

Development of Thai Spondee Words for SRT Measurement in Children

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ABSTRACT

OBJECTIVE The purpose of this study was to develop standardized Thai speech material for use in the measurement of speech recognition threshold (SRT) in children.

METHODS The Thai speech material was developed according to three essential criteria: children's familiarity with the word, phonetic dissimilarity, and homogeneity with respect to basic audibility. Disyllabic words selected from a Thai fundamental word list used in teaching the Thai language at the primary level were analyzed to measure the intensity of each syllable using a Computerized Speech Lab (CSL). The spondee words were then assessed for familiarity by the parents or guardians of the children. A total of 60 spondee words were selected for use in evaluating the threshold of recognition of each word by 30 normal-hearing children.

RESULTS Of the 60 spondee words, 25 words with relatively steep and homogeneous psychometric function slopes were selected for inclusion in a list of Thai speech material for children. The psychometric function slopes at the 50% threshold of the final 25 spondee words were found to have a mean of 10.76 %/dB.

CONCLUSIONS The Thai speech material for children was developed according to the speech material criteria. This list of words is suitable for use in evaluating the SRT of normal-hearing children

KEYWORDS SRT, speech recognition materials, Thai spondee words

INTRODUCTION

Hearing is considered to be one of the most crucial of the five human senses and is essential to the process of speech and oral language development. In order to evaluate the hearing ability of children, a complete set of audiological tests is required. The standard audiological test battery consists of measurements of pure-tone air conduction, pure-tone bone conduction, speech recognition threshold (SRT), and word recognition score (WRS).

The Speech Recognition Threshold (SRT), part of the test battery used in speech audiometry, is the minimum hearing level at which an

individual can perceive 50 percent of recognized speech material (1). SRT is commonly determined by asking the person to repeat spondee words, disyllabic words with equal stress on each syllable. For SRT material, there are three essential criteria that should be met: familiarity, phonetic dissimilarity, and homogeneity with respect to basic audibility (2).

Thai is the official language for both speaking and writing in Thailand. The syllables of Thai words are comprised of consonants, vowels, and tones (3). There are five tones in Thai: mid, low, falling, high, and rising (4), with different tone pronunciations corresponding to different

meanings. In contrast, in English, a non-tonal language, in some cases differentiation between the meanings of words is indicated by the degree of stress emphasis. Thai spondee words are disyllabic words with equal loudness and with a difference of no more than ± 2 dB on each syllable (5).

There are only two sets of Thai materials for SRT measurement that are currently being used in Thailand. The first is RAMA SRT-1, developed in 1973 (6), which uses spondee words for SRT measurement. At that time, the homogeneity of audibility did not meet the criteria because of limitations of available acoustic instruments. A second set of Thai material, RAMA SRT-2 (7), was developed in 1980 which better meet the criteria of SRT materials. However, neither of these was developed specifically for use in hearing evaluation of children.

Children regularly react to speech stimuli because speech is a signal of interest to most young children. Audiologists can estimate a child's ability to hear and understand by observing their responses (8). One of the simplest tests of speech is SRT. An SRT measurement can be made for children from about three to four years and up to eight years of age (9) by the use of an appropriate children's word list.

Due to the lack of a standard children's speech material list in Thai, pediatric audiologists have had to use adult materials in evaluating the hearing of young children. Differences in thresholds can be clinically significant when adult materials are used with children (10). The problem is exacerbated by a reduction in the set size (11) because of the children's unfamiliarity with some of the test items. To avoid an erroneous estimation of a child's recognition skills, word lists and set size should not be simply reduced (12). Rather, stimulus lists with the appropriate properties need to be developed. The purpose of the present study was to develop Thai speech material to be used for speech recognition threshold (SRT) measurement of Thai children with normal hearing age 4 to 8 years.

METHODS

Ethical approval for the present study was obtained from the Ethical Clearance Committee

of the Faculty of Medicine, Ramathibodi Hospital, Mahidol University (ID 08-61-14).

Speech material

1. All of the words must be spondee words in which each syllable is equal in loudness and is familiar to children. Therefore, the materials should be generally used in their everyday life and be well-known by children.

2. All of the words in the list ought to be different in phonetics so that an auditory cue will not be given to the child. For example, in cases of two words with the same pronunciation in one of the syllables, e.g., rot-fai (train) and rot-yon (car), only one word is allowed.

3. All of the spondee words should be homogeneous in audibility, i.e., each word in the test list should tend to reach the threshold of speech at the same presentation level. Thus, the word intelligibility will be within a narrow range of intensity, and its psychometric function will rise steeply from zero to one hundred percent.

Following these three criteria, the material was developed in three steps:

1. Spondee words test

All mono- and disyllabic words were collected from a 'List of Thai Fundamental Words' published by the Thai Ministry of Education (13). According to a study conducted in 2008, the list is still used in Thai language schoolbooks (14). This study identified the words that were most frequently spoken by children from all regions of Thailand. In the list of fundamental words for kindergarten and first grade children, there were 140 disyllabic words and 171 monosyllabic words. All of the 171 monosyllabic words were nouns, pronouns, verbs or conjunctions. Monosyllabic words were combined into 220 disyllabic words after meaningless words were removed. The result was a total of 360 disyllabic words which had been tested for the characteristics of spondee words.

A spondee word is a disyllabic word with equal loudness, which has a difference between each syllable of about ± 2 decibel (dB) on a volume unit (VU) meter (5). To test the spondee characteristics of disyllabic words, a 4500 model Computerized Speech Lab (CSL) was used. The CSL could compute the energy of a range of speech waveform data and display the energy

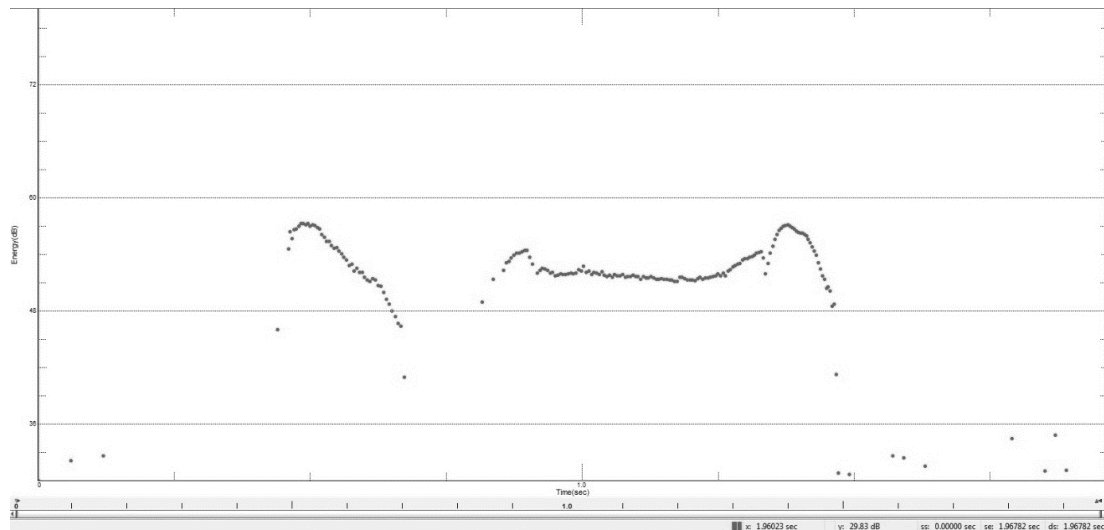


Figure 1. The energy contours (dB SPL) during the time (sec) of the disyllabic word “อาบน้ำ” (ʔà:p nám). The first and second syllables were approximately equal in loudness, so it was considered a spondee word.

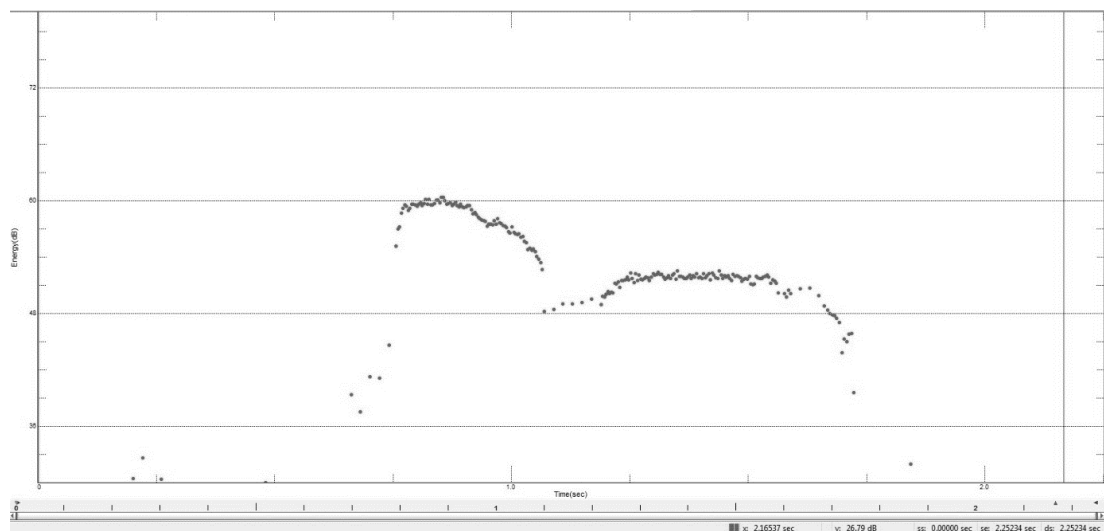


Figure 2. The energy contour (dB SPL) during the time (sec) of the disyllabic word “พ้อแมง” (pʰê: mé:). The first and second syllables were not equal in loudness. Consequently, “พ้อแมง” (pʰê: mé:) was not considered to be a spondee word.

contour results as a decibel sound pressure level (dB SPL). After all the disyllabic words had been analyzed with CSL, 140 spondee words which meet the criteria were chosen. Figures 1 and 2 show the energy contours of the first and second syllables of disyllabic words from CSL.

2. Familiarity words test

Twenty Thai native speakers who were parents or guardians of a 4- to 8-year-old child rated the familiarity of 140 spondee words on a scale of 1 to 5 based on the familiarity of each word according to his/her child (5 = extremely familiar, 4 = very familiar, 3 = somewhat familiar, 2 = slightly familiar, and 1 = unfamiliar).

After calculating the mean score of each spondee word, the words with a mean rating score of < 4 and those having the same pronunciation with different meanings were eliminated. As a result, 60 spondee words were retained for further use.

To habituate a child before administering the recognition-of-word test, a word familiarization list was created. Five experienced pediatric audiologists with over three years professional experience rated frequently used words in a child speech hearing evaluation. There are a total of 109 Thai spondee words in RAMA. SRT-1 and in RAMA. SRT-2 which were developed for

SRT measurement of adults. All of the adult spondee words were rated on a scale of 1 to 5 based on the frequency of use in children's SRT measurements (5 = always used, 4 = usually used, 3 = often used, 2 = rarely used, and 1 = never used). After calculating the mean score of each spondee word, the words with a mean rating score higher than 3 were included in the word familiarization list. There were 20 words that had a mean rating score higher than 3, but seven were the same as developed words and so were excluded. Finally, there were 13 words for habituation of the child.

3. Recordings

In order to ensure the perception equality of the word lists, a master recording of the words was created based on the noise criteria class 30 in a recording studio using a Studio Six filter-based one-third octave real time analyzer with iTestmic2, type 2-class measurement microphone. A large diaphragm condenser microphone (Audio-Technica model 4050) was positioned 20 cm from the speaker at 0° azimuth with a double-cloth type mesh filter in between. The audio signal was transferred to a Beringer XR18 analog-to-digital converter for digitization.

A female audiologist used normal vocal effort in the pronunciation of each spondee word at least three times. The records that had the best quality based on vocal quality, uninterrupted speech sound, equality of effort in each syllable, absence of background noise, and that the listener could hear clearly were selected by the audiologist for the recognition evaluation part of the study. After the selection process, each of the spondee words was normalized as a single utterance at the same level equivalent to that of a 1 kilohertz (kHz) calibration tone, and then converted to 16-bit/44.1 kHz as the final step in the mastering process.

Participants

A group of 30 healthy native speaking Thai children (16 girls and 14 boys) with an age range of 4;0 to 7;11 (years; months) (mean 5.74 ± 1.8) were recruited for this study and were accompanied by a parent/guardian to Ramathibodi Hospital. Each participant passed the following screening: 1) Normal outer and middle ear verified

by otoscopy and tympanometry demonstrating no cerumen impaction and a type A tympanogram, 2) Normal hearing sensitivities at 250, 500, 1000, 2000, and 4000 Hz (≤ 25 dB HL) indicated by a pulsed tone audiogram, 3) Normal speech and language development as evaluated by case history questionnaires (adapted from the Developmental Surveillance and Promotion Manual (15)) for speech, language, hearing, and medical histories completed by the parent/guardian of each participant. Every child was currently studying in a regular school and had passing grades. In addition, the parent/guardian of the child signed the consent form for children who were less than 7 years of age. Children 7 years and older signed the consent form themselves. The mean pulsed tone average (PTA) (arithmetic average of hearing thresholds at 500, 1000, 2000 Hz.) for the 30 children was 14.72 decibels Hearing Level (dB HL).

Procedures

The developed speech material lists were tested to insure that they met the homogeneity of audibility criteria. The 60 spondee words were divided into three lists, and there were 10 participants for each list. The signals of speech material were transferred from an iPad to the external input of an audiometer. The signal was then transferred by means of insert earphones from the audiometer to the participant who was seated in an audiometric exam booth accompanied by a research assistant. The inputs to the audiometer were calibrated to 0 VU using 1 kHz calibration prior to the test of each participant. Instructions regarding the SRT test were given to the child after hearing screening had been completed. Then, the familiarization word list was presented at 50 dB HL. If the child repeated five words correctly, the developed speech materials were then played.

Each of the developed spondee words was initially presented to the child at a sound level 10 dB below the child's PTA. The child repeated each word verbally and their response was scored as correct or incorrect. If the child repeated the word incorrectly, the intensity was increased in 2 dB increments until the child repeated it correctly or until the maximum intensity at 26 dB HL was reached (above the

normal limit). If the child still repeated a word incorrectly, the next word would be presented. In addition, positive reinforcement, e.g., compliments, stickers, or toys, were given to the child during the test as a reward and to increase their motivation.

Data analysis

Logistic regression was used to determine the regression slope and intercept for each of the spondee words. These values were then used in modified logistic regression equations designed to calculate the percentage of correct recognition at each intensity level. Each of the 60 spondee words was analyzed using logistic regression to compute their regression slopes and intercepts using the following four equations.

$$\ln \frac{p}{1-p} = a + bi \tag{1}$$

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

$$P = \left(\frac{\exp(a + bi)}{1 + \exp(a + bi)} \right) \times 100 \tag{2}$$

In equation 2, the percentage of correct recognition at any intensity level can be computed. The percentage of correct recognition was calculated for each of the spondee words over a range of -10 to 26 dB HL in 2 dB increments.

In order to calculate the intensity level required for a given proportion, equation 1 was solved for i (equation 3). The threshold (intensity required for 50% intelligibility) and the slope (%/dB) at threshold can be computed when the desired proportions are used in equation 3. Equation 3 can be simplified to equation 4 to solve for the threshold ($p = 0.5$).

$$i = \frac{\ln \frac{p}{1-p} - a}{b} \tag{3}$$

$$i = \frac{-a}{b} \tag{4}$$

Calculations of the threshold intensity (intensity required for 50% intelligibility) and

a slope of 50% were made for each spondee word using the logistic regression slopes and intercepts.

RESULTS

The mean threshold of 50% recognition for the 60 spondee words was 25.14 dB HL (standard deviation (SD) = 3.17). The minimum and maximum thresholds were 18.85 and 33.71 dB HL, respectively. Equation 2 was used to calculate the psychometric functions for each spondee word. The mean psychometric function slope at 50% was 9.60 %/dB (SD = 3.50) and ranged from 4.10 %/dB to 18.75 %/dB.

The final criteria in development of the speech material for SRT measurement was homogeneity of audibility. To meet the standard criteria, the spondee words with the steepest psychometric function slope were selected. There were 25 spondee words in the final list of Thai spondee words for children. Mean of the psychometric function slope at 50% threshold was 10.76 %/dB (SD = 3.72) and ranged from 5.30 %/dB to 18.75 %/dB. Table 1 shows the logistic regression analysis data of the selected 25 spondee words for children including the thresholds, International Phonetic Alphabet spelling, meaning of each word, regression intercept, regression slope, and psychometric function slope at 50%. Figure 3 shows the psychometric functions for each of the 25 final spondee words and the data points. Figure 4 shows the psychometric function slopes for the final 25 spondee words for children.

DISCUSSION

The psychometric function slopes at the 50% threshold of the 25 spondee words for children developed for the present study were found to have a mean of 10.76 %/dB. This value is similar to those reported for other languages. The mean psychometric function slope at 50% for materials in English have generally been reported to be between 7.2 %/dB and 12.0 %/dB (2, 5, 16-18). The mean psychometric function slope at 50% for materials in recorded Taiwanese Mandarin has been reported to be 11.3 %/dB for male speakers and 11.7 %/dB for female speakers (19). In Japanese, the mean slope at 50% for materials developed in SRT measurement had

Table 1. Logistics analysis of results for the final 25 spondee words

	Spondee word	IPA	Meaning	RI ^a	RS ^b	Slope at 50% ^c	Thres. ^d	ΔM dB ^e
1	แปรง ฟัน	prɛːŋ fan	brush teeth	-8.445	0.448	11.20	18.85	4.13
2	ท้องฟ้า	tʰɔːŋ fáː	sky	-5.445	0.277	6.93	19.66	4.94
3	ของเล่น	kʰɔːŋ lɛːn	toy	-6.981	0.352	8.80	19.83	5.11
4	อาบน้ำ	?àːp náːm	bathe	-7.507	0.372	9.30	20.18	5.46
5	บนโต๊ะ	bon tóʔ	on table	-7.412	0.359	8.98	20.65	5.93
6	ขวดนม	kʰùːat nom	milk bottle	-6.734	0.317	7.93	21.24	6.52
7	ทำงาน	tʰam ŋaːn	work	-7.752	0.360	9.00	21.53	6.81
8	ผู้ชาย	pʰùː tɕʰaːj	man	-8.342	0.384	9.60	21.72	7.00
9	ลมพัด	lom pʰát	wind blows	-7.883	0.362	9.05	21.78	7.06
10	กวาดบ้าน	kwàːt báːn	sweep floor	-12.035	0.549	13.73	21.92	7.20
11	ล้างจาน	láːŋ tɕaːn	wash dishes	-4.659	0.212	5.30	21.98	7.26
12	ร้องไห้	rɔːŋ háj	cry	-6.090	0.277	6.93	21.99	7.27
13	รถไฟ	rót faj	train	-16.525	0.750	18.75	22.03	4.13
14	คนเก่ง	kʰon kɛːŋ	smart kid	-15.410	0.693	17.33	22.24	7.31
15	ยางลบ	jaːŋ lóp	rubber	-6.705	0.297	7.43	22.58	7.52
16	นักเรียน	nák riːan	student	-12.480	0.543	13.58	22.98	7.86
17	ไข่ไก่	kʰàj kàj	egg	-13.583	0.586	14.65	23.18	8.46
18	ถูพื้น	tʰùː pʰúːn	mop floor	-11.406	0.490	12.25	23.28	8.56
19	ห้องนอน	hɔːŋ nɔːn	bedroom	-10.848	0.465	11.63	23.33	8.61
20	ผูกเชือก	pʰùːk tɕʰúːak	tie rope	-6.192	0.261	6.53	23.72	9.00
21	ซ้ายขวา	sáːj kʰwáː	left right	-6.739	0.283	7.08	23.81	9.09
22	ตื่นเต้น	tùːn tɛːn	excited	-11.022	0.457	11.43	24.12	9.40
23	หนังสือ	náj súː	book	-17.982	0.745	18.63	24.14	9.42
24	ในหลวง	naj lúːaŋ	king	-11.385	0.468	11.70	24.33	9.61
25	ฝนตก	fɔːn tók	rain	-11.143	0.452	11.30	24.65	9.93
		Mean		-9.628	0.430	10.76	22.23	7.51
		S.D.		3.59	0.15	3.72	1.56	1.56
		Min		-17.982	0.212	5.30	18.85	4.13
		Max		-4.659	0.750	18.75	24.65	9.93

^aRI, regression intercept; ^bRS, regression slope; ^cSlope at 50%, Psychometric function slope (%/dB) at 50%; ^dThres, Intensity required for 50% recognition; ^eΔM dB, the difference between word threshold and mean PTA [of children] (14.72 dB HL)

a slope of 10.3%/dB for male speakers and 8.7%/dB for female speakers (20). In Thai, the mean psychometric function slope at 50% for recorded materials has been reported to be 9.0 %/dB for male speakers and 8.6 %/dB for female speakers (21). The mean psychometric function slope at 50% of selected Spanish materials for measurement of SRT in children has been reported to be 9.8%/dB for male speakers and of 8.3%/dB for female speakers (22).

As shown in the psychometric function graphs in Figure 3, the percentage of correct recognition increased from 0% to 100% within a small range of presentation intensity. From other similar studies of adults, the presentation level at 100% correctness was within 25 dB

HL. However, the presentation level at 100% correct in this present study required an intensity higher than 25 dB HL, ranging from 28.16 dB HL to 43.65 dB HL with a mean of 34.13 dB HL (SD = 3.89) for all 25 spondee words. This is because the listeners were children rather than adults, i.e., they were much younger than participants in the other studies. For children, it may take a longer time and higher intensity than for adults to process and verbally respond to a word they have heard. Studies have shown that differences in the speed of processing between children and adults depends on their degree of brain development(23, 24). Furthermore, auditory discrimination was both lower and more inconsistent in children than in adults

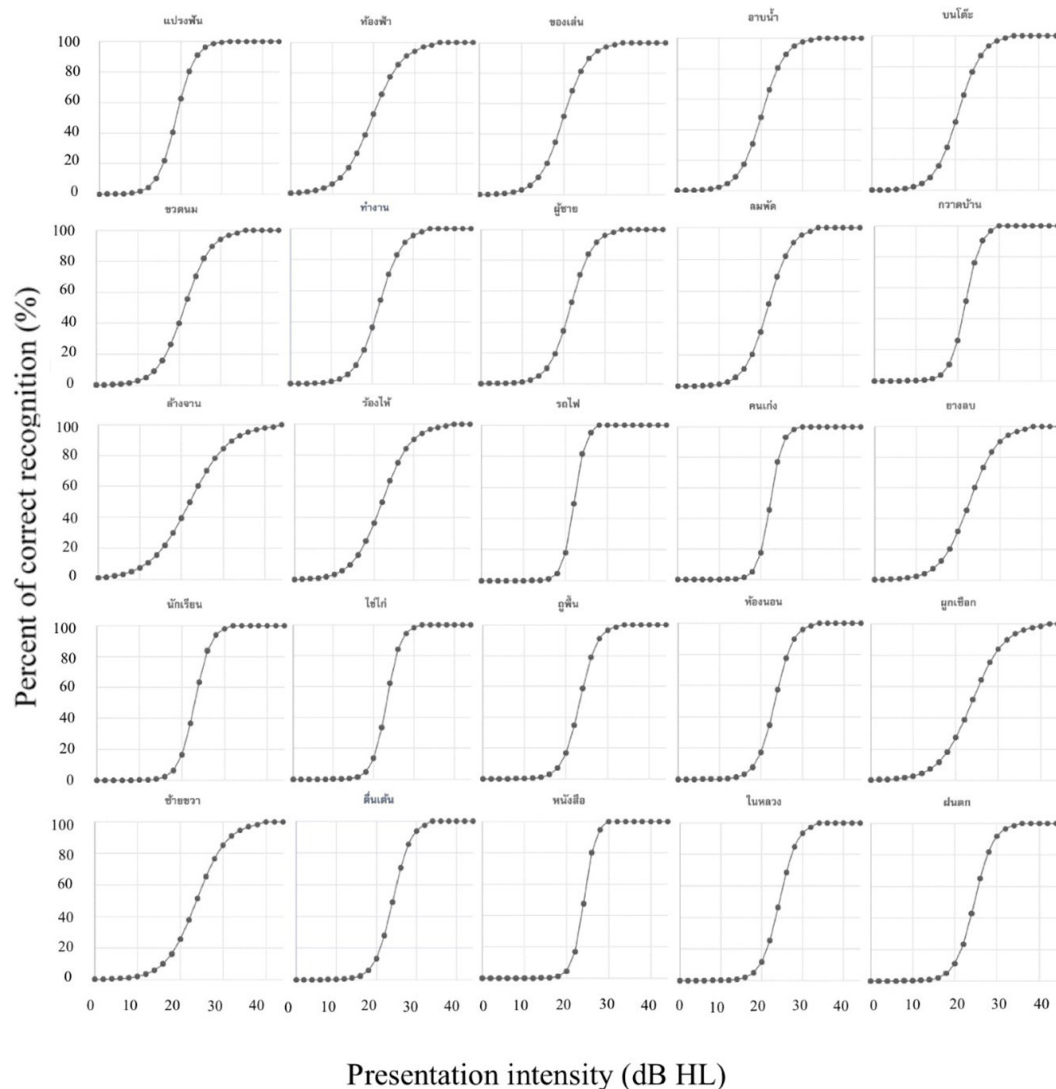


Figure 3. Psychometric function slopes for each of the 25 final spondee words and their data points

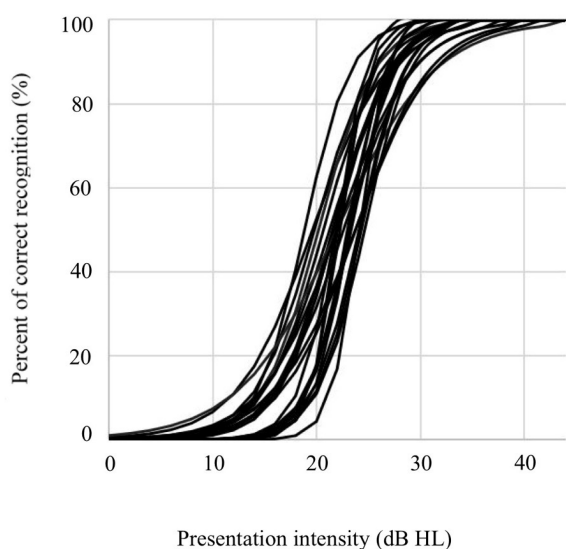


Figure 4. Psychometric function slopes for the final 25 spondee words

(25, 26). Nevertheless, the mean threshold of intelligibility of all 25 spondee words developed in this present study was 22.23 dB HL, which is within the 25 dB HL range.

This study was conducted in Bangkok which is located in the central region of Thailand. Although different dialects are spoken in each of the areas of Thailand, i.e., Central Thai, Northern Thai, Southern Thai, and Northeastern Thai, other studies indicate that dialect should not be a factor in SRT evaluation. A validation study of speech materials in Mainland Mandarin and Taiwanese Mandarin, mutually intelligible dialects, included SRT and WRS evaluation of single dialect speakers. That study showed a statistically significant difference in listener performance across material and

listener dialects, but clinical findings were statistically insignificant as differences were only minor (27). Additionally, a study of the effects of dialects on SRT measurements of children 6–7 years old reported that the differences in SRT results were non-significant between the dialects (28). Central Thai is the main dialect used by Thai people for oral communication, in public education as well as in most mass media in Thailand. For these reasons, the SRT materials developed in the present study are appropriate for use with children from all provinces of Thailand.

As a result of this present study, a new set of standardized speech recognition threshold materials (RAMA.SRT-3) for children was developed. This development was based on the following criteria: familiarity, phonetic dissimilarity, and homogeneity of audibility. This new set consists of 25 spondee words with an average threshold of intelligibility of about 22 dB HL having a 7 dB difference in PTA. Although these materials have not yet been tried in actual speech recognition threshold evaluations, this RAMA.SRT-3 list was developed according to speech material criteria. Thus, the RAMA.SRT-3 list can be used to determine the speech recognition threshold of Thai children. Further studies using other pediatric populations, a larger number of children, and including additional modern words should be conducted to further improve materials for measuring the SRT of children.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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