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The development of Thai monosyllable word lists for word recognition scores testing in pre-school age children

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Abstract

The study aimed at developing a Thai version of monosyllable word lists and picture lists to provide clinical hearing evaluations for pre-school children and to validate the reliability of the Thai version of the monosyllable word lists for two different age groups (2-3 years vs. 4-5 years). The monosyllable word lists and picture lists were developed in accordance with the following steps: 1) the familiarity of 100 words was chosen; 2) the pictures that represented the meanings of the matched 80 words were developed; 3) both the receptive and expressive vocabulary were evaluated in 62 children 2-3 years of age (Group 1) and in 62 children 4-5 years of age (Group 2); 4) monosyllable words were analyzed using a computerized speech lab and were arranged into sets of word lists (Khon Kaen University (KKU) kid word lists-A for Group 1 and KKU kid word lists-B for Group 2) with phonetically balanced fundamental frequency, the Thai five tones, and the initial consonants; 5) the word lists were recorded; and 6) The KKU kid word lists-A & B were validated with 31 children from each group, respectively. KKU kid word lists-A had word recognition scores (WRS) with a mean of above 90% for each list in passing and referring to the hearing screening ears. KKU kid word lists-B had a WRS of over 92% for each list. The development of the Thai monosyllable word lists was determined to be appropriate for assessing the WRS of pre-school children for conducting clinical hearing evaluations.

Keywords: Thai monosyllable word lists, Word recognition scores, Speech audiometry, Pre-school age

1. Introduction

Speech audiometry is part of the clinically standard audiological testing and is composed of speech recognition thresholds (SRT) and word recognition scores (WRS) [1]. SRT refers to the minimum hearing level at which a responder can detect the spondee words (dichotomous words) and can correctly repeat at least 50 percent of the words on the test. SRT is displayed in decibels (dB) and is considered in combination with the pure tone average threshold to confirm the accuracy of the audiometry results. Furthermore, the SRT level is the reference value of the presentation level in a word recognition test. WRS is used to determine hearing ability at an optimal level (approximately 30–40 dB above the SRT level) or at an uncomfortable listening level (minus 5 dB) in cases of mild to moderate hearing loss and steeply sloping hearing loss [2]. The results are presented as a percentage of the corrections' responses.

WRS is one of the battery tests that can be used with pure-tone audiometry results to differentiate between a cochlear lesion and a retro-cochlear lesion. WRS ranges from 90 to 100% in those with normal hearing; 80 to 100% in those with conductive hearing loss, such as otitis media with effusion or otosclerosis; and 0 to 100% in those with sensorineural hearing loss, depending on the underlying causes and the remaining degree of hearing loss [3]. WRS is one of the informative components that is utilized in the process of selecting an appropriate hearing aid or is one of the criteria that is used to determine whether a cochlear implant procedure is required. WRS is one method, which can be used to predict a patient’s communication success while wearing a hearing aid

or cochlear implant [4]. Also, WRS is used to advise patients about hearing loss and communication difficulties in noisy environments [5].

Materials for WRS testing consist of both a closed set and an open set. The selection of materials depends on the patient's age and his or her abilities. Closed-set materials are appropriate for young children with limited receptive and expressive language skills, delayed speech and language, and articulation issues [6]. Closed-set materials include words that are suitable for children's speech and language development and represent both receptive and expressive languages. Most of the words in the closed-set materials are related to the organs of our bodies, animals, toys, or things. The child needs to point to the corresponding picture after hearing the sound. Examples of WRS assessments in the English language are the Northwestern University Children's Perception of Speech (NU-CHIPS) [7] for children 3 to 5 years of age, the Pediatric Speech Intelligibility Test (PSI) [8,9] for children 3 to 6 years of age, and Word Intelligibility by Picture Identification (WIPI) [10] for children 4 to 6 years of age. Open-set materials consist of monosyllable word lists of 25 or 50 words each. The concept of open-set materials is that the word lists that are appropriate for assessing children should not be limited to receptive and expressive languages. Therefore, there are more numbers and types of words in each list, including verbs and adjectives.

An example of WRS assessments for children in another language is the Standard-Chinese version of the Lexical Neighborhood Test (LNT) [11], which was designed for children from 4 to 6 years of age. On the other hand, there is another type of Thai speech material, which was recently developed. It was reported for Thai children in 2022 and is used for SRT testing [12]. In audiological clinics, only adult word list materials Ramathibodi-Speech Discrimination Test No.1 (RAMA.SD-1) [13] and Ramathibodi-Speech Discrimination Test No.2 (RAMA.SD-2) [14] are currently being used. Other research on the creation of Thai monosyllable word lists for adults was uncovered in 2014–2015. The criteria for the construction of Thammasat University Phonetically Balanced Word Lists 2014 (TU PB'14) [15] and Thammasat University – Ramathibodi Hospital Phonetically Balanced Word Lists 2015 (TU-RAMA PB'15) [16] include phoneme distributions, word familiarity, and good distribution across categories. Nevertheless, numerous words in both the TU PB'14 and the TU-RAMA PB'15 materials cannot be represented by using pictures and are unfamiliar to children.

For many years, Thai pediatric audiologists have used adult WRS word lists to assess the speech audiometry of pre-school children due to a lack of standardized tests. Issues arise when children are unable to repeat the exact pronunciation of the words and are unable to recognize the true meaning of the words. The objectives of this study were as follows: 1) to develop a Thai version of monosyllable word lists and picture lists for clinical hearing evaluation and 2) to validate the reliability of the Thai version of monosyllable word lists for two different age groups (2-3 years of age vs. 4-5 years of age).

2. Materials and methods

The study consisted of six sequential stages. The details of the development of the Thai monosyllable word lists are provided below. Figure 1 shows the flowchart of the methodology.

2.1 The selection of words

The researchers selected 100 monosyllable words from three best-selling pre-school books, the fundamental pre-school vocabulary lists, and from the Thai Speech and Language Norms for Children 2½ to 4 Years of Age: TSLT2½-4. The selected words appeared in four or more of the five references cited above. The nouns and verbs were mainly selected due to their uncomplicated illustrations. Five teachers and five parents (or guardians), who were looking after children 2 to 5 years of age rated the 100 familiar words. Therefore, this section consisted of 80 words with a high degree of familiarity.

2.2 Pictorial representations

The entire set containing 80 words was digitally drawn by experienced artists without backgrounds. The researchers re-adjusted any ambiguous or unclear images until all the items had been deemed appropriate for young children. All images were then systematically arranged in groups of four per page.

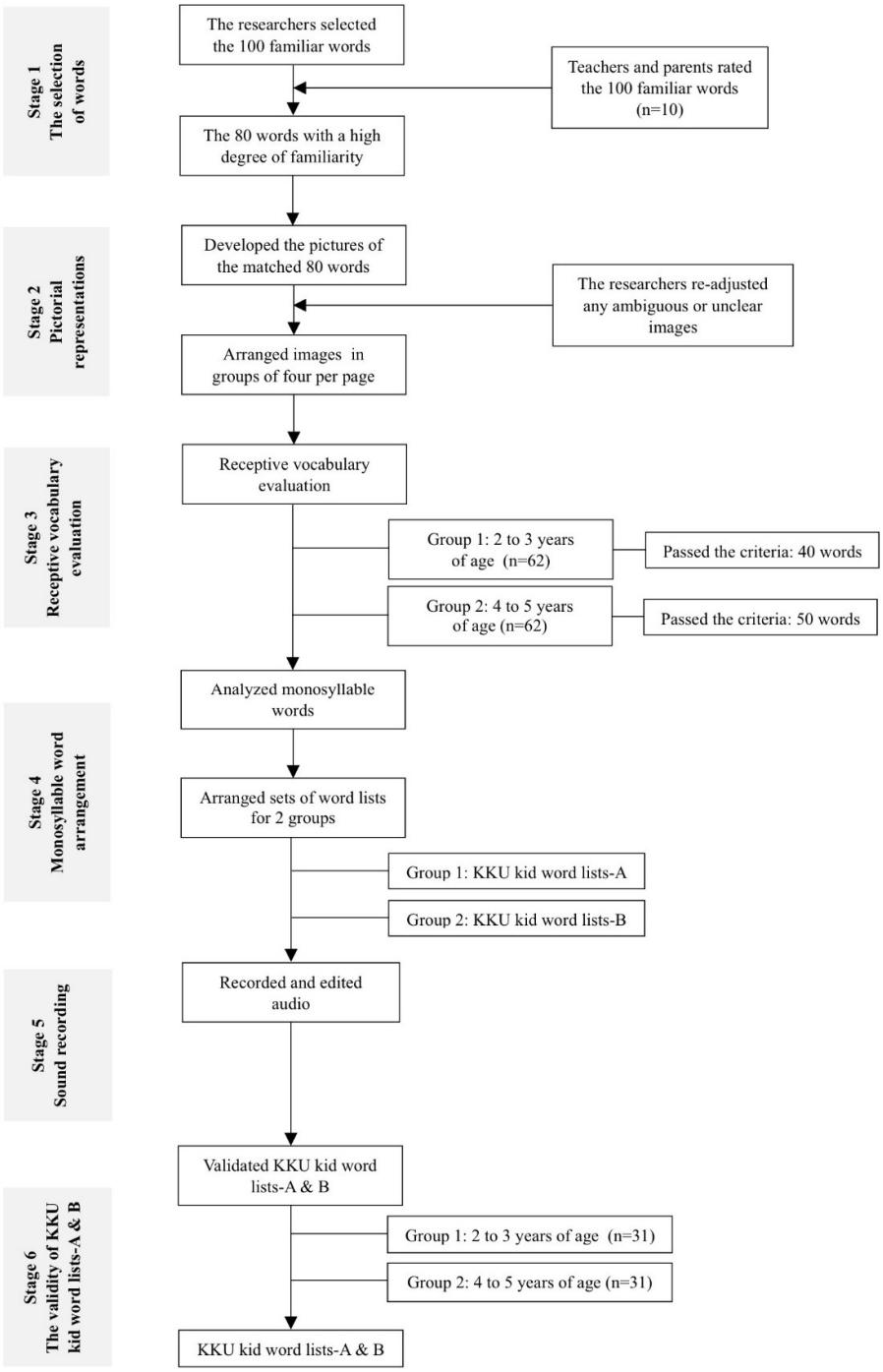

Figure 1 A flowchart of the methodology.

2.3 Receptive vocabulary evaluation

A total of 124 pre-school children, comprised of 62 children (2 to 3 years of age) and 62 children (4 to 5 years of age), completely validated all 80 words and pictures. In each age group, there were two kindergarten school areas: one area represented urban schools situated within the Nai Mueang Khon Kaen District and the other area represented rural schools located outside the Nai Mueang Khon Kaen District. Before starting the evaluation method, informed consent was obtained from the parents of the 124 children. In addition, all children were tested for hearing ability at a conversational level by asking several short questions that were used to confirm normal speech and language development.

2.3.1 The testing procedures

The testing procedures were divided into four sessions, with each session comprising 20 words. The children were allowed to take a break for 5–10 min between the testing sessions, and engagement was reinforced by giving both appreciation and prizes. The testing materials were presented at a normal conversational level in a quiet room at school. Each participant was randomly asked to point to the picture that corresponded to what he or she had heard, while the tester recorded the results in the case record forms. After finishing all the pictures, the tester showed them again, and one by one, asked the children *"What is the picture?"* and recorded the children's answers.

2.4 Monosyllable word arrangement

Using a Computerized Speech Lab (CSL), Model 4500, a professional female announcer (with over 30 years of experience) recorded all the included words. The microphone was positioned approximately 4 to 6 inches from the level of the speaker's mouth and at a 45° azimuth. The speaker's pitch ranged from 163.99 to 241.14 Hz. Subsequently, the recorded words were analyzed in terms of fundamental frequency (F_0), spectrogram, and pitch contours. The criteria for arranging monosyllable words are explained below:

1. The distribution of the fundamental frequency in each word within the list and inter-list.
2. The distribution of the Thai five tones within the list and inter-list.
3. The distribution of the initial consonant phonemes covering low, mid, and high frequencies within the list and inter-list.

The Thai monosyllable word lists, which were employed to determine WRS in the group of children 2 to 3 years of age, consisted of KKU kid word lists-A and picture materials. Table 1 shows the KKU kid word lists-A which are comprised of four lists, each consisting of 10 words, and Figure 2 shows the WRS picture materials, which consisted of 40 sets with four color pictures per page. Each picture set contained a different set of initial consonants.

Table 1 KKU kid word lists-A.

List 1A	IPA	List 2A	IPA	List 3A	IPA	List 4A	IPA
เต่า (turtle)	tàw	ไก่ (chicken)	kàj	หมวก (cap)	mùːak	ปาก (mouth)	pàːk
กิน (eat)	kin	ลิง (monkey)	liŋ	ปลา (fish)	plaː	รถ (car)	rót
หมา (dog)	măː	เตะ (kick)	tèʔ	ฟัน (teeth)	fan	บ้าน (house)	bâːn
เสื้อ (shirt)	sûːa	หมู (pig)	mŭː	ล้าง (wash)	láːŋ	แมว (cat)	mɛːw
บอล (ball)	bɔːn	ขา (legs)	kʰăː	แม่ (mother)	mêː	จาน (plate)	tɕaːn
มือ (hand)	mɯː	ปู (crab)	puː	ข้าว (rice)	kʰâːw	หมอ (doctor)	mɔ̌ː
เป็ด (duck)	pèt	ม้า (horse)	máː	ล้ม (fall down)	lóm	กล้วย (banana)	klûaj
ช้าง (elephant)	tɕʰáːŋ	นั่ง (sit)	nâŋ	กัด (bite)	kàt	ฝน (rain)	fŏn
นก (bird)	nók	ร้อง (cry)	rɔ́ːŋ	หมอน (pillow)	mɔ̌ːn	ไข่ (eggs)	kʰàj
พ่อ (father)	pʰɔ̂ː	มีด (knife)	mîːt	แปรง (toothbrush)	prɛːŋ	นอน (sleep)	nɔːn

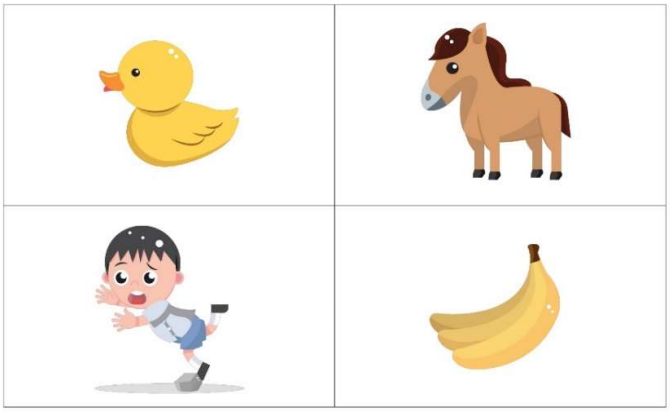

Figure 2 An example of the KKU kid word lists-A consisting of 40 sets with four color pictures per page. Each picture set contained a different set of initial consonants.

The open set of Thai monosyllable word lists was used to determine the WRS in the group of children from 4 to 5 years of age. Table 2 represents KKU kid word lists-B, which is composed of two lists, each consisting of 25 words.

Table 2 KKU kid word lists-B.

List 1B	IPA	List 2B	IPA
นม (milk)	nom	เป็ด (duck)	pèt
กิน (eat)	kin	กวาด (sweep)	kwà:t
ม้า (horse)	má:	วิ่ง (run)	wîŋ
กล่อง (box)	klɔ̀:ŋ	แมว (cat)	mɛ:w
ผม (hair)	pʰǒm	บอล (ball)	bɔ:n
บ้าน (house)	bâ:n	ร้อง (cry)	rɔ́:ŋ
ไข่ (eggs)	kʰàj	ไก่ (chicken)	kàj
นอน (sleep)	nɔ:n	มีด (knife)	mî:t
ช้าง (elephant)	tɕʰá:ŋ	เท้า (foot)	tʰá:w
หมา (dog)	mǎ:	หู (ear)	hǔ:
แปรง (toothbrush)	prɛ:ŋ	ปลา (fish)	pla:
ยิ้ม (smile)	jím	แม่ (mother)	mɛ̂:
เต่า (turtle)	tàw	นก (bird)	nók
หมู (pig)	mǔ:	ตา (eyes)	ta:
ล้ม (fall down)	lóm	กล้วย (banana)	klûaj
หมวก (cap)	mù:ak	มือ (hand)	mɯ:
ลิง (monkey)	liŋ	ฟัน (teeth)	fan
ยา (medicine)	ja:	ล้าง (wash)	lá:ŋ
หมอ (doctor)	mɔ̌:	หมอน (pillow)	mɔ̌:n
หวี (comb)	wǐ:	ฝน (rain)	fǒn
พ่อ (father)	pʰɔ̂:	ปาก (mouth)	pà:k
เตะ (kick)	tè?	รถ (car)	rót
เสื้อ (shirt)	sûː:a	ยาย (grandmother)	ja:j
ข้าว (rice)	kʰâ:w	หิน (rock)	hǐn
ปู (crab)	pu:	นั่ง (sit)	nâŋ

2.5 Sound recording

A professional female announcer with over 30 years of experience had a normal articulator and recorded at a sampling rate of 44.1 kHz. For the KKU kid word lists-A, the speaker recorded each word with 10 seconds of pause time, while for the KKU kid word lists-B, there were 3 seconds of pause time. Both an audiologist and a speech-language pathologist verified the sound quality, accent, and the spelling of the words during the recording process. All recording materials were produced in a standard sound-proof room at a music studio. A high-sensitivity condenser microphone (iTrack studio model CM25S) was covered with a pop filter microphone, 15 cm in diameter. The microphone was positioned approximately 20 cm from the speaker at an azimuth of 0°. The signal from the linear-weighted AC output was converted from analog to digital by using a Mackie ONYX-1640i with a sampling frequency of 44.1 kHz and a 24-bit amplitude resolution. The sound intensity of each word was edited so that it exhibited the same average intensity as that of a 1000-Hz calibration tone. Eventually, all word lists were kept in MP3 files.

2.6 The validity of the KKU kid word lists

2.6.1 The participants

This section included two groups of 62 pre-school students from Khon Kaen Province and the region of Northeastern Thailand. All of those participants, who had not previously participated in the receptive vocabulary evaluation section, were included in this final evaluation. The first group (2 to 3 years-old) was examined in WRS by using the KKU kid word lists-A. The second group (4 to 5 years-old) was assessed in WRS by using the KKU kid word lists-B.

Before the hearing evaluations, informed consent was obtained from the parents of the 62 children. The inclusion and exclusion criteria were the same. The inclusion criteria were having an understanding of standard Thai, being able to communicate, and having the ability to cooperate with a hearing evaluation. During the test, the volunteers were excluded if they had been uncooperative or if they had been unable to complete the testing. The researcher interviewed the parents of the children to access general information about each child, and then recorded the obtained information in the case record form. An otolaryngologist examined each child's ears without intervening to clean the external ear. The researcher performed the tympanometry testing at a 226 Hz probe tone and an ipsilateral acoustic reflex at a frequency of 1,000 Hz.

2.6.2 The testing procedures for Group 1

Transient evoked otoacoustic emissions (TEOAEs) screening was performed separately in each ear. The children received the speech awareness threshold (SAT) testing. Additionally, the recorded KKU kid word lists-A were presented at 30-40 dB SL in an audiometric booth at Srinagarind Hospital using DD45 headphones. The order of the presentation of the testing materials was random. The participant was instructed to point to the picture that corresponded to what he or she had heard. If the participant was unable to point at the target picture, no score was given. At the time of testing, the results for each participant were recorded.

If TEOAEs were present, the hearing screening was passed, while the absence of TEOAEs suggested hearing loss beyond 30 dB HL or signs of abnormalities in the middle ear.

2.6.3 The testing procedures for Group 2

Air-conduction thresholds were obtained at 500, 1000, 2000, and 4000 Hz in each ear using the conditioned play audiometry (CPA) method. The pure tone and the recorded KKU kid word lists-B were presented in an audiometric booth at Srinagarind Hospital using DD45 headphones. The WRS were performed at 30-40 dB SL, and the recorded KKU kid word lists-B were presented. The order in which the list was presented was randomly assigned. The subjects repeated the words that they had heard. If the subjects did not recognize the word, then they had to attempt to guess it. The results were recorded at the time of testing.

The hearing test results were considered to be normal if the air-conduction threshold at all frequencies across 500-4000 Hz, pure tone average (PTA), and SRT had been at 25 dB HL or lower. Conversely, the hearing test results were considered to be abnormal if the air-conduction threshold at any frequency across 500-4000 Hz or pure tone average (PTA) or the SRT had been greater than 25 dB HL.

2.7 The statistical analysis

A two-way ANOVA was used to determine the effects of the hearing results and word lists on the WRS.

3. Results

3.1 Word selection

Five teachers and five parents (or guardians), who were looking after a child (2 to 5 years old) rated the familiarity of the 100 monosyllable words on a scale of 1 to 4 based on the familiarity of each word. (4 = very familiar, 3 = moderately familiar, 2 = somewhat familiar, and 1 = unfamiliar). Only 80 words, which had shown a percentage of familiarity ranging from 95-100%, were included in this process. Of these, 59 were nouns and 21 were verbs. The selected noun words were related to family and occupation, the organs in our bodies, food, animals, things, and nature. In addition, the selected verbs were related to simple actions, such as sitting, eating, and sleeping. All 80 words were drawn and arranged in the format of four pictures per page.

3.2 Receptive vocabulary evaluation

The development of picture sets was tested for receptive and expressive language by 2 pre-school groups with 62 children per group. Group 1 was composed of children between the ages of 2 to 3 years, while Group 2 was composed of children between the ages of 4 to 5 years. Table 3 presents the demographic data of the children who participated in the process.

Table 3 The demographic data of the children who participated in the process.

	Group 1 2 to 3 years-old	Group 2 4 to 5 years-old		Group 1 2 to 3 years-old	Group 2 4 to 5 years-old		Group 1 2 to 3 years-old	Group 2 4 to 5 years-old
Urban schools			Rural schools			Both urban and rural schools		
Genders			Genders			Genders		
Males	15 (48%)	13 (42%)	Males	12 (39%)	15 (48%)	Males	27 (44%)	28 (45%)
Females	16 (52%)	18 (58%)	Females	19 (61%)	16 (52%)	Females	35 (56%)	34 (55%)
Total	31 people	31 people	Total	31 people	31 people	Total	62 people	62 people
Ages			Ages			Ages		
Mean	3.5 years	4.2 years	Mean	3.4 years	4.4 years	Mean	3.4 years	4.3 years
Min.	2.8 years	4 years	Min.	2.2 years	4 years	Min.	2.2 years	4 years
Max.	3.11 years	4.7 years	Max.	3.11 years	4.11 years	Max.	3.11 years	4.11 years

3.3 The final evaluation

There were 2 groups of children involved in this process: 31 pre-school children between the ages of 2 to 3 years (Group 1), and 31 pre-school children between the ages of 4 to 5 years (Group 2). Table 4 shows the demographic data of the participants, and Table 5 shows the results of otoscopy, audiometry, and tympanometry in the final evaluation process.

Table 4 The demographic data of the participants in the final evaluation process.

	Genders		Ages			Physical development				Speech & language development
	Male	Female	Mean (years)	Min. (years)	Max. (years)	Sit (months)	Crawl (months)	Stand (months)	Walk (months)	First spoken meaningful word (months)
Group 1 (2 to 3 years)	15	16	3.2	2.3	3.11	6	7	12	12	13
Group 2 (4 to 5 years)	13	18	4.4	4	5	6	8	10	12	14

Table 5 The results of otoscopy, audiometry, and tympanometry in the final evaluation process.

	Group 1 (2 to 3 years)		Group 2 (4 to 5 years)
Otoscopy			
Normal	47 ears (76%)		49 ears (79%)
Impacted cerumen	15 ears (24%)		13 ears (21%)
Audiometry			
In terms of the number of people			
TEOAEs: passed both ears	21 (68%)	Audiometry: normal both ears	23 (74%)
referred 1 ear	7 (22%)	abnormal 1 ear	3 (10%)
referred both ears	3 (10%)	abnormal both ears	5 (16%)
In terms of the number of ears			
TEOAEs: passed	49 (79%)	Audiometry: normal	49 (79%)
referred	13 (21%)	abnormal	13 (21%)
Tympanometry			
Type A	44 ears (71%)		50 ears (81%)
Type B	11 ears (18%)		7 ears (11%)
Type C	7 ears (11%)		5 ears (8%)

Group 1

There were 31 participants (15 boys and 16 girls), with a mean age of 3 years and 2 months. All participants showed normal physical, speech, and language development. Twenty-one children had bilateral pass otoacoustic emissions (OAEs), 7 had unilateral refer OAEs, and 3 had bilateral refer OAEs. All referred results indicated abnormalities in the external and/or middle ear. In terms of the number of ears, 49 were found to pass OAEs, while 13 were referred for OAEs with abnormal external and/or middle ears.

Group 2

Thirty-one children (13 boys and 18 girls) with a mean age of 4 years and 4 months participated in the final evaluation. No evidence of delayed physical, speech, or language development was discovered. Twenty-three children had normal hearing levels, while three had unilateral hearing loss and five had bilateral hearing loss. Focusing on the number of ears, 49 had normal hearing and 13 had hearing loss with abnormal external and/or middle ears, of which 12 had mild hearing loss and 1 exhibited moderately severe hearing loss.
The results of KKU kid word lists testing in the two groups of children.

Group 1

The mean of the percentage of correct responses for passing and referring to the hearing screening test was above 90% for each list of KKU kid word lists-A. Table 6 and Table 7 show the mean percentage of the correct responses with standard deviation (SD) and a 95% confidence interval (CI) for the normal hearing group and the hearing loss group, respectively.

A two-way analysis of variance (ANOVA) was performed in order to analyze the effects of the hearing results and the word lists on WRS. A two-way ANOVA revealed that there had been no statistically significant interactions between the effects of the hearing results and the word lists ($F(3, 54) = .499$, $p = .685$). A simple main effect analysis showed that the hearing results and word lists had not had a statistically significant effect on WRS.

Table 6 The mean percentage of correct responses with standard deviation (SD) and a 95% confidence interval (CI) for the normal hearing group.

		List 1A (n=15 ears)	List 2A (n=11 ears)	List 3A (n=12 ears)	List 4A (n=11 ears)
Mean ± SD		91.33 ± 7.43	95.45 ± 5.22	96.67 ± 6.51	95.45 ± 6.88
95% CI	Lower Bound	87.22	91.95	92.53	90.84
	Upper Bound	95.45	98.96	100.81	100.07

Table 7 The mean percentage of correct responses with standard deviation (SD) and a 95% confidence interval (CI) for the hearing loss group.

		List 1A (n=1 ear)	List 2A (n=4 ears)	List 3A (n=4 ears)	List 4A (n=4 ears)
Mean ± SD		90 ± 0	97.50 ± 5.00	95.00 ± 10.00	100 ± 0
95% CI	Lower Bound	-	89.54	79.09	100
	Upper Bound	-	105.46	110.91	100

Group 2

The mean percentage of the correct responses for normal hearing was above 92% for each list of KKU kid word lists-B. For the group with hearing loss that was due to external and/or middle ear conditions, the mean WRS was more than 86% with list 1B but was greater than 90% with list 2B. Table 8 and Table 9 show the mean percentage of the correct responses with SD and a 95% confidence interval (CI) for the normal hearing group and the hearing loss group, respectively.

A two-way ANOVA was performed to analyze the effects of the hearing results and word lists on WRS. A two-way ANOVA revealed that there had been no statistically significant interaction between the effects of the hearing results and the word lists ($F(1, 58) = .853$, $p = .359$). A simple main effect analysis showed that hearing results had had a statistically significant effect on WRS ($p = .014$). While in contrast, the simple main effects analysis showed that the word lists had not had a statistically significant effect on WRS ($p = .284$).

An independent-sample t-test compared the mean scores of the WRS from the normal and hearing loss groups, and a significant difference was found ($t(60) = 2.622$, $p = .011$). The mean of the WRS from the normal group ($m = 92.82$, $sd = 5.476$) was significantly different from the mean of the WRS from the hearing loss group ($m = 88.00$, $sd = 7.303$).

Table 8 The mean percentage of correct responses with standard deviation (SD) and a 95% confidence interval (CI) for the normal hearing group.

		List 1B (n=24 ears)	List 2B (n=25 ears)
Mean ± SD		92.67 ± 5.36	92.96 ± 5.69
95% CI	Lower Bound	90.40	90.61
	Upper Bound	94.93	95.31

Table 9 The mean percentage of correct responses with standard deviation (SD) and a 95% confidence interval (CI) for the hearing loss group.

		List 1B (n=7 ears)	List 2B (n=6 ears)
Mean ± SD		86.29 ± 6.47	90 ± 8.29
95% CI	Lower Bound	80.30	81.30
	Upper Bound	92.27	98.71

4. Discussion

It was discovered that the knowledge of the number of nouns among the pre-school children had been greater than the number of verbs. In particular, the largest number of nouns focused on things, which was followed by animals, the organs in our bodies, food, and nature, respectively. Considering the exclusion of nouns in terms of things, some words from the list of 100 words, such as "ขาม" (tɕʰaːm)—a round, deep dish or basin used for food or liquid—were rated as 'least familiar' by the teachers and parents/guardians. Animal words, e.g., wildlife (tiger, snake, and bear), were rated lower than other kinds of animals due to the fact that they are considered uncommon and cruel. Furthermore, it was expected that the word "ครู" (kʰruː) or teacher in English would be difficult to represent using a picture since teachers do not wear uniforms like other occupations, such as doctors. Due to the limitations of picture representation, the pre-school children were able to recognize and communicate the nouns with greater frequency than the verbs that were included in this study. The authors discovered that the types of selection words had been consistent with a previous study [8], which included simple nouns, such as animals, food, or toys, and the earliest verbs that children are able to use, such as action, process, or spontaneous verbs. The results contradicted the claims of another study in which it was stated that only nouns should be chosen for receptive and expressive language testing [10].

The evaluation of the receptive and expressive vocabulary indicated that the mean scores of recognition words in Group 2 (4 to 5 years of age) had been higher for almost all words when compared to Group 1 (2 to 3 years of age). Consequently, the results supported the theory that the age factor can directly affect speech and language development [17]. The older the children, the more opportunities there are to share their communications and experiences. As a result, all selected words should be recognized by pre-school children in order to improve the quality of the words related to the pre-school children's speech and language development.

The fundamental frequency (F_0) of monosyllable words from the KKU kid word lists-A and KKU kid word lists-B had been between 163.99 and 241.14 Hz. The mean of F_0 was 197.45 Hz (SD = 18.96), which was found to be higher than in other studies conducted both in Thai and in foreign languages [18–20]. Differences in the vocal fold length and mass, as well as the type of speech task, would result in fundamental frequencies that were both higher and lower than the average [21].

Tonal sounds are one of the factors that contribute to the meaning of each word in Thai. In this study, the fundamental frequency contour of the tones of each word had similar characteristics to another study [22]. For example, the word "นั่ง" (nâŋ) represents a falling tone that has the starter F_0 contour slightly rising and then suddenly falling. Conversely, the rising tone has a different F_0 pattern that reverses the falling tone, such as the words "หมู" (mǔː), "ขา" (kʰǎː), and "หมอน" (mɔ̌ːn).

From this study, we found that the prevalence of hearing loss in 62 pre-school children between the ages 2 and 5 years had been 29.03% (18 children). Bilateral hearing loss was found to be at 12.90% (8 children), while unilateral hearing loss was recorded at 16.13% (10 children).

According to the limitations in terms of the different audiometric criteria used to diagnose hearing loss, the prevalence of hearing loss in the group of children 4 to 5 years of age in this study had been 25.80%, which was higher than a previous study in which a 22.22% hearing loss prevalence had been reported [23]. This study demonstrated mild hearing loss, which resulted from impacted cerumen, ear infections, and Eustachian tube dysfunction. Meanwhile, the prevalence of hearing loss in children 2 to 3 years of age had been 32.26%.

The Thai versions of monosyllable word lists and picture lists were determined to be appropriate for the speech and language development of pre-school children. All monosyllable inclusion words were assessed by the pre-school children for both receptive and expressive language, which is related to another study, in which the WIPI test revisited for children was developed [24].

It was reported that the results of the final evaluation of the WRS using the KKU kid word lists-A had been above 90% for each list when performed in both passing and referring to the hearing screening ears. Because the receptive language skills are developed faster than the expressive language skills in young children, there were no statistically significant differences in WRS between the two groups. Furthermore, it could not be assumed that the participants had had actual hearing outcomes due to the presence of impacted cerumen.

Regarding the KKU kid word lists-B, the mean scores of WRS had been above 92% for each list in normal hearing ears but had been 88% in those ears with hearing loss. In this study, the results of WRS were not found to be different from another study, which revealed that the WRS of those with normal hearing had between 90

and 100% [3]. There were statistically significant differences in WRS between the two hearing groups, which had most likely caused mixed hearing loss. However, due to the time-consuming nature of the evaluation, the procedure did not cover pure-tone bone conduction audiometry in order that those children with mixed hearing loss could be included. For this reason, a statistically significant difference between the normal and the hearing loss groups with regard to WRS was evident.

In the current study, due to the lack of intervention regarding the cleaning of the ears following the ear examination, the hearing results could not differentiate the causality. Earwax was identified in 15 out of 62 (24%) of the children in Group 1 (2-3 years) and in 13 out of 62 (21%) of the children in Group 2 (4-5 years). Additionally, it was found that there had been a high prevalence of hearing loss in the two groups of pre-school children. Furthermore, the 95% confidence interval of the word recognition scores in several of the word lists had been broad, which was the result of only a small percentage of hearing-impaired volunteers being included in this study.

5. Conclusion

The Thai monosyllable word lists for pre-school children were developed in accordance with the phonetically balanced fundamental frequency, the Thai five tones, and the initial consonants.

The future aspects of this work include using the KKU kid word lists-A & B with larger numbers of children, including children from different regions of Thailand, as well as assessing other types and levels of hearing loss, especially hearing levels that exceed 40 decibels.

6. Ethical approval

This study was approved by the Khon Kaen University Ethical Committee for Human Research (approval number HE651069) and was registered in the Thai Clinical Trials Registry (TCTR) (reference number 20220430003). Prior to participating in the trial, full written informed consent was provided for all subjects.

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