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Psychometrically Equivalent Trisyllabic Words for Speech Reception Threshold Testing in Spanish

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PSYCHOMETRICALLY EQUIVALENT TRISYLLABIC WORDS FOR SPEECH RECEPTION THRESHOLD TESTING IN SPANISH

by

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As chair of the candidate's graduate committee, I have read the thesis of Laurel Anne Keller 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

PSYCHOMETRICALLY EQUIVALENT TRISYLLABIC WORDS FOR SPEECH RECEPTION THRESHOLD TESTING IN SPANISH

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The purpose of this study was to develop, digitally record, evaluate, and equate Spanish trisyllabic words which could then be used in the measurement of the speech reception threshold. A selection of 90 frequently utilized trisyllabic words were selected and then digitally recorded by male and female talkers of Spanish and presented to 20 subjects with normal hearing beginning at 6 dB below their pure-tone average (PTA) and ascending in 2 dB increments until one of the following criteria had been met: (a) the participant responded correctly to 100% of the test items, or (b) the presentation level reached 16 dB HL. Using logistic regression, psychometric functions were calculated for each word. Twenty-eight trisyllabic words with the steepest psychometric function slopes were selected. To decrease the variability among the words the intensities were digitally adjusted to match the mean subject PTA (5.83 dB HL). The resulting lists included mean

slopes at 50% threshold which ranged from 7.3 %/dB to 12.7 %/dB (*M* = 10.1) for the male talker recording and from 7.1 %/dB to 12.8 %/dB (*M* = 8.7) for the female talker. Digital recordings of the 28 final psychometrically equivalent trisyllabic words are available on compact disc.

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Introduction

The benefits of speech audiometry are well documented and have made speech audiometry a standard part of a complete diagnostic evaluation for almost all audiologists (Martin, Armstrong, & Champlin, 1994). The majority of speech audiometric tests have been designed for the English speaking client; fewer materials in other languages are readily available. This situation has left many professionals with the dilemma of presenting tests in English to non-English speaking clients, knowing the validity of the test is decreased significantly when the stimuli are not in that individual's native language (Ramkissoon, 2001). Being tested in a second language also denies the individual some of the advantages of rehabilitation and testing (Cancel de Irizarry, 1971). Clinicians should be hesitant to make clinical decisions based solely on testing done in a second language (Rudmin, 1987).

A variety of materials for speech audiometry are available in the Spanish language. For example, Berruecos and Rodríquez (1967) developed four lists of 25 phonetically balanced trochaic words. These lists were not designed specifically for speech audiometry, but to further the understanding of the Spanish language. Multiple choice lists for testing speech discrimination ability were created by selecting words from newspapers and common literature and were recorded in analog format by Cancel (1965), who found that a list of 50 words could satisfactorily reveal an individual's speech discrimination ability. Cancel (1968) created a visual hearing (lip-reading) skills test for the Spanish speaking individual. Comstock and Martin (1984) developed a children's Spanish word discrimination test, which relied on a picture-pointing task and consisted of four lists of 25 bisyllabic words.

Other Spanish language speech audiometry materials have been developed. Danhauer, Crawford, and Edgerton (1984) examined native Spanish speaker's performance on a nonsense syllable test (NST). The authors discovered the native speakers scored significantly worse on the NST than did bilingual (Spanish-English) and English-only speaking participants. A picture identification task in Spanish using a multimedia format was developed (McCullough, Wilson, Birck, & Anderson, 1994) and further explored by McCullough and Wilson (2001). The authors discovered that the tasks in the study yielded similar results to other Spanish speech discrimination tasks. Spitzer (1980) produced a Spanish speech reception threshold (SRT) task using 51 words selected from a variety of sources. Zubick et al. (1983) developed the Boston College Auditory Tests lists, which were created using a sample of 10 normal hearing Spanish speakers as the test population.

However, existing Spanish language speech audiometry materials have several limitations. The advent of digital technology has almost eliminated the use of analog materials. Harris et al. (2007) delineate many of the improvements in digital technology relevant to speech audiometry. Spanish language digital recordings are available from Auditec of St. Louis, but these materials were remastered from the analog recordings onto a compact disk (CD). Cokely & Yager (1993) explored Auditec's commercially available speech discrimination materials and discovered the lists were not equivalent. The lack of standardization of Auditec's materials and the analog nature of the recordings has left room for further research in this area (Christensen, 1995).

Digital materials were developed at Brigham Young University as part of a master's thesis by Christensen (1995). However, there are several limitations to these materials as well. The most important limitation lies in the word selection for recording. Christensen (1995) chose words for testing from frequency dictionaries created in the early 1960s. As language is not static and constantly changes, it is important for SRT test stimuli to be chosen from current corpora of frequently used words because familiarity enhances test validity (Nissen, Harris, Jennings, Eggett & Buck, 2005).

Additional improvements have been made in the selection of the words to be included in the word lists. Current methodology uses the statistical analysis procedure of logistic regression to determine the performance intensity function of each word, resulting in a more accurate estimation of the individual word thresholds (R. W. Harris, personal communication, November 2007). This technique was not employed to select the words for inclusion in the Christensen (1995) study.

Thus, there is a need for the development of improved Spanish speech audiometry materials. The purpose of this study was to develop, digitally record, and evaluate speech audiometry materials which may be used to evaluate the SRT of individuals who speak Spanish, using the improved technology, methods, and current word frequency data now available.

Review of Literature

Speech Audiometry

Pure-tone audiometry is perhaps the method most preferred by audiologists to determine if an individual has a hearing loss (Egan, 1979). Pure-tone audiometry is reliable, valid, and relatively simple, but results from this test do not provide a complete picture of an individual's hearing abilities (Hagerman, 1993). Since human beings use their acoustic system primarily to understand speech signals, a hearing evaluation should not be said to be complete without procedures that provide insight into how well that individual can hear speech signals. Often, the lack of understanding of speech sounds is the primary concern of many of the patients who seek audiological evaluations (Brandy, 2002).

Speech audiometry is more complex test than pure-tone audiometry and has been shown to be a more accurate measure of an individual's communicative abilities (Bell & Wilson, 2001). Speech audiometry began first as a clinician speaking with the patient at varying distances and intensities, which provided the clinician with some information with which to estimate the patient's ability to understand speech (Brandy, 2002; Feldman, 1970). This type of speech testing had some serious disadvantages in that there was a lack of standardization, reliability, and validity.

The need for standardized procedures led to the development of new procedures and tests (American Speech, Language, and Hearing Association (ASHA), 1988; Beattie, Forrester, & Ruby, 1977; Carhart & Porter, 1971; Chaiklin, Font, & Dixon, 1967; Creston, Gillespie, & Krohn, 1966; Fletcher, 1922; Fletcher & Steinberg, 1929; Hirsh et al., 1952; Hood & Poole, 1980; Jerger, Carhart, Tillman, & Peterson, 1959; Martin & Stauffer, 1975; Wilson, Morgan, & Dirks, 1973; Young, Dudley, & Gunter, 1982). Early research began to show a relationship between speech discrimination and intensity. As the intensity of a stimulus increases, so should the percentage of correct response increase (Hirsch et al., 1952). Young et al. (1982) also found that the steepness of the performance intensity function depends on the type of test stimuli presented to the patient.

The Western Electric 4A was the first recorded auditory test designed to determine an individual's SRT, which is defined as the lowest dB level that the patient can correctly repeat 50% of the spondee words (ASHA, 1988; Carhart, 1952; Ferrer, 1960; Hirsh et al., 1952; Young et al., 1982). Fletcher produced the Western Electric 4A at the Bell Telephone Laboratories in 1929 (Christensen, 1995). The stimuli for this test were digits recorded as pairs with 3 dB of attenuation from one pair to the following pair (Christensen, 1995). The Western Electric 4A was revised and became the Western Electric 4-C test, but there was a major limitation to this test. The Western Electric 4-C test stimuli were recorded on a phonograph which failed to produce enough intensity to accurately identify high-frequency hearing loss (Hudgins, Hawkins, Karlin, & Stevens, 1947). Years of research and advancement in technology led to the production and wide spread distribution of the CID-W1 and W-22 lists for speech audiometry testing (Hirsh et al., 1952; Wilson, Preece, & Thornton, 1990).

The advent of improved speech audiometry materials has drastically increased the value of speech audiometry as a diagnostic tool. Speech audiometry is extremely useful in the differential diagnosis of several disorders including; inner ear problems, nonorganic hearing disorders, and peripheral and central auditory disorders (Creston et al., 1966; Hood & Poole, 1977; Jerger, Speaks, & Trammell, 1968; Ostergard, 1983; Van Dijk, Duijndam, & Graamans, 2000). Two tests, speech discrimination testing and SRT, are the most widely accepted forms of speech audiometry. The present study focuses on SRT as a diagnostic tool for Spanish speakers.

Speech Reception Threshold

Tillman and Olsen (1973) presented a method for obtaining the SRT score in the early 1970s that has long been the standard for this test. The pure-tone average from pure-tone testing is used to estimate a starting threshold for the test, and the stimuli for testing are presented in 2 dB increments (Tillman & Olsen, 1973). Some variations on this method have been proposed and accepted over the years. The Wilson et al. (1973)

method is similar except that the test stimuli are presented in 5 dB increments instead of 2 dB. The American Speech-Language and Hearing Association has approved both the 5 dB and the 2 dB method for clinical use today (ASHA, 1988). Martin and Stauffer (1975) modified the procedure as to how to obtain the starting threshold. Their method did not require previous pure-tone testing and has been proven to be helpful when differentiating non-organic hearing impairments.

The most basic function of the SRT test is to establish the threshold of the individual's ability to hear speech. Another vital function of the SRT is establishing the feasibility of a hearing aid by determining the actual effectiveness of the various types of hearing aids for the patient (ASHA, 1988; Carhart, 1952). An additional important function of the SRT is to confirm the pure-tone audiometric results (ASHA, 1988). A mismatch between the results of the pure-tone results and SRT results can indicate an exaggerated hearing loss, irregular auditory sensitivity, or the presence of an auditory, cognitive, or central auditory disorder (ASHA, 1988; Carhart, 1952; Young et al., 1982).

The SRT is defined as the lowest dB level that the patient can correctly repeat 50% of the presented materials (ASHA, 1988; Carhart, 1952; Ferrer, 1960; Hirsh et al., 1952; Young et al., 1982). The test stimuli for obtaining an SRT are typically spondaic words which are familiar to the listener, phonetically dissimilar, and sample the target population's language (Young et al., 1982). The testing environment and speech audiometer need to meet the standards set forth by the American National Standards Institute (1999; 2004).

When choosing testing stimuli, there are four important characteristics of the stimuli that should be considered. These four aspects are (a) the familiarity of the words to the listener, (b) phonetic dissimilarity, (c) normal sampling of the target language, and (d) homogeneity of threshold recognition (Young et al., 1982). Familiarity of words is perhaps the most important characteristic to consider when creating testing materials (Nissen et al., 2005; Young et al., 1982). Nissen et al. (2005) found that using familiar words when testing increases the test's validity. When the words are familiar in SRT testing, the materials are more likely to be a measure of an individual’s threshold of speech intelligibility rather than vocabulary (Ramkissoon, 2001). This is a critical characteristic to consider when testing an individual in their non-native language. For example, a Spanish speaker being testing in English may hear the item *hot dog* and not recognize it because of a lack of exposure rather than an inability to discriminate the word. This would create an inaccurate representation of the individual's hearing ability (Ramkissoon, 2001).

Another critical characteristic to consider when choosing test materials is the homogeneity of the threshold recognition. Homogeneity of threshold recognition is also known as homogeneity of audibility and implies that all test stimuli have the same amplitude regardless of the method of delivery (Ramkissoon, 2001). Homogeneity is important as it facilitates a more precise measurement of the individual’s hearing threshold with fewer test items (Ramkissoon, 2001; Young et al., 1982). Word familiarity and phonetic dissimilarity of the stimuli can also affect the homogeneity of any list of test words.

Homogeneity is commonly determined by computing the psychometric performance intensity functions for each word. Since the 50% intelligibility level can vary from word to word, it is important to know the rate for which each word becomes intelligible (Young et al., 1982). Wilson and Carter (2001) concluded that steeper slopes on performance intensity function slopes indicate greater homogeneity. In essence, psychometric function slopes signify the ability of the listener to comprehend a given stimulus (speech materials) as a function of the presentation level (Wilson & Carter, 2001). Homogeneity is critical to the ability to equate the audibility of the testing materials, to decreasing testing time, and to increasing test-retest reliability (Epstein, 1978; Wilson & Carter, 2001; Wilson & Strouse, 1999).

The third characteristic of phonetic dissimilarity of stimuli is important as this characteristic ensures that the listener is not gaining cues from the auditory similarity of the words (Ramkissoon, 2001). Words should be familiar to the listener, but should not have several words that are phonemically similar (Luce, 1986). A hearing impairment decreases an individual's ability to accurately discriminate between specific phonemes. When there are a high number of words phonemically similar to the target word, the task becomes extremely difficult for someone with a hearing impairment (Bell & Wilson, 2001). Recognition scores are improved when the test stimuli includes words that occur frequently and are phonemically dissimilar (Dirks, Takayanagi, & Moshfegh, 2001).

An additional consideration regarding testing stimuli is the method of delivery. Testing stimuli has been administered in a variety of ways over the years. Over time, spondaic lists were presented via phonographic records, tape recordings, monitored live voice, and digital recordings. Digital recordings, specifically CDs, are fast becoming the standard for SRT materials (Wilson et al., 1990). CDs are relatively inexpensive, have better channel separation, eliminate wow and flutter found in tape recordings, have reduced amount of damage due to use, greater data storage capabilities, higher signal to noise ratios, and greater standardization than monitored live voice (ASHA, 1988; Harris et al., 2007; Wilson et al., 1990). Additionally, digital recordings allow faster and more in-depth editing of the test stimuli (Harris et al., 2007). These characteristics were all examined and it was determined that digital recordings would be used in this study due to the many advantages of digital recordings.

Spanish Speech Audiometry

Spanish Language. The United States of America is made of a variety of different people with a myriad of linguistic backgrounds. Of the many languages that are spoken in the United States, Spanish is the second most common language (U.S. Census Bureau, 2000). In the United States, 43.1 million people are of Hispanic or Latino origin and nearly 14 million of those individuals report their English speaking abilities as “less than very well” (U.S. Census Bureau). Of course, Spanish is a common language outside the United States as well, primarily in Central and South America.

Audiometry Materials. There are some materials available in Spanish for speech audiometry (Berruecos & Rodríquez, 1967; Cancel, 1965, 1968; Cancel de Irizarry, 1971; Christensen, 1995; Cokely & Yager, 1993; Comstock & Martin, 1984; Connery, 1977; Danhauer et al., 1984; Ferrer, 1960; Martin & Hart, 1978; McCullough et al., 1994; McCullough & Wilson, 2001; Rosenblut & Cruz, 1962; Spitzer, 1980; Weisleder & Hodgson, 1989; Zubick et al., 1983), but many of these materials were created before digital recording became a common procedure for audiometric materials. The use of digital recordings has become a standard practice in Audiology because of the many advantages of digital materials over analog materials (ASHA, 1988; Wilson et al., 1990) mentioned above.

Christensen (1995) did use digital recordings for the materials in her study, but the stimuli for the testing were drawn from frequency dictionaries and common usage indexes from the early 1960s. A newer frequency dictionary for the most commonly used Spanish words was recently completed and made available for purchase (Davies, 2006). Current usage information is critical when creating SRT materials, because frequently used words create test validity (Nissen et al., 2005; Ramkissoon, 2001).

Increased test validity is important for the patient as it supports an accurate diagnosis and directs the correct course of treatment. von Hapsburg & Peña (2002) found in a review of available Spanish speech audiometry materials that native Spanish speakers consistently performed better on tests that in Spanish rather than in English. Better test results for these individuals could indicate a more accurate description of the individual's hearing abilities (von Hapsburg & Peña, 2002).

Since there is a lack of current, standardized, and widely distributed materials available in the Spanish language for SRT testing, the purpose of this study is to (a) identify a native male and a native female Spanish talker who use speak Spanish as their primary language to serve as talkers for the Spanish speech audiometry recordings; (b) construct a list of familiar trisyllabic Spanish words which have steep psychometric function slopes for use in measurement of the SRT; (c) create high-quality digital recordings of the selected Spanish trisyllabic words; (d) collect normative data on these trisyllabic words; (e) select a subset of words which are homogeneous with respect to audibility and psychometric function slope. These materials can then be distributed for the use of audiologists in the United States as well as other countries whose population speaks Spanish and to those whose who are responsible for testing individuals whose native language is Spanish.

Method

Participants

The individuals who participated in this study were native talkers of Spanish, originating from Mexico. In addition, all participants indicated that they have continued to speak Spanish on a daily basis. A total of 20 subjects (12 female, 8 male) who ranged in age from 18 to 51 years old with a mean age of 25.5 years old, participated in evaluating the Spanish trisyllabic words. All participants had pure-tone air-conduction thresholds ≤ 15 dB HL at octave and mid-octave 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). Characteristics of the participants are described in Table 1.

Materials

Words. Trisyllabic words were chosen as stimuli for the SRT materials from the 2,000 most commonly used words in Spanish, as rated in the frequency column according to data in a dictionary by Davies (2006). Initially, 300 trisyllabic words were selected from a corpus created from Davies' dictionary. These words were then rated by six native judges on a scale of 1 to 5 based on how familiar a word would be to a native speaker of Spanish and whether the word was appropriate to use (1 = extremely, 2 = very, 3 = average, 4 = seldom used, 5 = rarely used).The words selected for recording received an average score of 1 or 2, with any word receiving a 5 from any judge being automatically eliminated. Of the 300 trisyllabic words considered, 150 words were eliminated prior to listener evaluation for the following reasons: (a) thought to be

Table 1

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

	M	*Minimum*	*Maximum*	*SD*
0.125 kHz	7.3	0	10	3.0
0.25 kHz	4.8	-10	15	5.3
0.5 kHz	6.3	-5	15	4.6
0.75 kHz	6.0	-5	15	5.0
1.0 kHz	6.3	0	15	4.6
1.5 kHz	5.5	-5	15	4.8
2.0 kHz	5.0	0	10	4.0
3.0 kHz	4.5	-5	15	5.6
4.0 kHz	4.5	-5	15	5.8
6.0 kHz	6.8	-10	15	7.1
8.0 kHz	7.3	0	15	6.2
PTA[a]	5.83	0.0	13.3	3.4

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

culturally insensitive, (b) considered to be unfamiliar, (c) thought to possibly represent inappropriate content, or (d) had the same pronunciation but different meanings.

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

Recordings. All recordings were made in a large anechoic chamber located in the Eyring Science Center 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 then digitized by an Apogee AD-8000 24-bit analog-to-digital converter and subsequently stored on a hard drive for later editing. A 44.1 kHz sampling rate with 24-bit quantization was used for all recordings, and every effort was made to utilize the full range of the 24-bit analog-to-digital converter. Ambient noise levels in the anechoic chamber were approximately 0 dB SPL, which allowed a signal-to-noise ratio of at least 65 dB during recording, which was verified by measurement of ambient noise and speech levels on the recording.

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

After the word selection process, the intensity of each trisyllabic word to be included in the test materials was edited as a single utterance using Sadie Disk Editor software (Studio Audio & Video Limited, 2004) to yield the same average RMS power as that of a 1000 Hz calibration tone in an initial attempt to equate test word threshold audibility (Harris, Nielson, McPherson, Skarzynski, & Eggett, 2004; Wilson & Strouse, 1999). Each of the individually recorded and edited words were then saved as 24-bit *wav* files. Finally, the words were edited using Adobe Audition software (Adobe Systems Incorporated, 2006) to remove any extraneous noise and provide consistent pre-presentation timing.

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 subject via a single TDH-50P headphone. All testing was carried out in a double-walled sound suite that met ANSI S3.1 standards for maximum permissible ambient noise levels for the ears not covered condition using one-third octave-bands (ANSI, 1999).

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

Each subject participated in two test sessions after passing a screening exam. The 90 trisyllabic words were presented to each of the participants beginning at 6 dB below their PTA and ascending in 2 dB increments until one of the following criteria had been met: (a) the participant responded correctly to 100% of the test items, or (b) the presentation level reached 16 dB HL. The sequence of the 90 words was randomized prior to presentation at each intensity level. Each subject listened to both the male and female talker recordings of all 90 trisyllabic words, in a sequence determined randomly. Subjects repeated words verbally which were scored as being correct or incorrect by a native Spanish judge. Each subject was allowed to have several rest periods during each test session. Prior to the evaluation of the trisyllabic words, each individual was given the following instructions:

> 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 listen carefully and 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

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

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

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

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

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

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

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

Thresholds for the male talker of the 90 trisyllabic words ranged from -0.5 dB HL to 14.8 dB HL (*M* = 6.7), and for the female talker from -4.8 dB HL to 16.5 dB HL (*M* = 5.6). Equation 2 was used to calculate the psychometric performance-intensity functions each trisyllabic word using the logistic regression intercept and slope values. The slopes for the male talker at 50% ranged from 4.8 %/dB to 12.7 %/dB (*M* = 9.2) and from 3.3 %/dB to 12.8 %/dB (*M* = 7.5) for the female talker. The slopes from 20-80% ranged from 4.2 %/dB to 11.0 %/dB (*M* = 8) for the male talker and from 2.8 %/dB to 11.1 %/dB (*M* = 6.5) for the female talker. Thus, the slopes at 50% threshold were steeper compared to the slopes at 20-80%. Slopes of the psychometric performance-intensity functions and 50% thresholds for all trisyllabic words are presented in Table 2 (male talker) and Table 3 (female talker).

Words included on the final list were chosen based on steep psychometric performance-intensity function slopes and relative homogeneity as these features improve reliability and reduce testing time (Wilson & Strouse, 1999). A list of 37 words was compiled of words with the steepest psychometric performance-intensity function slopes for both male and female talkers (≥ 7.0 %/dB for both male and female talkers). These words also had to have enough headroom for the necessary adjustments.

Table 2

Mean Performance for 90 Spanish Male Trisyllabic SRT words

#	Word	a[a]	b[b]	at 50%[c]	Slope 20-80%[d]	Slope Threshold[e]	ΔdB[f]
1	acaban	3.11540	-0.34123	8.5	7.4	9.1	3.3
2	acerca	2.88802	-0.48226	12.1	10.4	6.0	0.2
3	además	2.37488	-0.41117	10.3	8.9	5.8	-0.1
4	ahora	-0.16992	-0.38734	9.7	8.4	-0.4	-6.3
5	apenas	1.66336	-0.44646	11.2	9.7	3.7	-2.1
6	apoyan	1.79107	-0.34911	8.7	7.6	5.1	-0.7
7	apoyo	1.18119	-0.37629	9.4	8.1	3.1	-2.7
8	aprenden	2.55827	-0.25226	6.3	5.5	10.1	4.3
9	aquello	1.90969	-0.44993	11.2	9.7	4.2	-1.6
10	cabeza	0.50015	-0.31806	8.0	6.9	1.6	-4.3
11	calidad	2.49552	-0.30260	7.6	6.5	8.2	2.4
12	cerrado	2.36729	-0.41720	10.4	9.0	5.7	-0.2
13	comentar	2.60604	-0.27994	7.0	6.1	9.3	3.5
14	comienza	2.60955	-0.32632	8.2	7.1	8.0	2.2
15	comparten	3.43974	-0.28644	7.2	6.2	12.0	6.2
16	comprender	1.49761	-0.31993	8.0	6.9	4.7	-1.1
17	conocer	1.47601	-0.37972	9.5	8.2	3.9	-1.9
18	contesta	2.97032	-0.40580	10.1	8.8	7.3	1.5
19	contiene	3.29259	-0.33921	8.5	7.3	9.7	3.9
20	cuidado	3.50704	-0.35868	9.0	7.8	9.8	3.9
21	defiende	3.93906	-0.29086	7.3	6.3	13.5	7.7
22	depender	4.49338	-0.31371	7.8	6.8	14.3	8.5
23	derecho	0.93034	-0.43525	10.9	9.4	2.1	-3.7
24	despiertan	3.63955	-0.29526	7.4	6.4	12.3	6.5
25	dificil	3.24374	-0.44996	11.2	9.7	7.2	1.4
26	dirigen	3.90629	-0.32079	8.0	6.9	12.2	6.3
27	durante	3.81293	-0.37024	9.3	8.0	10.3	4.5
28	ejemplo	2.01060	-0.40627	10.2	8.8	4.9	-0.9
29	enfermo	3.20750	-0.47167	11.8	10.2	6.8	1.0
30	entonces	2.83958	-0.48234	12.1	10.4	5.9	0.1
31	entrada	1.37199	-0.41732	10.4	9.0	3.3	-2.5
32	entregar	1.81158	-0.35296	8.8	7.6	5.1	-0.7
33	equipo	3.78775	-0.39836	10.0	8.6	9.5	3.7
34	esperan	2.62730	-0.19304	4.8	4.2	13.6	7.8
35	exigen	2.95841	-0.41599	10.4	9.0	7.1	1.3
36	explican	3.31629	-0.35457	8.9	7.7	9.4	3.5
37	figura	2.26832	-0.36068	9.0	7.8	6.3	0.5

#	Word	a[a]	b[b]	at 50% [c]	Slope 20-80%[d]	Slope Threshold[e]	ΔdB[f]
38	fisico	4.15670	-0.41955	10.5	9.1	9.9	4.1
39	general	3.10575	-0.48569	12.1	10.5	6.4	0.6
40	humano	2.61202	-0.38369	9.6	8.3	6.8	1.0
41	importan	3.92554	-0.29327	7.3	6.3	13.4	7.6
42	incluir	4.84143	-0.35532	8.9	7.7	13.6	7.8
43	incluso	2.82835	-0.31872	8.0	6.9	8.9	3.0
44	informar	4.08503	-0.37302	9.3	8.1	11.0	5.1
45	interés	3.87850	-0.35248	8.8	7.6	11.0	5.2
46	lectura	1.96483	-0.27794	6.9	6.0	7.1	1.2
47	levantar	2.39018	-0.45340	11.3	9.8	5.3	-0.6
48	manera	2.66609	-0.45310	11.3	9.8	5.9	0.1
49	medida	3.58683	-0.38864	9.7	8.4	9.2	3.4
50	mercado	2.99183	-0.48321	12.1	10.5	6.2	0.4
51	minuto	4.24838	-0.42451	10.6	9.2	10.0	4.2
52	moderno	1.17387	-0.31725	7.9	6.9	3.7	-2.1
53	momento	1.37720	-0.29594	7.4	6.4	4.7	-1.2
54	ninguno	3.73798	-0.39287	9.8	8.5	9.5	3.7
55	nosotros	2.04017	-0.47942	12.0	10.4	4.3	-1.6
56	obtener	2.19217	-0.45092	11.3	9.8	4.9	-1.0
57	palabra	-0.12771	-0.25944	6.5	5.6	-0.5	-6.3
58	pasado	1.57730	-0.35872	9.0	7.8	4.4	-1.4
59	pequeño	2.56951	-0.50602	12.7	11.0	5.1	-0.8
60	perfecto	1.61876	-0.34419	8.6	7.4	4.7	-1.1
61	permiten	2.89682	-0.32274	8.1	7.0	9.0	3.1
62	persona	1.53899	-0.29004	7.3	6.3	5.3	-0.5
63	popular	1.81890	-0.27920	7.0	6.0	6.5	0.7
64	posible	2.52632	-0.40165	10.0	8.7	6.3	0.5
65	pregunta	1.92856	-0.39832	10.0	8.6	4.8	-1.0
66	preparar	1.06896	-0.22459	5.6	4.9	4.8	-1.1
67	primero	1.60021	-0.45430	11.4	9.8	3.5	-2.3
68	principal	3.35007	-0.47837	12.0	10.4	7.0	1.2
69	problema	1.52167	-0.34691	8.7	7.5	4.4	-1.4
70	produce	1.92078	-0.29509	7.4	6.4	6.5	0.7
71	profesor	1.43749	-0.37064	9.3	8.0	3.9	-2.0
72	programa	0.86062	-0.36426	9.1	7.9	2.4	-3.5
73	propone	1.99454	-0.30656	7.7	6.6	6.5	0.7
74	provocan	1.38921	-0.20352	5.1	4.4	6.8	1.0
75	próximo	2.46846	-0.40572	10.1	8.8	6.1	0.3
76	proyecto	1.28128	-0.44363	11.1	9.6	2.9	-2.9
77	público	2.39990	-0.42287	10.6	9.2	5.7	-0.2

#	Word	a[a]	b[b]	Slope at 50% [c]	Slope 20-80%[d]	Threshold[e]	ΔdB[f]
78	rápido	1.53886	-0.41526	10.4	9.0	3.7	-2.1
79	recoger	0.04949	-0.37813	9.5	8.2	0.1	-5.7
80	recordar	1.18485	-0.36644	9.2	7.9	3.2	-2.6
81	responde	1.97173	-0.36167	9.0	7.8	5.5	-0.4
82	retiran	3.06414	-0.29452	7.4	6.4	10.4	4.6
83	salida	3.55498	-0.43715	10.9	9.5	8.1	2.3
84	tamaño	0.55030	-0.35278	8.8	7.6	1.6	-4.3
85	tampoco	0.04161	-0.24465	6.1	5.3	0.2	-5.7
86	tarea	1.27589	-0.47271	11.8	10.2	2.7	-3.1
87	trabajo	0.11649	-0.31362	7.8	6.8	0.4	-5.5
88	último	5.34782	-0.40235	10.1	8.7	13.3	7.5
89	visita	3.65889	-0.35007	8.8	7.6	10.5	4.6
90	visitar	4.79564	-0.32353	8.1	7.0	14.8	9.0
	M	2.40925	-0.36831	9.2	8.0	6.7	0.9
	Min	-0.16992	-0.50602	4.8	4.2	-0.5	-6.3
	Max	5.34782	-0.19304	12.7	11.0	14.8	9.0
	Range	5.51774	0.31298	7.8	6.8	15.3	15.3
	SD	1.19624	0.07006	1.8	1.5	3.6	3.6

[a]*a* = regression intercept. [b]*b* = regression slope. [c]Psychometric function slope (%/dB) at 50% was calculated from 49.999 to 50.001%. [d]Psychometric function slope (%/dB) from 20-80%. [e]Intensity required for 50% intelligibility. [f]Change in intensity required to adjust the threshold of a word to the mean PTA of the subjects (5.83 dB HL)

Table 3

Mean Performance for 90 Spanish Female Trisyllabic SRT words

#	Word	a[a]	b[b]	at 50% [c]	Slope 20-80%[d]	Slope Threshold[e]	ΔdB[f]
1	acaban	1.10393	-0.22426	5.6	4.9	4.9	-0.9
2	acerca	-0.03175	-0.20430	5.1	4.4	-0.2	-6.0
3	además	-0.61577	-0.25701	6.4	5.6	-2.4	-8.2
4	ahora	-1.31038	-0.31979	8.0	6.9	-4.1	-9.9
5	apenas	1.07640	-0.34007	8.5	7.4	3.2	-2.7
6	apoyan	1.71839	-0.23853	6.0	5.2	7.2	1.4
7	apoyo	-0.16766	-0.32327	8.1	7.0	-0.5	-6.3
8	aprenden	1.63726	-0.17443	4.4	3.8	9.4	3.6
9	aquello	1.58737	-0.18806	4.7	4.1	8.4	2.6
10	cabeza	0.20989	-0.26842	6.7	5.8	0.8	-5.0
11	calidad	1.33519	-0.26466	6.6	5.7	5.0	-0.8
12	cerrado	0.95388	-0.25732	6.4	5.6	3.7	-2.1
13	comentar	1.58947	-0.22270	5.6	4.8	7.1	1.3
14	comienza	1.45333	-0.32834	8.2	7.1	4.4	-1.4
15	comparten	2.93542	-0.22117	5.5	4.8	13.3	7.4
16	comprender	0.13811	-0.32957	8.2	7.1	0.4	-5.4
17	conocer	0.18823	-0.25750	6.4	5.6	0.7	-5.1
18	contesta	1.45907	-0.29511	7.4	6.4	4.9	-0.9
19	contiene	3.01159	-0.32742	8.2	7.1	9.2	3.4
20	cuidado	1.97267	-0.37397	9.3	8.1	5.3	-0.6
21	defiende	3.59492	-0.21807	5.5	4.7	16.5	10.7
22	depender	1.84287	-0.31212	7.8	6.8	5.9	0.1
23	derecho	0.52844	-0.28334	7.1	6.1	1.9	-4.0
24	despiertan	2.56486	-0.24847	6.2	5.4	10.3	4.5
25	dificil	1.29056	-0.32272	8.1	7.0	4.0	-1.8
26	dirigen	3.45323	-0.31672	7.9	6.9	10.9	5.1
27	durante	1.88077	-0.26771	6.7	5.8	7.0	1.2
28	ejemplo	1.56617	-0.51285	12.8	11.1	3.1	-2.8
29	enfermo	2.41555	-0.32256	8.1	7.0	7.5	1.7
30	entonces	1.43386	-0.30297	7.6	6.6	4.7	-1.1
31	entrada	1.72154	-0.26583	6.6	5.8	6.5	0.6
32	entregar	2.15187	-0.34649	8.7	7.5	6.2	0.4
33	equipo	1.15623	-0.34213	8.6	7.4	3.4	-2.5
34	esperan	3.23927	-0.27291	6.8	5.9	11.9	6.0
35	exigen	3.50607	-0.32990	8.2	7.1	10.6	4.8
36	explican	3.37230	-0.35197	8.8	7.6	9.6	3.8
37	figura	1.29341	-0.33165	8.3	7.2	3.9	-1.9

#	Word	a[a]	b[b]	at 50% [c]	Slope 20-80%[d]	Slope Threshold[e]	ΔdB[f]
38	fisico	2.15886	-0.31477	7.9	6.8	6.9	1.0
39	general	1.28035	-0.32851	8.2	7.1	3.9	-1.9
40	humano	2.83130	-0.30207	7.6	6.5	9.4	3.5
41	importan	3.37323	-0.27239	6.8	5.9	12.4	6.6
42	incluir	3.01730	-0.24656	6.2	5.3	12.2	6.4
43	incluso	2.94556	-0.29968	7.5	6.5	9.8	4.0
44	informar	2.32423	-0.33446	8.4	7.2	6.9	1.1
45	interés	1.80739	-0.33625	8.4	7.3	5.4	-0.5
46	lectura	2.25032	-0.29927	7.5	6.5	7.5	1.7
47	levantar	1.07369	-0.31988	8.0	6.9	3.4	-2.5
48	manera	1.41009	-0.46415	11.6	10.0	3.0	-2.8
49	medida	3.59892	-0.28389	7.1	6.1	12.7	6.8
50	mercado	2.19402	-0.27815	7.0	6.0	7.9	2.1
51	minuto	2.92879	-0.33906	8.5	7.3	8.6	2.8
52	moderno	1.56211	-0.13112	3.3	2.8	11.9	6.1
53	momento	2.19446	-0.29134	7.3	6.3	7.5	1.7
54	ninguno	2.40968	-0.29033	7.3	6.3	8.3	2.5
55	nosotros	1.65182	-0.39846	10.0	8.6	4.1	-1.7
56	obtener	0.94171	-0.29310	7.3	6.3	3.2	-2.6
57	palabra	-0.25056	-0.30799	7.7	6.7	-0.8	-6.6
58	pasado	2.03999	-0.20847	5.2	4.5	9.8	4.0
59	pequeño	2.20830	-0.40272	10.1	8.7	5.5	-0.3
60	perfecto	0.09568	-0.35964	9.0	7.8	0.3	-5.6
61	permiten	2.22425	-0.24648	6.2	5.3	9.0	3.2
62	persona	0.50382	-0.31346	7.8	6.8	1.6	-4.2
63	popular	2.45875	-0.26861	6.7	5.8	9.2	3.3
64	posible	3.72985	-0.45886	11.5	9.9	8.1	2.3
65	pregunta	0.38091	-0.32186	8.0	7.0	1.2	-4.6
66	preparar	0.50317	-0.36554	9.1	7.9	1.4	-4.5
67	primero	0.91541	-0.35922	9.0	7.8	2.5	-3.3
68	principal	1.46128	-0.40253	10.1	8.7	3.6	-2.2
69	problema	0.30224	-0.28266	7.1	6.1	1.1	-4.8
70	produce	2.32187	-0.27467	6.9	5.9	8.5	2.6
71	profesor	1.34246	-0.24445	6.1	5.3	5.5	-0.3
72	programa	0.32166	-0.37775	9.4	8.2	0.9	-5.0
73	propone	0.89304	-0.35165	8.8	7.6	2.5	-3.3
74	provocan	2.11922	-0.16905	4.2	3.7	12.5	6.7
75	próximo	1.08333	-0.15502	3.9	3.4	7.0	1.2
76	proyecto	0.51972	-0.37414	9.4	8.1	1.4	-4.4
77	público	0.93568	-0.24616	6.2	5.3	3.8	-2.0

#	Word	a[a]	b[b]	at 50% [c]	Slope 20-80%[d]	Slope Threshold[e]	ΔdB[f]
78	rápido	0.98973	-0.23354	5.8	5.1	4.2	-1.6
79	recoger	-0.31338	-0.43354	10.8	9.4	-0.7	-6.6
80	recordar	1.31141	-0.29750	7.4	6.4	4.4	-1.4
81	responde	0.83082	-0.27974	7.0	6.1	3.0	-2.9
82	retiran	3.48879	-0.27322	6.8	5.9	12.8	6.9
83	salida	1.54381	-0.32557	8.1	7.0	4.7	-1.1
84	tamaño	0.45508	-0.30720	7.7	6.6	1.5	-4.3
85	tampoco	0.98023	-0.35556	8.9	7.7	2.8	-3.1
86	tarea	0.37002	-0.33542	8.4	7.3	1.1	-4.7
87	trabajo	-0.87536	-0.18190	4.5	3.9	-4.8	-10.6
88	último	2.53935	-0.32537	8.1	7.0	7.8	2.0
89	visita	4.16702	-0.32631	8.2	7.1	12.8	6.9
90	visitar	3.28155	-0.22858	5.7	4.9	14.4	8.5
	M	1.60099	-0.29980	7.5	6.5	5.6	-0.2
	Min	-1.31038	-0.51285	3.3	2.8	-4.8	-10.6
	Max	4.16702	-0.13112	12.8	11.1	16.5	10.7
	Range	5.47740	0.38173	9.5	8.3	21.3	21.3
	SD	1.15738	0.06697	1.7	1.4	4.3	4.3

[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 (5.83 dB HL)

The 37 words were then perceptually evaluated by five judges. Nine additional words were eliminated as being either too soft or too loud resulting in final list of 28 words. The threshold, slope at threshold, and the slope from 20% to 80% for the 28 selected words are listed in Table 4 (male talker) and Table 5 (female talker). Figure 1 reveals less variability in the slope of the psychometric performance functions for the selected words (C-D) when compared to the complete list of 90 words (A-B). Figure 2 (male talker) and Figure 3 (female talker) contain the psychometric performance intensity functions for each of the 28 words with the logistic regression slopes and intercepts (see Table 4 and Table 5) being used to fit the data. The composite psychometric performance intensity functions for the selected words are shown in the middle panels (C-D) of Figure 1. The psychometric performance intensity function slopes for the 28 selected words, at 50% threshold, ranged from 7.3 %/dB to 12.7 %/dB (*M* = 10.1) for the male talker recording and from 7.1 %/dB to 12.8 %/dB (*M* = 8.7) for the female talker.

To increase homogeneity of the thresholds of the final 28 words, the intensity of each was digitally adjusted so that the 50% threshold of each word was equal to the mean PTA of the subjects (5.83 dB HL). Adjustments for each selected word for both talker recordings are presented in Table 4 (male talker) and Table 5 (female talker). The bottom panels (E-F) of Figure 1 show predicted psychometric performance-intensity functions for the selected words after adjusting intensity to equate 50% thresholds for the male talker (E) and female talker (F). The mean psychometric performance-intensity functions for the selected words (both male and female talkers) are shown in Figure 4, showing a steeper mean slope for the male talker recordings (10.1 %/dB) than the female talker recordings (8.7 %/dB).

Table 4

Mean Performance for28 Selected Spanish Male Trisyllabic SRT words

#	Word	a[a]	b[b]	at 50% [c]	20-80%[d]	SlopeSlope Threshold[e]	ΔdB[f]
1	apenas	1.66336	-0.44646	11.2	9.7	3.7	-2.1
2	apoyo	1.18119	-0.37629	9.4	8.1	3.1	-2.7
3	comienza	2.60955	-0.32632	8.2	7.1	8.0	2.2
4	comprender	1.49761	-0.31993	8.0	6.9	4.7	-1.1
5	derecho	0.93034	-0.43525	10.9	9.4	2.1	-3.7
6	ejemplo	2.01060	-0.40627	10.2	8.8	4.9	-0.9
7	entonces	2.83958	-0.48234	12.1	10.4	5.9	0.1
8	figura	2.26832	-0.36068	9.0	7.8	6.3	0.5
9	general	3.10575	-0.48569	12.1	10.5	6.4	0.6
10	levantar	2.39018	-0.45340	11.3	9.8	5.3	-0.6
11	manera	2.66609	-0.45310	11.3	9.8	5.9	0.1
12	minuto	4.24838	-0.42451	10.6	9.2	10.0	4.2
13	momento	1.37720	-0.29594	7.4	6.4	4.7	-1.2
14	ninguno	3.73798	-0.39287	9.8	8.5	9.5	3.7
15	nosotros	2.04017	-0.47942	12.0	10.4	4.3	-1.6
16	obtener	2.19217	-0.45092	11.3	9.8	4.9	-1.0
17	pequeño	2.56951	-0.50602	12.7	11.0	5.1	-0.8
18	perfecto	1.61876	-0.34419	8.6	7.4	4.7	-1.1
19	persona	1.53899	-0.29004	7.3	6.3	5.3	-0.5
20	pregunta	1.92856	-0.39832	10.0	8.6	4.8	-1.0
21	primero	1.60021	-0.45430	11.4	9.8	3.5	-2.3
22	programa	0.86062	-0.36426	9.1	7.9	2.4	-3.5
23	propone	1.99454	-0.30656	7.7	6.6	6.5	0.7
24	proyecto	1.28128	-0.44363	11.1	9.6	2.9	-2.9
25	recoger	0.04949	-0.37813	9.5	8.2	0.1	-5.7
26	recordar	1.18485	-0.36644	9.2	7.9	3.2	-2.6
27	tamaño	0.55030	-0.35278	8.8	7.6	1.6	-4.3
28	tarea	1.27589	-0.47271	11.8	10.2	2.7	-3.1
	M	1.90041	-0.40238	10.1	8.7	4.7	-1.1
	Min	0.04949	-0.50602	7.3	6.3	0.1	-5.7
	Max	4.24838	-0.29004	12.7	11.0	10.0	4.2
	Range	4.19889	0.21598	5.4	4.7	9.9	9.9
	SD	0.92554	0.06320	1.6	1.4	2.2	2.2

[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 (5.83 dB HL).

Table 5

Mean Performance for28 Selected Spanish Female Trisyllabic SRT words

#	Word	a[a]	b[b]	at 50% [c]	Slope 20-80%[d]	Slope Threshold[e]	ΔdB[f]
1	apenas	1.07640	-0.34007	8.5	7.4	3.2	-2.7
2	apoyo	-0.16766	-0.32327	8.1	7.0	-0.5	-6.3
3	comienza	1.45333	-0.32834	8.2	7.1	4.4	-1.4
4	comprender	0.13811	-0.32957	8.2	7.1	0.4	-5.4
5	derecho	0.52844	-0.28334	7.1	6.1	1.9	-4.0
6	ejemplo	1.56617	-0.51285	12.8	11.1	3.1	-2.8
7	entonces	1.43386	-0.30297	7.6	6.6	4.7	-1.1
8	figura	1.29341	-0.33165	8.3	7.2	3.9	-1.9
9	general	1.28035	-0.32851	8.2	7.1	3.9	-1.9
10	levantar	1.07369	-0.31988	8.0	6.9	3.4	-2.5
11	manera	1.41009	-0.46415	11.6	10.0	3.0	-2.8
12	minuto	2.92879	-0.33906	8.5	7.3	8.6	2.8
13	momento	2.19446	-0.29134	7.3	6.3	7.5	1.7
14	ninguno	2.40968	-0.29033	7.3	6.3	8.3	2.5
15	nosotros	1.65182	-0.39846	10.0	8.6	4.1	-1.7
16	obtener	0.94171	-0.29310	7.3	6.3	3.2	-2.6
17	pequeño	2.20830	-0.40272	10.1	8.7	5.5	-0.3
18	perfecto	0.09568	-0.35964	9.0	7.8	0.3	-5.6
19	persona	0.50382	-0.31346	7.8	6.8	1.6	-4.2
20	pregunta	0.38091	-0.32186	8.0	7.0	1.2	-4.6
21	primero	0.91541	-0.35922	9.0	7.8	2.5	-3.3
22	programa	0.32166	-0.37775	9.4	8.2	0.9	-5.0
23	propone	0.89304	-0.35165	8.8	7.6	2.5	-3.3
24	proyecto	0.51972	-0.37414	9.4	8.1	1.4	-4.4
25	recoger	-0.31338	-0.43354	10.8	9.4	-0.7	-6.6
26	recordar	1.31141	-0.29750	7.4	6.4	4.4	-1.4
27	tamaño	0.45508	-0.30720	7.7	6.6	1.5	-4.3
28	tarea	0.37002	-0.33542	8.4	7.3	1.1	-4.7
	M	1.03123	-0.34682	8.7	7.5	3.0	-2.8
	Min	-0.31338	-0.51285	7.1	6.1	-0.7	-6.6
	Max	2.92879	-0.28334	12.8	11.1	8.6	2.8
	Range	3.24217	0.22951	5.7	5.0	9.4	9.4
	SD	0.79477	0.05452	1.4	1.2	2.4	2.4

[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 (5.83 dB HL).

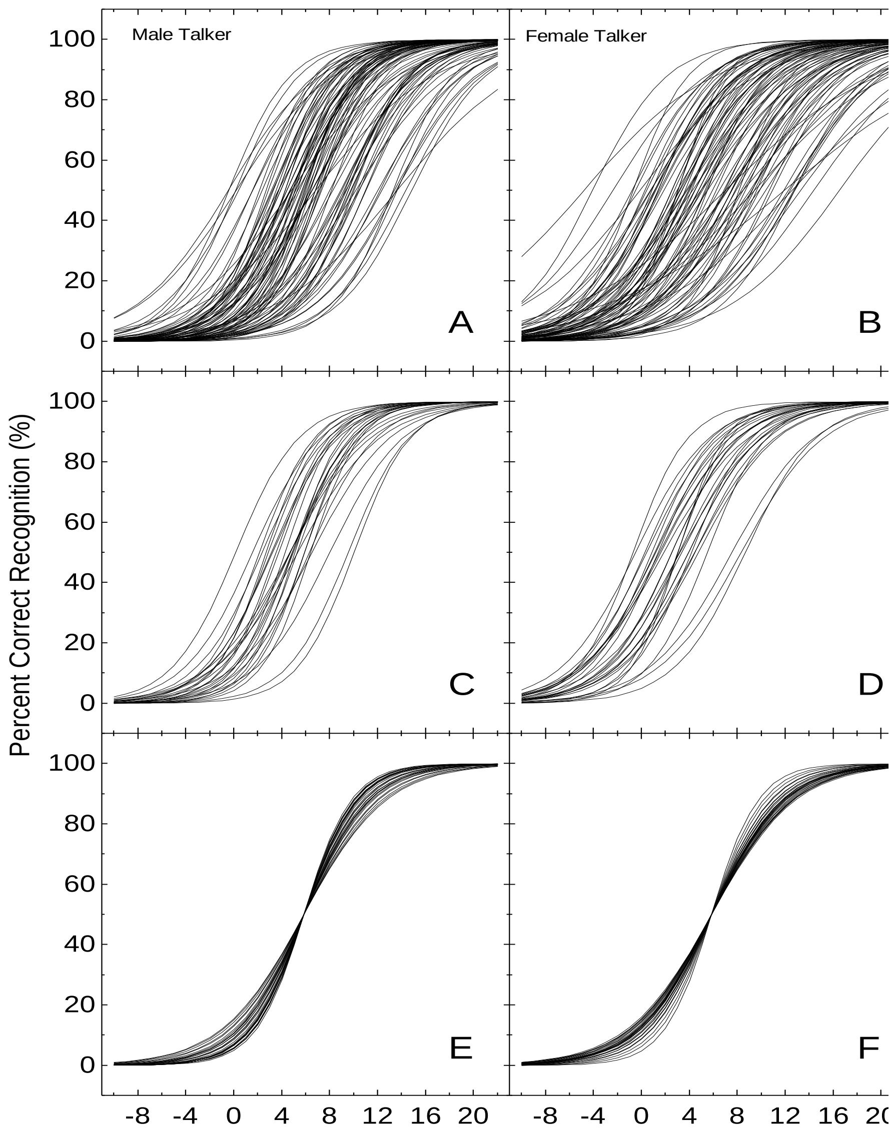

Figure 1. Psychometric functions for Spanish trisyllabic words for male talker (left panels) and female talker (right panels) recordings. All 90 unadjusted words (top panels A-B), 28 selected unadjusted words (middle panels C-D), and 28 selected adjusted words (bottom panels E-F). The 28 selected adjusted words were digitally adjusted to have 50% thresholds equal to the mean PTA (5.83 dB HL) for the 20 normally hearing subjects.

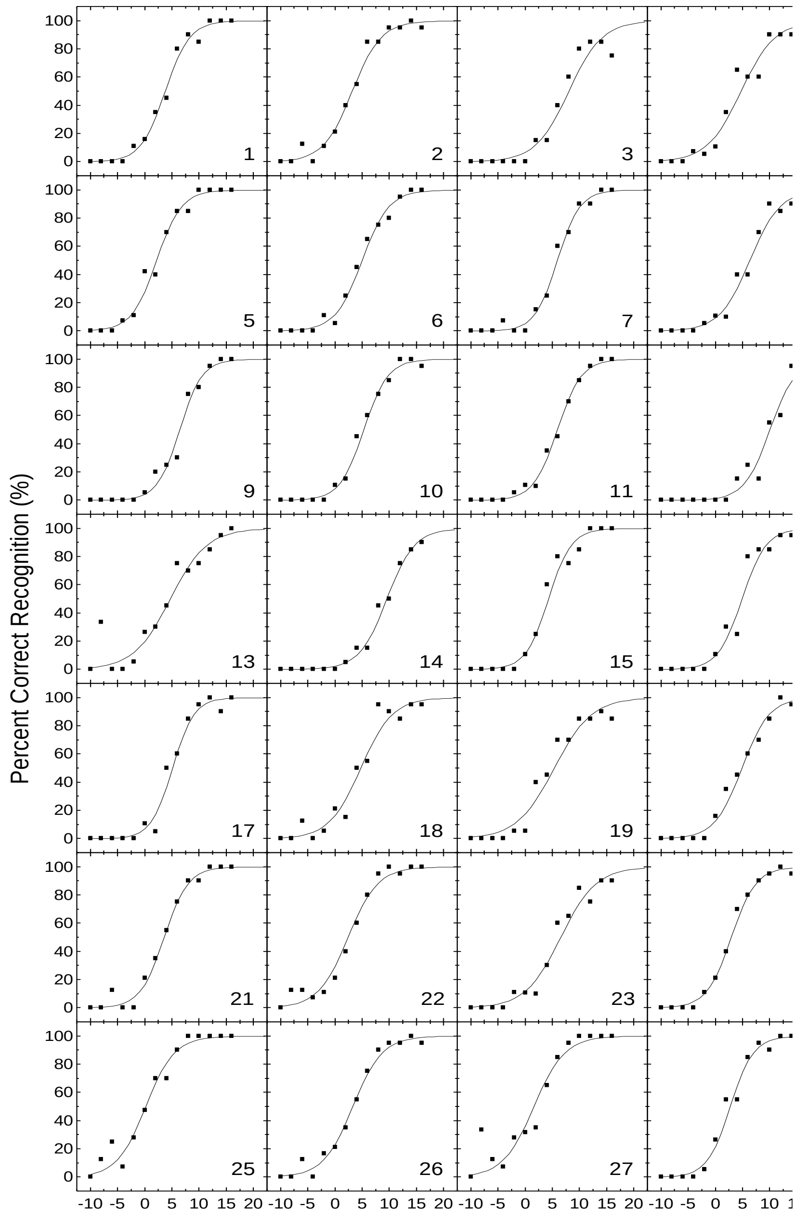

Figure 2. Psychometric functions for the 28 selected unadjusted Spanish trisyllabic words spoken by a male talker. The functions were calculated using logistic regression; the symbols represent mean percentage of correct recognition calculated from the raw data for 20 normally hearing subjects.

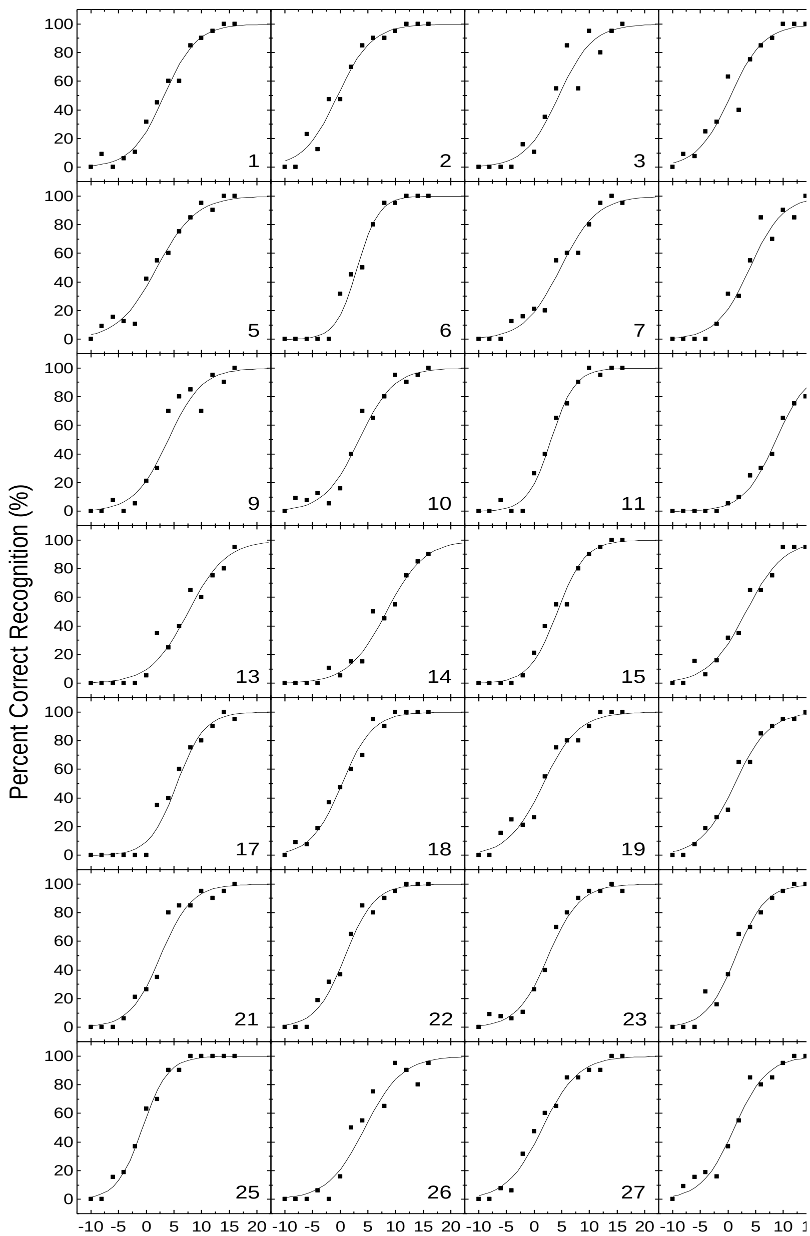

Figure 3. Psychometric functions for the 28 selected unadjusted Spanish trisyllabic words spoken by a female talker. The functions were calculated using logistic regression; the symbols represent mean percentage of correct recognition calculated from the raw data for 20 normally hearing subjects.

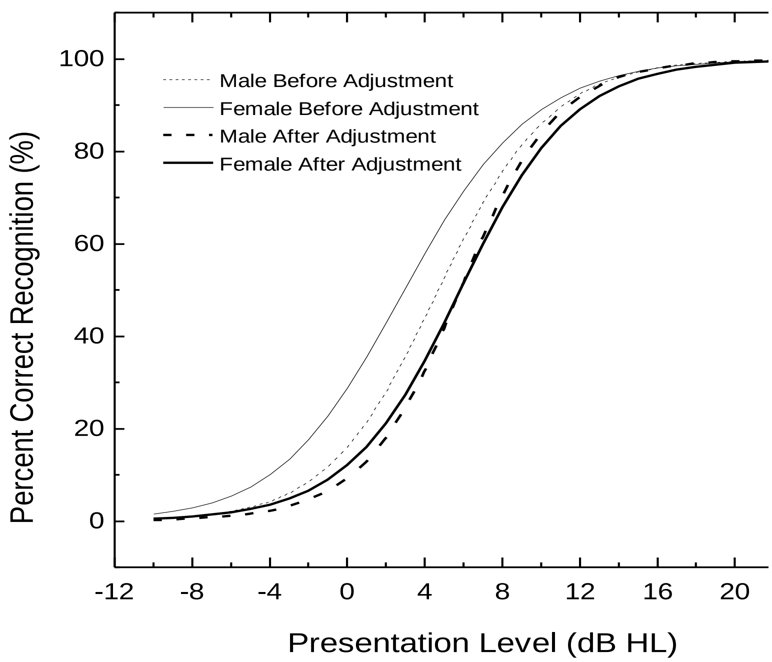

Figure 4. Mean psychometric functions for 28 selected Spanish male and female talker trisyllabic words after intensity adjustment to equate 50% threshold performance to the mean PTA (5.83 dB HL) for the 20 normally hearing subjects.

Discussion

Digital recordings were created during this study that were evaluated and psychometrically equated to produce SRT materials. These materials are better able to assist audiologists to more validly test individuals whose native language is Spanish. A total of 28 trisyllabic words were chosen based on the homogeneity of performance regarding psychometric function slope and audibility. Each of the 28 words had been recorded by a native male and female Spanish speaker.

Intensity adjustment of the final 28 selected words resulted in greater homogeneity than the original unadjusted words, specifically regarding the threshold of audibility and the psychometric performance intensity function slope of the words. Figure 1 demonstrated the changes in homogeneity of slopes through its various panels. These mean slopes (male talker M = 10.1 and female talker M = 8.7) are similar to slopes found in other studies that have developed SRT materials. Mean slopes for Polish SRT materials were 10.7%/dB for the male talkers and 11.2%/dB for the female talkers (Harris et al., 2004). Korean SRT materials were shown to have mean slopes of 11.9%/dB for the male talker and 10.45%/dB for the female talker (Harris, Kim, & Eggett, 2003). The study completed by Christensen (1995) of Spanish words also revealed similar slopes which were 11.1%/dB and 9.7%/dB for the male and female talkers respectively. Spondaic words in English have previously been reported as being between 7.2%/dB and 10%/dB, while some studies have reported means to be as high as 12%/dB (Beattie, Svihovec, & Edgerton, 1975; Hirsh et al., 1952; Hudgins et al., 1947; Ramkissoon, 2001).

It is interesting to note that the mean slope at 50%/dB for the male talker (*M* = 10.1%/dB) is steeper than the mean slope at 50%/dB of the female talker (*M* = 8.7%/dB). These differences in slopes could be caused by a variety of factors, including the individual differences between the talkers, the degree of the bilingualism of the participants, dialect differences, and word selection.

Bradlow, Nygaard, and Pisoni (1999) found that speaker rate has an effect on the recognition of words. A multiple rate list (list of words presented at different speaking rates) was harder for the subjects to accurately identify the words on than was a word list in which all of the words were a single rate. It may be that the talkers in this study produced the words at variable rates or that the individual rate of speech of each talker affected the ability of the listeners to accurately identify the words. This same study revealed that when the listener is presented with the same talker consistently, the rate of recognition increases (Bradlow et al., 1999). Goldinger, Pisoni, and Logan (1991) also advocated the use of a single talker when presenting spoken word lists, finding that if a subject is presented with a single talker, the perceptual characteristics of an individual's voice become an additional cue that subjects rely on to process linguistic information (Goldinger et al., 1991).

Hood and Poole (1980) also found evidence that individual talkers can have more of an impact on the difficulty of recognizing words presented to a listener than almost any other factor, but that any well chosen randomized list of words would be suitable for inclusion in speech audiometry testing (Hood & Poole, 1980). This research would definitely favor the use of the CD resulting from this study, as the word lists used in this study are current, high frequency words that have been tested and found to be relatively homogeneous and effective for their designed purpose.

An important aspect to consider when using these SRT materials is the fact that all of the participants were at least minimally bilingual. Bilingualism may have an effect on speech perception as the core lexicon of a individual is increased and has more varied sounds (von Hapsburg & Pena, 2002). Different aspects of bilingualism may have affected the perception of the words included in this study, such as type of bilingualism, time of second-language acquisition, type of language skills, and frequency of second language use. This would be an interesting future study to be completed as a follow-up to the current study; perhaps the creation of materials controlling for bilingualism might yield improved testing validity.

Another limitation to the current materials is that the sample population may not match the intended testing population. The sample population consisted of normal hearing individuals while the intended test population is individuals with diagnosed and undiagnosed hearing impairments which can be a serious limitation to the testing materials (Jerger, 2006). McArdle and Wilson (2006) found that materials which were homogenous on a normal hearing population demonstrated significant variability when tested on individuals with hearing impairment. A future study examining this limitation would be beneficial both clinically and empirically.

The performance of words may have been influenced by the decision to use a combination of conjugated and infinitive verbs. The Spanish language has a variety of verb conjugations that are used in everyday language. Some of the conjugations that were presented may have been difficult for the listeners to identify because the word was presented in a decontextualized environment (Hoopingarner, 2004). A future study may be beneficial to consider the effect of various conjugations on word recognition.

Regional dialect may have also been a factor in the differences of the lists. While all the subjects and talkers were from Mexico, there may have been slight allophonic variations between the talker's and the tested participants' dialects due to regional differences. Weisleder and Hodgson (1989) did find that people of Mexican origin scored better than other Spanish dialects on word recognition lists spoken by a Mexican speaker when presented at lower intensity levels. These differences tended to disappear as the presentation level increased   Richardson (2008) discovered that while there can be a statistically significant difference in dialects, there is not a clinically significant difference between dialects. Schneider (1992) examined three dialects of Spanish with children. She found no statistically significant differences in the SRT scores of the children. These findings would support the use of the current study's materials for Spanish speakers of various dialects.

Many avenues of research are open to pursue when considering the creation of SRT materials in Spanish. The aforementioned suggestions are in no way considered to be comprehensive, complete, or exhaustive. The word list could be further studied perceptively, linguistically, and to examine other applications of the completed list. Additionally, this study was a successful update of previous work done by Christensen (1995). Christensen's (1995) materials were excellent for the time that they were created, however, the words selected were outdated. In fact, only 6 of the 39 words that were included in Christensen's word lists were included on the word list in the current study. The current study used a more recently published frequency dictionary (Davies, 2006). .

In summary this study, while having some limitations, was successful in the creation of clinically useful SRT materials in Spanish. The 28 homogeneous words were shown to be effective at the given performance intensity levels to accurately measure the SRT of individuals whose native language is Spanish. This enables this word list to be used to assist in the accurate diagnosis and treatment of individuals with various types of hearing impairments. The list of 28 words is available on CD from Brigham Young University.

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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 Communications Disorders 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. Christopher Dromey, Chair of the Institutional Review Board, 133 TLRB, Brigham Young University, Provo, UT 84602; phone (801) 422-6461, email: dromey@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 Trisyllabic Word Definitions

	Word	Definition	Part of Speech
1	apenas	barely, hardly	adverb
2	apoyo	support, backing	noun
3	comienza	it begins	noun
4	comprender	to understand	verb
5	derecho	right	noun
6	ejemplo	example	noun
7	entonces	then	adverb
8	figura	figure	noun
9	general	general	noun
10	levantar	to raise, lift	verb
11	manera	way, manner	noun
12	minuto	minute	noun
13	momento	moment	noun
14	ninguno	no, none, nobody	adverb
15	nosotros	we	pronoun
16	obtener	to obtain	verb
17	pequeño	little, small, young	adjective
18	perfecto	perfect	adjective
19	persona	person	noun
20	pregunta	question	noun
21	primero	first	adjective
22	programa	program, plan	noun
23	propone	he/she/you propose	verb
24	proyecto	project/plan	noun
25	recoger	to pick up	verb
26	recordar	to remember	verb
27	tamaño	size	noun
28	tarea	job, task	noun