope (%/dB) at threshold, and the slope from 20 to 80% for each psychometric function. When solving for the threshold ($p = 0.5$), Equation 3 can be simplified to Equation 4:

$$i = \frac{\log \frac{p}{1-p} - a}{b} \quad (3)$$

$$i = \frac{-a}{b} \quad (4)$$

Calculations of threshold (intensity required for 50% correct perception), slope at 50%, and slope from 20% to 80% intelligibility were made for each bisyllabic word using the logistic regression slopes and intercepts.

Thresholds for 50% intelligibility for the 90 bisyllabic words ranged from 2.7 dB HL to 17.0 dB HL ($M = 10.3$ dB HL) for the male talker words, and from 4.7 dB HL to 20.9 dB HL ($M = 11.9$ dB HL) for the female talker words. Psychometric functions for each bisyllabic word were calculated with Equation 2 using the logistic regression intercept and slope values. The slopes at 50% ranged from 6.1%/dB to 18.3%/dB ($M = 11.2$ %/dB) for the male talker and from 4.0%/dB to 18.1%/dB ($M = 10.2$ %/dB) for the female talker. In comparison, the slopes at 50% intelligibility were steeper than the slopes from 20-80% of the psychometric function. These thresholds for the 90 bisyllabic words, and their psychometric function slopes at 50% and from 20-80% are presented in Table 2 (male talker) and Table 3 (female talker).

In an effort to reduce test time, as well as improve reliability, words with relatively homogeneous and steep psychometric function slopes were selected for inclusion in the final set of SRT materials (Wilson & Strouse, 1999). A separate final list of 28 bisyllabic words for both male and female talkers resulted.

Table 2

Mean Performance for 90 Mongolian Male Bisyllabic SRT Words

#	Word	a ^a	b ^b	Slope at 50% ^c	Slope 20-80% ^d	Threshold ^e	Δ dB ^f
1	adil	3.39510	-0.35875	9.0	7.8	9.5	8.9
2	agaar	2.13551	-0.43735	10.9	9.5	4.9	4.3
3	avah	1.54723	-0.33291	8.3	7.2	4.6	4.1
4	ayalal	3.51983	-0.42686	10.7	9.2	8.2	7.7
5	bayar	3.61452	-0.42241	10.6	9.1	8.6	8.0
6	bayshin	2.32215	-0.43900	11.0	9.5	5.3	4.7
7	belen	4.54441	-0.38437	9.6	8.3	11.8	11.2
8	bichig	3.45026	-0.35210	8.8	7.6	9.8	9.2
9	bichih	3.15019	-0.47687	11.9	10.3	6.6	6.0
10	bolgoh	2.64017	-0.33881	8.5	7.3	7.8	7.2
11	chadah	1.22275	-0.44648	11.2	9.7	2.7	2.2
12	chuluu	3.61624	-0.61301	15.3	13.3	5.9	5.3
13	dahin	6.49890	-0.46579	11.6	10.1	14.0	13.4
14	daraa	4.02307	-0.35079	8.8	7.6	11.5	10.9
15	davhar	3.58195	-0.44590	11.1	9.6	8.0	7.5
16	delhiy	4.53017	-0.34377	8.6	7.4	13.2	12.6
17	dotor	3.98175	-0.37485	9.4	8.1	10.6	10.0
18	durtay	3.25840	-0.39421	9.9	8.5	8.3	7.7
19	duuchin	4.04886	-0.30433	7.6	6.6	13.3	12.7
20	dzaaval	3.23560	-0.30504	7.6	6.6	10.6	10.0
21	dzaluu	2.82924	-0.46373	11.6	10.0	6.1	5.5
22	dzorig	4.14397	-0.42273	10.6	9.1	9.8	9.2
23	dzurag	8.41825	-0.62026	15.5	13.4	13.6	13.0
24	dürem	6.19594	-0.36526	9.1	7.9	17.0	16.4
25	düüren	3.44249	-0.47061	11.8	10.2	7.3	6.7
26	ehner	4.77051	-0.45880	11.5	9.9	10.4	9.8
27	emee	8.51312	-0.51017	12.8	11.0	16.7	16.1
28	erүүл	4.71783	-0.35244	8.8	7.6	13.4	12.8
29	garah	2.22897	-0.29610	7.4	6.4	7.5	6.9
30	gerel	4.17799	-0.35788	8.9	7.7	11.7	11.1
31	goyo	3.10658	-0.44938	11.2	9.7	6.9	6.3
32	hachin	5.13060	-0.46541	11.6	10.1	11.0	10.4
33	haluun	3.30734	-0.50078	12.5	10.8	6.6	6.0
34	harah	1.69984	-0.40854	10.2	8.8	4.2	3.6
35	hariu	3.80518	-0.34490	8.6	7.5	11.0	10.5
36	hatuu	4.55210	-0.40161	10.0	8.7	11.3	10.8
37	heleh	4.19421	-0.37542	9.4	8.1	11.2	10.6
38	hetsüü	4.92748	-0.35461	8.9	7.7	13.9	13.3
39	hural	4.20026	-0.41932	10.5	9.1	10.0	9.4
40	hurdan	3.56852	-0.43292	10.8	9.4	8.2	7.7
41	huuchin	4.61014	-0.54132	13.5	11.7	8.5	7.9
42	höörhön	3.85654	-0.40570	10.1	8.8	9.5	8.9

#	Word	a ^a	b ^b	Slope at 50% ^c	Slope 20-80% ^d	Threshold ^e	ΔdB ^f
43	hüreh	4.06889	-0.39226	9.8	8.5	10.4	9.8
44	hüyten	6.58321	-0.59044	14.8	12.8	11.1	10.6
45	hüühed	3.95147	-0.49909	12.5	10.8	7.9	7.3
46	ilüü	4.30614	-0.51766	12.9	11.2	8.3	7.7
47	jargal	3.85008	-0.53425	13.4	11.6	7.2	6.6
48	jishee	3.48686	-0.52807	13.2	11.4	6.6	6.0
49	medee	5.51392	-0.37406	9.4	8.1	14.7	14.2
50	medeh	5.29595	-0.37731	9.4	8.2	14.0	13.5
51	medleg	7.58800	-0.58111	14.5	12.6	13.1	12.5
52	muuhay	2.60620	-0.40654	10.2	8.8	6.4	5.8
53	nerthey	5.12510	-0.39976	10.0	8.7	12.8	12.2
54	nulims	12.04740	-0.73083	18.3	15.8	16.5	15.9
55	nutag	6.56480	-0.62366	15.6	13.5	10.5	9.9
56	nöhör	5.62420	-0.57840	14.5	12.5	9.7	9.1
57	ochih	3.77450	-0.45276	11.3	9.8	8.3	7.8
58	ohin	4.68260	-0.50704	12.7	11.0	9.2	8.7
59	olgoh	3.89210	-0.31183	7.8	6.7	12.5	11.9
60	oloh	4.41100	-0.40934	10.2	8.9	10.8	10.2
61	olon	5.04030	-0.45683	11.4	9.9	11.0	10.5
62	ongots	4.61660	-0.44337	11.1	9.6	10.4	9.8
63	orchin	4.20410	-0.55262	13.8	12.0	7.6	7.0
64	oron	4.57450	-0.46332	11.6	10.0	9.9	9.3
65	sanaa	4.51980	-0.32360	8.1	7.0	14.0	13.4
66	sayhan	4.84730	-0.42955	10.7	9.3	11.3	10.7
67	shüleg	3.44660	-0.48472	12.1	10.5	7.1	6.5
68	sonin	6.06280	-0.46196	11.5	10.0	13.1	12.5
69	sudlah	4.82010	-0.50514	12.6	10.9	9.5	9.0
70	talbay	6.87910	-0.55331	13.8	12.0	12.4	11.9
71	taviih	4.24260	-0.43808	11.0	9.5	9.7	9.1
72	temdeg	7.48920	-0.63733	15.9	13.8	11.8	11.2
73	tenger	4.92300	-0.37418	9.4	8.1	13.2	12.6
74	tolgoy	3.92460	-0.54465	13.6	11.8	7.2	6.6
75	tömör	8.12290	-0.66835	16.7	14.5	12.2	11.6
76	udaa	11.28000	-0.72275	18.1	15.6	15.6	15.0
77	udaan	5.03840	-0.38009	9.5	8.2	13.3	12.7
78	unshih	2.77740	-0.47086	11.8	10.2	5.9	5.3
79	yaria	4.29090	-0.56410	14.1	12.2	7.6	7.0
80	yavah	2.62020	-0.57049	14.3	12.3	4.6	4.0
81	yostoy	5.11350	-0.41954	10.5	9.1	12.2	11.6
82	ödör	8.30790	-0.56987	14.2	12.3	14.6	14.0
83	ögöh	3.19670	-0.24439	6.1	5.3	13.1	12.5
84	ömnö	6.90670	-0.57606	14.4	12.5	12.0	11.4
85	öndör	7.11030	-0.46025	11.5	10.0	15.4	14.9
86	örgön	5.58530	-0.35771	8.9	7.7	15.6	15.0
87	ööröö	5.04750	-0.47653	11.9	10.3	10.6	10.0
88	üdzeh	3.49250	-0.27005	6.8	5.8	12.9	12.4

#	Word	a ^a	b ^b	Slope at 50% ^c	Slope 20-80% ^d	Threshold ^e	Δ dB ^f
89	ünen	5.09410	-0.38892	9.7	8.4	13.1	12.5
90	üüreg	4.92970	-0.38680	9.7	8.4	12.7	12.2
	<i>M</i>	4.62879	-0.44935	11.2	9.7	10.3	9.8
	<i>Min</i>	1.22275	-0.73083	6.1	5.3	2.7	2.2
	<i>Max</i>	12.04740	-0.24439	18.3	15.8	17.0	16.4
	<i>Range</i>	10.82465	0.48644	12.2	10.5	14.2	14.2
	<i>SD</i>	1.85730	0.09898	2.5	2.1	3.1	3.1

^a*a* = regression intercept. ^b*b* = regression slope. ^cPsychometric function slope (%/dB) at 50% was calculated from 49.999 to 50.001%. ^dPsychometric function slope (%/dB) from 20-80%. ^eIntensity required for 50% intelligibility. ^fChange in intensity required to adjust the threshold of a word to the mean PTA of the subjects (0.58 dB HL).

Table 3

Mean Performance for 90 Mongolian Female Bisyllabic SRT Words

#	Word	a ^a	b ^b	Slope at 50% ^c	Slope 20-80% ^d	Threshold ^e	Δ dB ^f
1	adil	4.68480	-0.46977	11.7	10.2	10.0	9.4
2	agaar	4.31080	-0.38677	9.7	8.4	11.1	10.6
3	avah	1.57843	-0.31843	8.0	6.9	5.0	4.4
4	ayalal	3.88784	-0.43901	11.0	9.5	8.9	8.3
5	bayar	4.71270	-0.49911	12.5	10.8	9.4	8.9
6	bayshin	4.72663	-0.56186	14.0	12.2	8.4	7.8
7	belen	4.26100	-0.31229	7.8	6.8	13.6	13.1
8	bichig	4.41087	-0.40933	10.2	8.9	10.8	10.2
9	bichih	2.05030	-0.43817	11.0	9.5	4.7	4.1
10	bolgoh	2.60437	-0.21242	5.3	4.6	12.3	11.7
11	chadah	2.75301	-0.30063	7.5	6.5	9.2	8.6
12	chuluu	7.29869	-0.64377	16.1	13.9	11.3	10.8
13	dahin	5.92687	-0.43327	10.8	9.4	13.7	13.1
14	daraa	3.74330	-0.35049	8.8	7.6	10.7	10.1
15	davhar	3.29639	-0.32311	8.1	7.0	10.2	9.6
16	delhiy	3.74930	-0.38482	9.6	8.3	9.7	9.2
17	dotor	6.23156	-0.43563	10.9	9.4	14.3	13.7
18	durtay	5.49243	-0.52523	13.1	11.4	10.5	9.9
19	duuchin	5.04746	-0.47653	11.9	10.3	10.6	10.0
20	dzaaval	1.73644	-0.27308	6.8	5.9	6.4	5.8
21	dzaluu	4.55077	-0.29872	7.5	6.5	15.2	14.7
22	dzorig	4.37497	-0.45225	11.3	9.8	9.7	9.1
23	dzurag	4.16623	-0.44983	11.2	9.7	9.3	8.7
24	dürem	4.55200	-0.40160	10.0	8.7	11.3	10.8
25	düüren	4.42030	-0.38904	9.7	8.4	11.4	10.8
26	ehner	5.48493	-0.53528	13.4	11.6	10.2	9.7
27	emee	5.26305	-0.29285	7.3	6.3	18.0	17.4
28	erүүл	3.26721	-0.27928	7.0	6.0	11.7	11.1
29	garah	2.41142	-0.27036	6.8	5.9	8.9	8.3
30	gerel	4.67108	-0.43042	10.8	9.3	10.9	10.3
31	goyo	3.58182	-0.44589	11.1	9.6	8.0	7.5
32	hachin	4.25639	-0.28525	7.1	6.2	14.9	14.3
33	haluun	7.15761	-0.43130	10.8	9.3	16.6	16.0
34	harah	1.65485	-0.34782	8.7	7.5	4.8	4.2
35	hariu	4.92438	-0.26555	6.6	5.7	18.5	18.0
36	hatuu	4.52012	-0.25730	6.4	5.6	17.6	17.0
37	heleh	3.54159	-0.29978	7.5	6.5	11.8	11.2
38	hetsüü	6.42170	-0.39829	10.0	8.6	16.1	15.5
39	hural	3.93103	-0.36969	9.2	8.0	10.6	10.1
40	hurdan	5.17649	-0.43806	11.0	9.5	11.8	11.2
41	huuchin	4.51829	-0.46756	11.7	10.1	9.7	9.1
42	höörhön	4.13089	-0.47848	12.0	10.4	8.6	8.1

#	Word	a ^a	b ^b	Slope at 50% ^c	Slope 20-80% ^d	Threshold ^e	Δ dB ^f
43	hüreh	3.21315	-0.28796	7.2	6.2	11.2	10.6
44	hüyten	4.67108	-0.43042	10.8	9.3	10.9	10.3
45	hüühed	2.42801	-0.37845	9.5	8.2	6.4	5.8
46	ilüü	7.07629	-0.52550	13.1	11.4	13.5	12.9
47	jargal	3.21373	-0.47917	12.0	10.4	6.7	6.1
48	jishee	4.84284	-0.36724	9.2	7.9	13.2	12.6
49	medee	5.39489	-0.39380	9.8	8.5	13.7	13.1
50	medeh	3.92172	-0.33329	8.3	7.2	11.8	11.2
51	medleg	5.90690	-0.46225	11.6	10.0	12.8	12.2
52	muuhay	4.75350	-0.37528	9.4	8.1	12.7	12.1
53	nerthey	8.04260	-0.51283	12.8	11.1	15.7	15.1
54	nulims	10.90380	-0.66897	16.7	14.5	16.3	15.7
55	nutag	4.45310	-0.22057	5.5	4.8	20.2	19.6
56	nöhör	8.85420	-0.63738	15.9	13.8	13.9	13.3
57	ochih	3.33150	-0.27874	7.0	6.0	12.0	11.4
58	ohin	4.94260	-0.40428	10.1	8.7	12.2	11.6
59	olgoh	3.62290	-0.29693	7.4	6.4	12.2	11.6
60	oloh	3.15510	-0.15945	4.0	3.5	19.8	19.2
61	olon	3.88000	-0.34068	8.5	7.4	11.4	10.8
62	ongots	4.23260	-0.26331	6.6	5.7	16.1	15.5
63	orchin	4.39550	-0.40349	10.1	8.7	10.9	10.3
64	oron	3.82950	-0.32812	8.2	7.1	11.7	11.1
65	sanaa	2.95760	-0.24714	6.2	5.3	12.0	11.4
66	sayhan	2.93390	-0.37298	9.3	8.1	7.9	7.3
67	shüleg	5.14050	-0.48563	12.1	10.5	10.6	10.0
68	sonin	4.95280	-0.37275	9.3	8.1	13.3	12.7
69	sudlah	3.08810	-0.23008	5.8	5.0	13.4	12.8
70	talbay	9.27170	-0.55652	13.9	12.0	16.7	16.1
71	taviih	3.82420	-0.44762	11.2	9.7	8.5	8.0
72	temdeg	6.63020	-0.41403	10.4	9.0	16.0	15.4
73	tenger	9.11020	-0.67343	16.8	14.6	13.5	12.9
74	tolgoy	4.52710	-0.35899	9.0	7.8	12.6	12.0
75	tömör	5.92060	-0.47686	11.9	10.3	12.4	11.8
76	udaa	9.88060	-0.47240	11.8	10.2	20.9	20.3
77	udaan	4.92950	-0.38679	9.7	8.4	12.7	12.2
78	unshih	2.60700	-0.39394	9.8	8.5	6.6	6.0
79	yaria	4.57450	-0.46332	11.6	10.0	9.9	9.3
80	yavah	2.58730	-0.52887	13.2	11.4	4.9	4.3
81	yostoy	13.62300	-0.72201	18.1	15.6	18.9	18.3
82	ödör	10.09320	-0.68325	17.1	14.8	14.8	14.2
83	ögöh	3.43100	-0.45002	11.3	9.7	7.6	7.0
84	ömnö	6.20360	-0.47358	11.8	10.2	13.1	12.5
85	öndör	5.76880	-0.46831	11.7	10.1	12.3	11.7
86	örgön	4.09350	-0.27857	7.0	6.0	14.7	14.1
87	ööröö	3.61600	-0.36173	9.0	7.8	10.0	9.4
88	üdzeh	4.29170	-0.36472	9.1	7.9	11.8	11.2

#	Word	a ^a	b ^b	Slope at 50% ^c	Slope 20-80% ^d	Threshold ^e	Δ dB ^f
89	ünen	6.47600	-0.50994	12.7	11.0	12.7	12.1
90	üüreg	3.42690	-0.41528	10.4	9.0	8.3	7.7
	<i>M</i>	4.80561	-0.40706	10.2	8.8	11.9	11.3
	<i>Min</i>	1.57843	-0.72201	4.0	3.5	4.7	4.1
	<i>Max</i>	13.62300	-0.15945	18.1	15.6	20.9	20.3
	<i>Range</i>	12.04457	0.56256	14.1	12.2	16.2	16.2
	<i>SD</i>	2.07539	0.11209	2.8	2.4	3.5	3.5

^a*a* = regression intercept. ^b*b* = regression slope. ^cPsychometric function slope (%/dB) at 50% was calculated from 49.999 to 50.001%. ^dPsychometric function slope (%/dB) from 20-80%. ^eIntensity required for 50% intelligibility. ^fChange in intensity required to adjust the threshold of a word to the mean PTA of the subjects (0.58 dB HL).

Due to differences in psychometric function slopes between the male and female talker recording words, the two lists do not contain the same words. Table 4 (male talker) and Table 5 (female talker) present the threshold, the slope at 50%, and the slope from 20-80% for the 28 selected bisyllabic words respectively. The psychometric function slopes for the 28 selected words shown in Figure 1 (C-D) demonstrates less variability than the slopes of all 90 words (A-B). Figure 2 (male talker) and Figure 3 (female talker) display the psychometric functions for each of the 28 words and the data points used to fit the data. The combined psychometric functions for the 28 selected words are shown in the middle panels (C-D) of Figure 1.

As presented in Tables 4 and 5, the thresholds for 50% intelligibility for the 28 selected words ranged from 4.2 dB HL to 13.2 dB HL ($M = 7.9$ dB HL) for the male talker and from 4.8 dB HL to 13.6 dB HL ($M = 9.1$ dB HL) for the female talker. The psychometric function slopes at 50% threshold, ranged from 8.3%/dB to 15.3%/dB ($M = 11.4$ %/dB) for the male talker and from 6.8%/dB to 14.0%/dB ($M = 10.5$ %/dB) for the female talker. In order to decrease the variability that still existed across the thresholds of the final 28 words for both the male and female recordings, the intensity of these words was digitally adjusted so that the 50% threshold of each word was equal to the mean PTA of the subjects (0.58 dB HL). The necessary adjustments for each of the 28 selected words for the male and female talker recordings are also presented in Tables 4 and 5, respectively. The bottom panels of Figure 1 portray predicted psychometric functions for the 28 selected words following the intensity adjustment to equate 50% thresholds for the male (E) and female talker (F). The mean psychometric functions for

Table 4

Mean Performance for 28 Selected Mongolian Male Bisyllabic SRT Words

#	Word	a ^a	b ^b	Slope at 50% ^c	Slope 20-80% ^d	Threshold ^e	ΔdB ^f
1	adil	3.39510	-0.35875	9.0	7.8	9.5	8.9
2	agaar	2.13551	-0.43735	10.9	9.5	4.9	4.3
3	avah	1.54723	-0.33291	8.3	7.2	4.6	4.1
4	bayar	3.61452	-0.42241	10.6	9.1	8.6	8.0
5	bayshin	2.32215	-0.43900	11.0	9.5	5.3	4.7
6	bichig	3.45026	-0.35210	8.8	7.6	9.8	9.2
7	bichih	3.15019	-0.47687	11.9	10.3	6.6	6.0
8	chuluu	3.61624	-0.61301	15.3	13.3	5.9	5.3
9	delhiy	4.53017	-0.34377	8.6	7.4	13.2	12.6
10	dzaluu	2.82924	-0.46373	11.6	10.0	6.1	5.5
11	dzorig	4.14397	-0.42273	10.6	9.1	9.8	9.2
12	düüren	3.44249	-0.47061	11.8	10.2	7.3	6.7
13	haluun	3.30734	-0.50078	12.5	10.8	6.6	6.0
14	harah	1.69984	-0.40854	10.2	8.8	4.2	3.6
15	hariu	3.80518	-0.34490	8.6	7.5	11.0	10.5
16	hüreh	4.06889	-0.39226	9.8	8.5	10.4	9.8
17	hüühed	3.95147	-0.49909	12.5	10.8	7.9	7.3
18	ilüü	4.30614	-0.51766	12.9	11.2	8.3	7.7
19	jishee	3.48686	-0.52807	13.2	11.4	6.6	6.0
20	muuhay	2.60620	-0.40654	10.2	8.8	6.4	5.8
21	nöhör	5.62420	-0.57840	14.5	12.5	9.7	9.1
22	ohin	4.68260	-0.50704	12.7	11.0	9.2	8.7
23	ööröö	5.04750	-0.47653	11.9	10.3	10.6	10.0
24	orchin	4.20410	-0.55262	13.8	12.0	7.6	7.0
25	shüleg	3.44660	-0.48472	12.1	10.5	7.1	6.5
26	unshih	2.77740	-0.47086	11.8	10.2	5.9	5.3
27	yavah	2.62020	-0.57049	14.3	12.3	4.6	4.0
28	üüreg	4.92970	-0.38680	9.7	8.4	12.7	12.2
<i>M</i>		3.52647	-0.45566	11.4	9.9	7.9	7.3
<i>Min</i>		1.54723	-0.61301	8.3	7.2	4.2	3.6
<i>Max</i>		5.62420	-0.33291	15.3	13.3	13.2	12.6
<i>Range</i>		4.07697	0.28010	7.0	6.1	9.0	9.0
<i>SD</i>		0.99305	0.07613	1.9	1.6	2.4	2.4

^aa = regression intercept. ^bb = regression slope. ^cPsychometric function slope (%/dB) at 50% was calculated from 49.999 to 50.001%. ^dPsychometric function slope (%/dB) from 20-80%. ^eIntensity required for 50% intelligibility. ^fChange in intensity required to adjust the threshold of a word to the mean PTA of the subjects (0.58 dB HL).

Table 5

Mean Performance for 28 Selected Mongolian Female Bisyllabic SRT Words

#	Word	a ^a	b ^b	Slope at 50% ^c	Slope 20-80% ^d	Threshold ^e	ΔdB ^f
1	adil	4.68480	-0.46977	11.7	10.2	10.0	9.4
2	avah	1.57843	-0.31843	8.0	6.9	5.0	4.4
3	ayalal	3.88784	-0.43901	11.0	9.5	8.9	8.3
4	bayar	4.71270	-0.49911	12.5	10.8	9.4	8.9
5	bayshin	4.72663	-0.56186	14.0	12.2	8.4	7.8
6	belen	4.26100	-0.31229	7.8	6.8	13.6	13.1
7	delhiy	3.74930	-0.38482	9.6	8.3	9.7	9.2
8	duuchin	5.04746	-0.47653	11.9	10.3	10.6	10.0
9	dzurag	4.16623	-0.44983	11.2	9.7	9.3	8.7
10	dürem	4.55200	-0.40160	10.0	8.7	11.3	10.8
11	düüren	4.42030	-0.38904	9.7	8.4	11.4	10.8
12	erүүл	3.26721	-0.27928	7.0	6.0	11.7	11.1
13	garah	2.41142	-0.27036	6.8	5.9	8.9	8.3
14	gerel	4.67108	-0.43042	10.8	9.3	10.9	10.3
15	harah	1.65485	-0.34782	8.7	7.5	4.8	4.2
16	huuchin	4.51829	-0.46756	11.7	10.1	9.7	9.1
17	höөрhön	4.13089	-0.47848	12.0	10.4	8.6	8.1
18	hüyten	4.67108	-0.43042	10.8	9.3	10.9	10.3
19	hүүhed	2.42801	-0.37845	9.5	8.2	6.4	5.8
20	jargal	3.21373	-0.47917	12.0	10.4	6.7	6.1
21	taviih	3.82420	-0.44762	11.2	9.7	8.5	8.0
22	tömör	5.92060	-0.47686	11.9	10.3	12.4	11.8
23	unshih	2.60700	-0.39394	9.8	8.5	6.6	6.0
24	yaria	4.57450	-0.46332	11.6	10.0	9.9	9.3
25	yavah	2.58730	-0.52887	13.2	11.4	4.9	4.3
26	ögöh	3.43100	-0.45002	11.3	9.7	7.6	7.0
27	ööröö	3.61600	-0.36173	9.0	7.8	10.0	9.4
28	үүereg	3.42690	-0.41528	10.4	9.0	8.3	7.7
<hr/>							
	<i>M</i>	3.81217	-0.42150	10.5	9.1	9.1	8.5
	<i>Min</i>	1.57843	-0.56186	6.8	5.9	4.8	4.2
	<i>Max</i>	5.92060	-0.27036	14.0	12.2	13.6	13.1
	<i>Range</i>	4.34217	0.29150	7.3	6.3	8.9	8.9
	<i>SD</i>	1.04973	0.07174	1.8	1.6	2.3	2.3

^a*a* = regression intercept. ^b*b* = regression slope. ^cPsychometric function slope (%/dB) at 50% was calculated from 49.999 to 50.001%. ^dPsychometric function slope (%/dB) from 20-80%. ^eIntensity required for 50% intelligibility. ^fChange in intensity required to adjust the threshold of a word to the mean PTA of the subjects (0.58 dB HL).

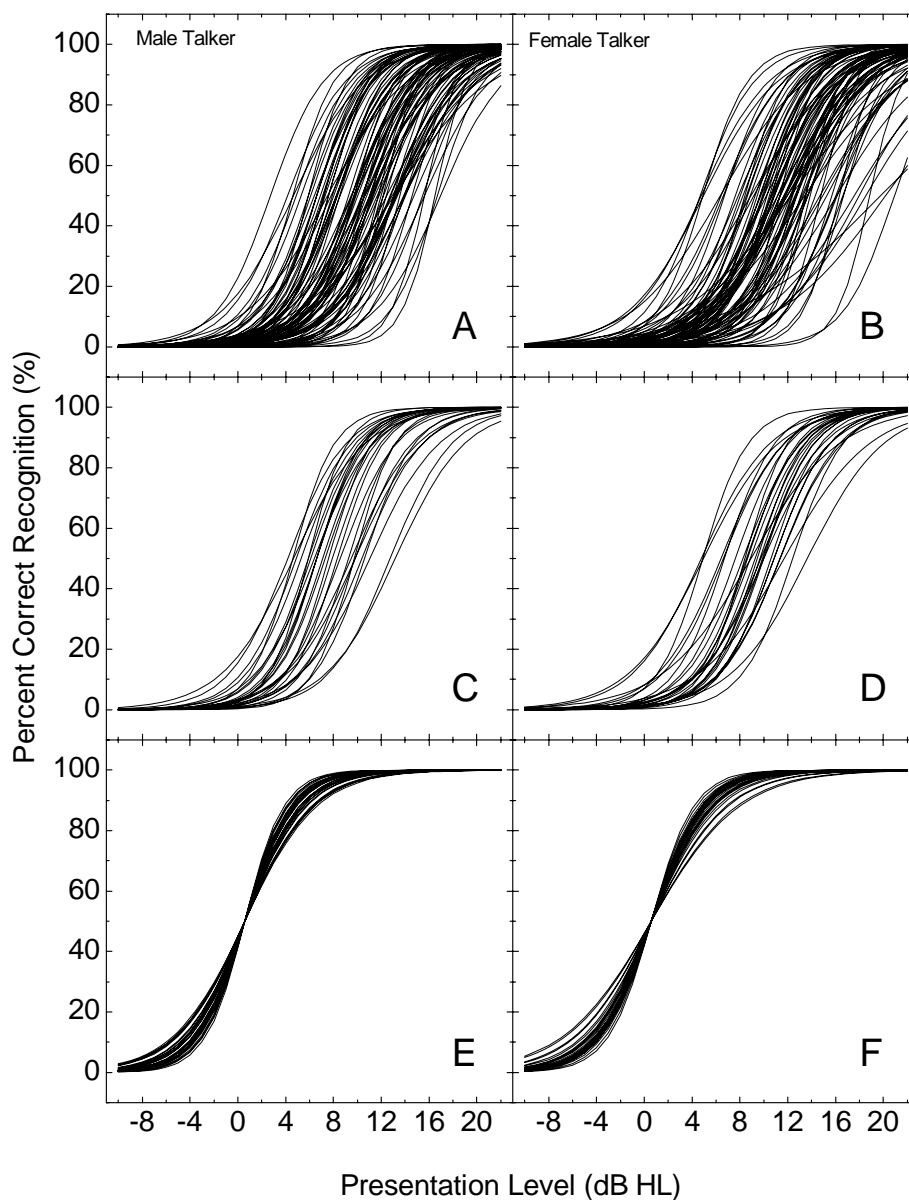


Figure 1. Psychometric functions for Mongolian bisyllabic words for male talker (left panels) and female talker (right panels) recordings. All 90 unadjusted words (top panels A-B), 28 selected unadjusted words (middle panels C-D), and 28 selected adjusted words (bottom panels E-F). The 28 selected adjusted words were digitally adjusted to have 50% thresholds equal to the mean PTA (0.58 dB HL) for the 20 normally hearing subjects.

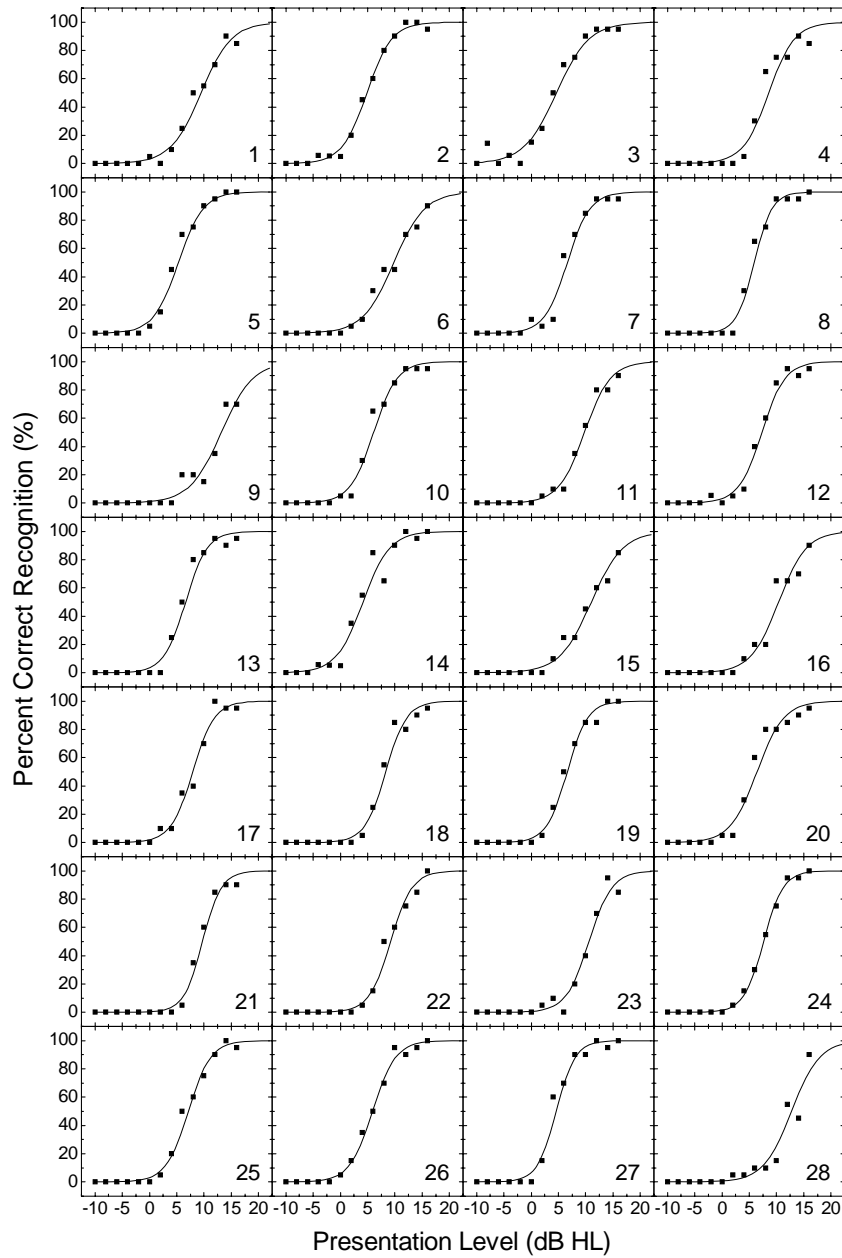


Figure 2. Psychometric functions for the 28 selected unadjusted Mongolian bisyllabic words spoken by a male talker. The functions were calculated using logistic regression; the symbols represent mean percentage of correct recognition calculated from the raw data for 20 normally hearing subjects.

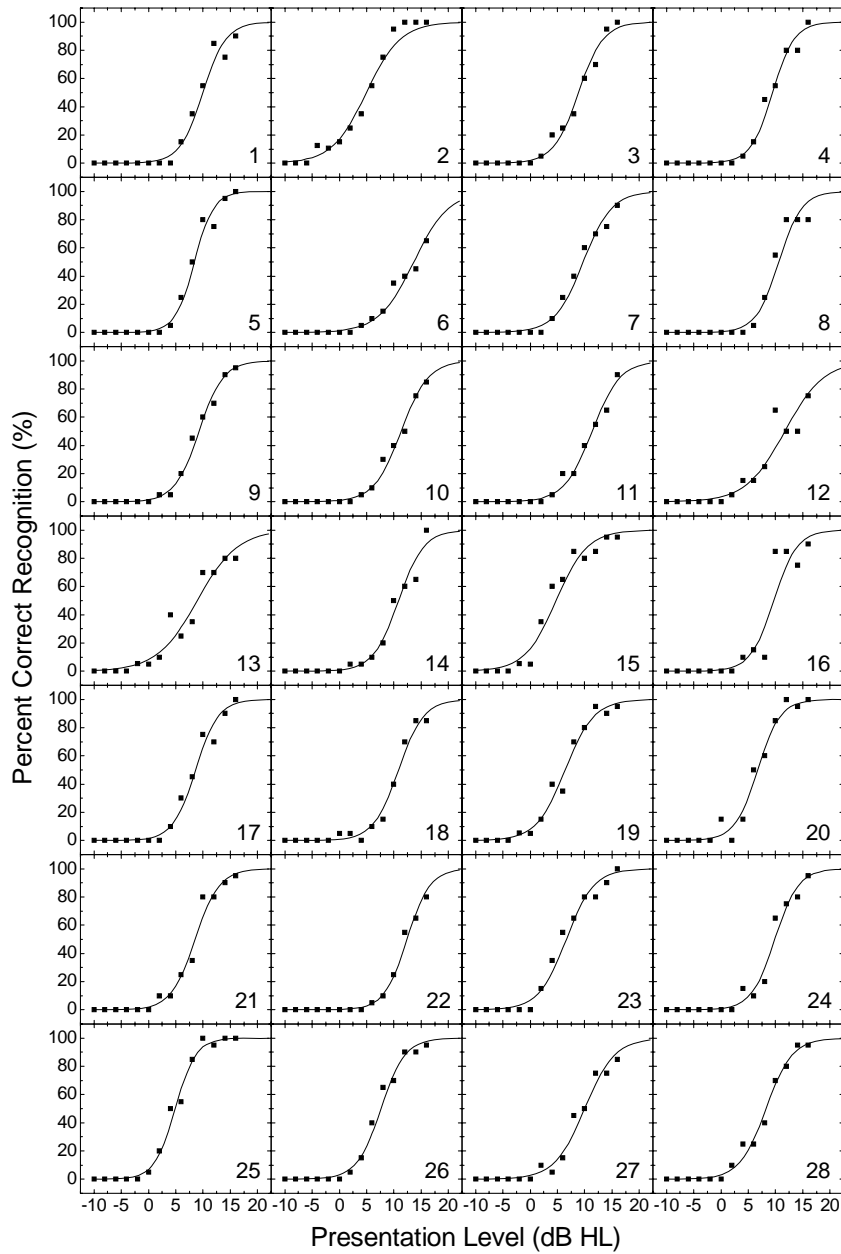


Figure 3. Psychometric functions for the 28 selected unadjusted Mongolian bisyllabic words spoken by a female talker. The functions were calculated using logistic regression; the symbols represent mean percentage of correct recognition calculated from the raw data for 20 normally hearing subjects.

the selected 28 words for both male and female talkers are shown in Figure 4. This figure illustrates the slightly steeper mean slopes for the male talker recordings (11.4%/dB) compared to the female talker recordings (10.5%/dB).

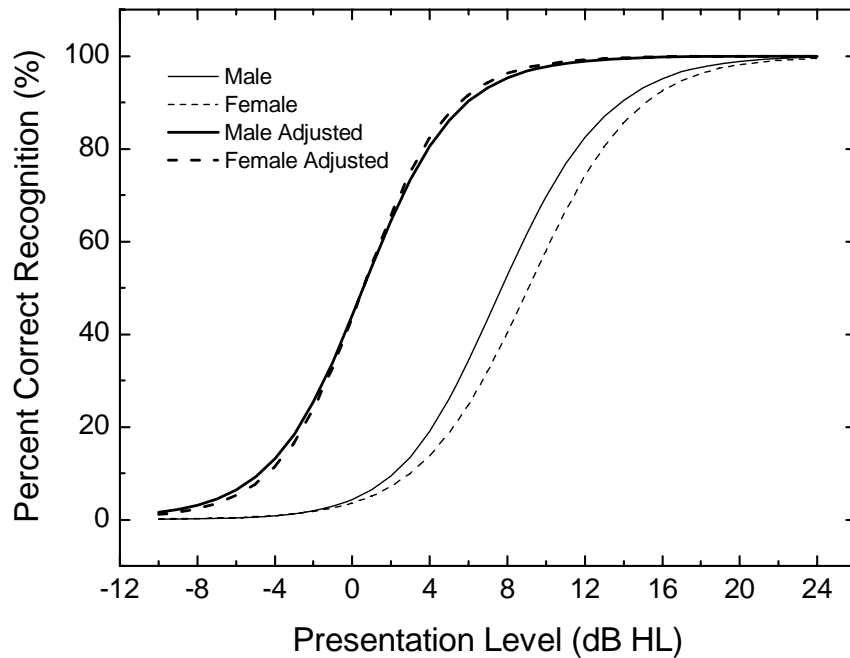


Figure 4. Mean psychometric functions for 28 selected Mongolian male and female talker bisyllabic words after intensity adjustment to equate 50% threshold performance to the mean PTA (0.58 dB HL) for the 20 normally hearing subjects.

Discussion

This study was undertaken for the purposes of developing, digitally recording, and psychometrically equating bisyllabic Mongolian words to utilize for SRT testing of native Mongolian speakers. A native male and female were chosen as talkers for the digital recording of 90 commonly used bisyllabic Mongolian words. Upon evaluation of the 90 bisyllabic words by 20 Mongolian listeners with normal hearing, 28 words were selected for inclusion on a final SRT list. These 28 bisyllabic words were selected based on homogeneity in performance with respect to audibility and psychometric function slope. Finally, digital adjustment was done to reduce intensity threshold variability.

Digital intensity adjustment resulted in the 28 bisyllabic words being more homogeneous with respect to audibility and psychometric function slope when compared to the original, unadjusted bisyllabic words. This difference is apparent in the different panels of Figure 1. The psychometric function slopes from 20 to 80% intelligibility for the 28 bisyllabic words ranged from 7.2 to 13.3%/dB ($M = 9.9$) for the male talker and 5.9 to 12.2%/dB ($M = 9.1$) for the female talker. Mean psychometric slopes for the spondaic words used in English SRT testing have been reported to be between 7.2%/dB and 10%/dB (Hirsh et al., 1952; Hudgins et al., 1947). In other studies, the mean psychometric slopes have been reported to be as high as 12%/dB (Beattie, Svihovec, & Edgerton, 1977; Ramkissoo, 2001). Materials developed in other languages have comparable mean slopes to those reported in this present study. For example, the mean slopes for Taiwanese Mandarin SRT materials were 9.8%/dB for a male talker and 10.1 %/dB for a female talker (Slade, 2006); for Spanish SRT materials mean slopes were reported to be 8.7%/dB and 7.5%/dB for a male and female talker, respectively (Keller, 2009).

Difference Between Mean Listener PTA and Psychometric Thresholds

Of significance in this study was the difference between the mean PTA of the listeners and the threshold for 50% intelligibility. The change in intensity required to adjust the threshold of a word to the mean PTA of the subjects was 7.3 dB for the male talker and 8.5 dB for the female talker. Several recent studies of similar methodology reported much smaller intensity adjustments. The mean intensity adjustment required for Tongan materials was 3.3 dB for the male talker and -.1 dB for the female talker (Bunker, 2008); Thai materials required mean adjustments of 0.2 dB and -1.6 dB for male and female talkers, respectively (Hart, 2008); and Cantonese materials required mean intensity changes of only 1.9 dB for the male talker and -3 dB for the female talker (Kim, 2007).

Several factors may have contributed to the relatively large difference between the mean PTA of the listeners and the mean thresholds found in this study. One factor may be differences in regional dialects between the talkers in the recordings. There are a variety of different dialects spoken across the country of Mongolia, especially in the West where many ethnic minorities reside. Although there are some phonological and lexical differences between the eastern and western dialects, they are considered to be in general mutually intelligible.

Both talkers reported speaking the Khalkha dialect, however, the male talker originated from Ulaanbaatar and the female talker was from Khovd, a western city of Mongolia, and it is still possible that linguistic differences exist across individuals. Of the 20 native Mongolian listeners in this study, 17 were from the capital city, Ulaanbaatar, 2 from other eastern cities, and only 1 from a western city in Mongolia. Richardson (2008) concluded that a slight mismatch between the dialect of the talker and

listener did not have a clinically significant effect on the SRT results. However, earlier research involving native Spanish speakers has demonstrated that listeners with a similar dialect as the talker scored better on SRT measures at lower intensities than listeners with somewhat different, yet still mutually intelligible, dialects (Weisleder & Hodgson, 1989). Although talkers and the listeners reported speaking the Khalkha dialect, regional or cultural differences may have had an effect on overall word intelligibility. Although the listeners in this study were fairly homogenous in terms of geographic place of origin, dialect can also vary as a function of other cultural factors, such as socioeconomic status, religion, and education level. It is unknown whether any of these factors influenced the results of this study.

Relatively large differences between the listener PTA thresholds and the thresholds for 50% intelligibility may also be due to the linguistic characteristics of Mongolian. Compared to other languages, the Mongolian language is rich with vowels, with seven primary vowels and four additional sub-vowels. Hoopingartner (2004) indicated that vowel perception is greatly influenced by context. However, due to the nature of SRT testing, words are presented in isolation without sentential contextual cues.

Clinical Benefits

Although the task of developing speech audiometry materials for foreign languages is time consuming, the benefits of standardized materials are far reaching for those in need of audiological services. In adhering to specified calibration, recording, and testing requirements, developers are able to adequately describe the physical properties of the stimulus and therefore psychometrically equate the resulting materials. Having access to standardized materials allows audiologists to make valid inferences regarding an individual's hearing as well as share clinical information among facilities without

compromising the validity of the test results (Tucci, Ruth, Schoeny, Rupp, & Stockdell, 1980).

Future Research

The SRT materials resulting from this study are a first step in creating speech audiometry materials that can be used to test the hearing acuity of Mongolian speakers. Additional research is needed to further extend the quality and understanding of Mongolian speech audiometry. Although not exhaustive, areas of further research might include replicating studies to observe test-retest reliability, examining the effect of bilingualism on the selection of stimulus items, and extending the selection of test stimuli to a hearing impaired population to compare similarities and differences between studies.

The Mongolian language also has a rich suffix-based morphology. Since it is an agglutinative language, most words are formed by joining morphemes together, with each component of meaning being represented by its own morpheme. It is possible that words with additional consonants and suffixes have greater phonetic dissimilarity in Mongolian and would therefore have lower thresholds for intelligibility when compared to the bisyllabic words used in this study. A follow up study using Mongolian trisyllabic words for SRT would be of interest to determine if phonetic context plays a role in intelligibility thresholds.

It is unclear whether or not the words selected in this study would produce similar results if testing again or in a different location. Gelfand (1998) pointed out that there should not be a significant difference between the test and retest results in order to consider the test reliable. Additional research to determine if this study could be replicated would be important to establish if the created materials exhibit a high level of validity and reliability.

The role bilingualism played in this study is of important consideration. Many of the participants of this study came to the United States to study at an English-speaking university. Most of the participants had learned English as a second language, either through study in Mongolia or by enrolling in English language learning programs upon coming to the United States. While the effect that bilingualism has on the native language speech perception is unclear, there is research to support that it is an important variable to consider. von Hapsburg and Pena (2002) speculated that as the core lexicon and variety of phonological categories of an individual increases, their threshold for speech intelligibility might also increase. Weiss and Dempsey (2008) suggested that the longer a person has been exposed to a second language, the greater difficulty that person will have in processing his or her first or native language. Participants in their study who were exposed to English training after early childhood showed lower thresholds for both languages. Perhaps an additional study controlling for bilingualism might yield improved stimuli validity.

In addition to test-retest reliability and consideration of the effect of bilingualism, another viable area of future study would be to extend the stimuli to Mongolian speakers with hearing impairments. Recent research has found that there is a significant difference between the performance of individuals with normal hearing and those with hearing impairment on speech audiometry testing (McArdle & Wilson, 2006). The present study utilized only normal hearing listeners to test the materials, so it is uncertain whether or not results would be similar if presented to listeners with hearing impairments. Jerger (2006) has indicated the necessity to use speech audiometry test stimuli on the population for which they are intended when developing materials. Although access to Mongolian

speakers with various hearing abilities was limited for this study, future research examining the performance of these materials with individuals with hearing impairments would be beneficial.

Conclusion

This study resulted in the development of 28 digitally-recorded words, recorded by male and female talkers, which can be used in testing the hearing acuity of native Mongolian speakers. The materials were developed to be relatively homogeneous in terms of audibility and psychometric function slope. Reduction in threshold variability between the words was accomplished through intensity adjustments so that the 50% threshold of each word was equal to the mean PTA of the subjects. The 28 bisyllabic words from both the male and female talkers were then digitally recorded onto compact disk to facilitate SRT testing for native Mongolian speakers.

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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 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 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, UT 84602; phone (801) 422-3873, email: renea_beckstrand@byu.edu.

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

Signature of Participant_____
Date_____
Signature of Witness_____
Date

Appendix B

Selected Bisyllabic Word Definitions

Mongolian word	Romanization	Part of Speech	Definition
1 адил	adil	adjective	same, identical, alike
2 агаар	agaar	noun	air
3 авах	avah	verb	to take
4 аялал	ayalal	noun	travel, trip, journey, tour
5 баяр	bayar	noun	celebration, festival, holiday
6 байшин	bayshin	noun	house, building
7 бэлэн	belen	adjective	ready, prepared
8 бичиг	bichig	noun	script, writing
9 бичих	bichih	verb	to write
10 болгох	bolgoh	verb	to make, cause, to cook
11 чадах	chadah	verb	afford, can, contrive, to pull off, to be able, capable
12 чулуу	chuluu	noun	rock, stone
13 дахин	dahin	adverb	again
14 дараа	daraa	adjective	next, afterwards, later
15 давхар	davhar	noun	store, floor
16 дэлхий	delhiy	noun	world, earth
17 дотор	dotor	noun	inside, among
18 дуртай	durtay	adjective	favourite, like
19 дуучин	duuchin	noun	singer
20 заавал	dzaaval	noun	necessarily, must, obligatory
21 залуу	dzaluu	noun	fellow, guy, jack, lad
22 зориг	dzorig	noun	courage
23 зураг	dzurag	noun	drawing, picture, painting, illustration, photograph
24 дүрэм	dürem	noun	grammar, rule
25 дүүрэн	düüren	adjective	full
26 эхнэр	ehner	noun	wife, married woman
27 эмээ	emee	noun	granny, grandmother
28 эрүүл	erүүл	adjective	health, healthy, sound
29 гарах	garah	verb	to go out
30 гэрэл	gerel	noun	light, beam
31 гоё	goyo	adjective	elegant
32 хачин	hachin	adjective	odd, bizarre, strange, peculiar
33 халуун	haluun	adjective	hot, warm, heat, burning and fever
34 харах	harah	verb	to look at, behold, see, to glance, to watch and to look after, care for
35 хариу	hariu	noun	answer, reply, response, in return
36 хатуу	hatuu	adjective	hard, stiff, unbending, rigorous, strict
37 хэлэх	heleh	verb	to speak, say, tell, narrate
38 хэцүү	hetsüü	adjective	difficult, hard, troublesome
39 хурал	hural	noun	assembly, conference, convention, meeting, gathering
40 хурдан	hurdan	adjective	quick, fast, rapid, swift
41 хуучин	huuchin	adjective	old, ancient, of the past, time-worn, former, previous, obsolete, worn out
42 хөөрхөн	höörhön	adjective	prettiness, pretty, beautiful, cute

Mongolian word	Romanization	Part of Speech	Definition
43 хүрэх	hüreh	verb	to reach, arrive at, to touch, to amount to, to achieve gain
44 хүйтэн	hüyten	noun	chill, chilly, cold, coldness, cool, unfriendly
45 хүүхэд	hüühed	noun	baby, bantling, child, kiddy
46 илүү	ilüü	noun	extra, spare, excess, excessive, extra, more, surplus
47 жаргал	jargal	adjective	happiness, joy, pleasure
48 жишээ	jishee	noun	example
49 мэдээ	medee	noun	news, message
50 мэдэх	medeh	verb	to know
51 мэдлэг	medleg	noun	knowledge, learning, understanding
52 муухай	muuhay	adjective	ugly, unattractive, unpleasant, nasty, bad, awful
53 нэртэй	nertey	adjective	famous, prominent, well known, renowned
54 нулимс	nulims	noun	tear
55 нутаг	nutag	noun	birthplace, homeland, native land
56 нөхөр	nöhör	noun	associate, comrade, friend and husband
57 очих	ochih	verb	to go
58 охин	ohin	noun	girl, daughter
59 олгох	olgoh	verb	to provide, to grant, bestow, give, allow, issue
60 олох	oloh	verb	to find, obtain, earn
61 олон	olon	noun	many, multitude, the mass
62 онгоц	ongots	noun	airplane
63 орчин	orchin	noun	surroundings, around
64 орон	oron	noun	country
65 санаа	sanaa	noun	thought, thinking, idea
66 сайхан	sayhan	adjective	pleasant, nice, fine, lovely
67 шүлэг	shüleg	noun	poetry, poem, vers
68 сонин	sonin	noun	newspaper, gazette and news and interesting
69 судлах	sudlah	verb	to study, investigate, research
70 талбай	talbay	noun	area, field, square
71 тавих	tavih	verb	to set free, release and to place, put out, lay or put down, to put on and to heed, pay attention
72 тэмдэг	temdeg	noun	sign, symbol, mark and medal
73 тэнгэр	tenger	noun	sky, heaven
74 толгой	tolgoy	noun	head
75 төмөр	tömör	noun	iron, metal
76 удаа	udaa	noun	instance, occasion, occurrence, once
77 удаан	udaan	adjective	slow
78 унших	unshih	verb	to read
79 яриа	yaria	noun	talk, conversation, chat
80 явах	yavah	verb	to go, move forward, leave, depart, go away
81 ёстой	yostoy	noun	must
82 өдөр	ödör	noun	day, date
83 өгөх	ögöh	verb	to give, grant, hand over
84 өмнө	ömnö	noun	south, southern, front, ahead and before, in front of, prior to, ago
85 өндөр	öndör	adjective	tall, high, height
86 өргөн	örgön	adjective	broad, wide, vast, width, broadly, widely
87 өөрөө	ööröö	noun	self, oneself
88 үзэх	üdzeh	verb	to see, look at, glance at, behold, gaze upon,

Mongolian word	Romanization	Part of Speech	Definition
89 үНЭН	ünen	noun	view, watch and to learn, study and to regard as, deem, consider truth
90 ҮҮРЭГ	üüreg	noun	truth duty, responsibility, obligation, role