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Psychometric properties of the apraxia of speech rating scale Thai version

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ABSTRACT

Background: Thai speech-language pathologists lack appropriate tools to describe apraxia of speech (AOS) characteristics in Thai patients.

Objectives: This study aimed to translate and adapt the most recent version of the Apraxia of Speech Rating Scale (ASRS) 3.3, the ASRS 3.3, into a Thai version and evaluate the psychometric properties of the Thai version (ASRS-Thai).

Materials and methods: The original ASRS 3.3 has been translated into Thai using the backward-translation approach. The original developer was also included in the translation process to improve the translation accuracy. The resulting tool, ASRS-Thai, was administered to 28 adults with neurological speech or language disorders, along with another AOS test available in Thai, Apraxia Test for Thai Adults (ATTA). The recordings were rated independently by 5 experienced speech-language pathologists at different hospitals. The clinical assessment of patients' performance on the ATTA was used as the reference standard to measure the sensitivity and specificity of ASRS-Thai for AOS diagnosis. Concurrent validity and reliability measures were also examined. Reliability was examined by evaluating intra-rater and inter-rater reliability.

Results: Moderate-to-strong negative correlations were found between the ATTA and the ASRS-Thai (-0.575 to -0.900). Additionally, the sensitivity and specificity of the ASRS-Thai at a cut-off score of 16 were 100% and 86.7%, respectively. Reliability was computed by measuring the intraclass correlation (ICC) values. The intra-rater ICCs were 0.96, 0.968, and 0.976, and the inter-rater ICC was 0.927 for the total score.

Conclusion: The ASRS-Thai is a reliable, valid instrument to describe the presence and severity of AOS characteristics in clinical settings and research. Additional data collection by testing a larger sample size with diverse severities, including cases of pure AOS, is warranted in future studies.

Introduction

Apraxia of speech (AOS) is a neurological speech disorder that indicates an impaired ability to plan or program the sensorimotor commands necessary to guide movements that result in phonetically, prosodically normal speech.[1] AOS can occur in the absence of language disturbances or physiological disturbances associated with dysarthria. It occurs frequently in individuals with aphasia, dysarthria, or other neurological communication disorders.[2] Additionally, the most common cause of AOS is stroke.[3] According to a study of the incidence of stroke in Thailand, the estimated prevalence of stroke is 1.88% among adults aged 45 years and older.[4] With a prevalence of 122 patients per 100,000 individuals in the population.[5] Approximately 4-20% of stroke patients have language and speech problems[2], and AOS may account for

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6.9% of motor speech disorders.[1] Of further note, AOS tends to co-occur with Broca's aphasia[6] and rarely presents without other speech-language deficits.[7]

The primary method used in the differential diagnosis of AOS is auditory perceptual assessment.[1, 8] Challenges in the differential diagnosis of AOS include its probable co-occurrence with aphasia or dysarthria and controversies regarding its diagnostic criteria.[9] The clinical diagnosis of AOS requires a task that can reveal a patient's apraxic performance.[8]

In Thailand, based on Darley's definition of AOS[10], Akamanon developed the Apraxia Test for Thai Adults (ATTA) to be administrated by speech-language pathologists (SLPs).[11] The key points of Darley's definition are that (a) AOS affects articulation, (b) AOS compromises the positioning and sequencing of the articulators, (c) AOS is not caused by muscular weakness and is unrelated neuromuscular deficits, and (d) AOS affects prosody.[10] ATTA consists of seven subtests that require nonspeech or speech tasks: the former includes automatic control of articulators, imitation of the articulatory movement, oral apraxia, and limb apraxia; while the latter includes repetition, vowel prolongation, and diadochokinetic rate, and spontaneous and automatic speech. All the subtests are used to identify the characteristics of AOS, and each subtest has a scoring system ranging from a 3-point scoring scale to a 12-point scoring scale, with no cut-off score.[11]

Sarankawin studied the test-retest reliability of ATTA and compared the performance of 100 healthy Thai participants aged 20-40 years and 41-65 years. Ranging from 0.71 to 0.97, the test-retest reliability coefficient of each subtest was high. However, the validity of ATTA in determining the level of severity of speech impairments exhibited by the tested patients has not been studied. Additionally, ATTA's scoring criteria only evaluate articulatory errors without providing details about specific AOS characteristics and their frequencies (the scoring criteria of ATTA are presented in Table 3). ATTA's scoring criteria contain a mix of numerous target behaviors and symptoms, rather than measuring one symptom along a meaningful continuum of severity. For example, a score value of 3 for the spontaneous speech and automatic speech subtest, incorporates word length, correct word use, and appropriate grammar. The limitations inherent in the variability of these scoring descriptors decrease their potential utility. Decreasing ATTA scores may not reflect an increasing severity of AOS. Clinicians who employ ATTA must interpret the results without a cut-off score, and extra examinations may be required for differential diagnosis. Furthermore, some clinicians used words and pictures from ATTA in their clinical AOS diagnosis without employing the scoring criteria.[12]

Published tests for the diagnosis of AOS include the Apraxia Battery for Adults second edition (ABA-2)[13] and Quick Assessment for Apraxia of Speech.[14] However, these tests contain words and sentences in English, which cannot be translated for assessing Thai speech defects because of cultural and phonological differences. Although the translated words and sentences for collecting speech samples would have the same content as the original test, they cannot be used for assessment within the Thai phonetic context. Only the translated scoring criteria can be used across languages. For example, "cat, catnip, catapult, catastrophe[15]" would be translated into Thai (pronunciation): "แมว (mɛ:w), กัญชาแมว (kan-t͡ɕʰa:-mɛ:w), เครื่องยิงก้อนหิน (kʰrɯ̂ạŋ-jiŋ-kɔ̂:n-hǐn), ภัยพิบัติ (pʰaj-pʰí-bàt)." The translated stimuli do not share the same first syllable and do not successively increase in length. Furthermore, the word "กัญชา (kan-t͡ɕʰa:)" is not appropriate in Thai culture because it also means cannabis (a narcotic), and Thai patients may not be familiar with the word "เครื่องยิงก้อนหิน (kʰrɯ̂ạŋ-jiŋ-kɔ̂:n-hǐn)." Therefore, any assessment in the Thai language would require developing a set of words and sentences suitable for Thai culture. Alternatively, it could be possible to use existing feasible and valid Thai words and sentences combined with translated scoring criteria from another language.

Apraxia of Speech Rating Scale (ASRS) 1.0[16] was developed at the Mayo Clinic to describe the characteristics frequently associated with AOS by using speaking tasks from the Western Aphasia Battery-Revised (WAB-R)[17], alternate motion rate (AMR), sequential motion rate (SMR), and supplementary motor speech tasks as speech samples for scoring. The validity and reliability of ASRS 1.0 were measured in 133 adults with neurodegenerative speech or language disorders. Inter-rater reliability was strong: the intraclass correlation (ICC) was 0.94 for the total score and 0.91 for the number of AOS characteristics identified to be present. Intra-rater ICC ranged from 0.91 to 0.98. Validity was strong based on correlations with clinical diagnoses and assessments of severity. Specificity was 100% when the cut-off ASRS score was set at 8. Sensitivity was 75% with a cut-off score of 14, 90.5% with the cut-off of 10, and 96% with the cut-off of 8. These results suggested that the ASRS 1.0 was a potentially useful instrument for measuring the presence and severity of AOS characteristics. However, some of the items were not easily scored, and there was some redundancy across items that required a revision of the scale.[16] The ASRS 1.0 was also translated into Spanish.[18]

In the process of validation, ASRS has undergone multiple revisions. The most recently published version is ASRS 3.0.[19] ASRS 3.0 rates 13 speech features, while ASRS 1.0 rates 16 speech features. In terms of the overall organization, ASRS 3.0 was reduced from four to three categories: articulatory features, prosodic features, and others. ASRS 3.0 also eliminates some features: a) increased distortions or distorted substitutions with an increased speech rate, b) lengthened intersegment durations, and c) sound prolongations (beyond lengthened segments). Some features were reorganized: The audible or visible group is now a single feature, and false starts are grouped with repetitions. Several features have been clarified (e.g., overall speech rate, AMRs, SMRs). Like ASRS 1.0, ASRS 3.0 uses a 5-point scale with operationalized descriptors for each rating level. ASRS 3.0 was studied in 28 adults with chronic aphasia and suspected AOS from stroke and brain injury.[20] Inter-rater ICC was 0.954 for the total ASRS score and ranged from 0.034 to 0.789 for individual items. The concurrent validity of ASRS 3.0 ranged from 0.593 to 0.991. These results suggested that the ASRS 3.0 may be a reliable measurement of AOS characteristics, and additional operationalization of rating procedures may be required to improve the inter-rater reliability of a few items.[20]

The developers' unpublished update of ASRS 3.3[21] is

similar to ASRS 3.0, but there was a wording change in item 13: from "score on a maximum number of syllables/repetitions per breath group" to "score on an average number of syllables/repetitions per breath group across tasks." Since some patients perform differently in different contexts, this feature reflects the respiratory coordination of AOS using the average number of performances when perceiving a reduction. The validity or reliability of the ASRS 3.3 has not been established.[21]

Considering the lack of a test to describe AOS characteristics in Thai patients, the present study sought to translate the ASRS, which provides details of the presence and severity of speech impairments associated with AOS and is suitable for assessing speech across languages by collecting speaking tasks from the WAB-Thai, AMR, and SMR as speech samples for scoring. Furthermore, the sensitivity and specificity of the ASRS in assessing stroke- or brain injury-induced AOS has never been studied before.

Thus, the aims of this study were as follows: Translate ASRS 3.3 into Thai language, adapt ASRS 3.3 for Thai language, and evaluate the concurrent validity, sensitivity, specificity, and reliability of ASRS Thai in assessing neurological communication disorders to achieve clinical diagnostic accuracy for acquired AOS in Thai adults. The achievement of these objectives would facilitate appropriate treatment planning by Thai clinicians and provide information regarding the additional refinement of the original ASRS.

Materials and methods

This study includes 2 phases; Phase 1 is to translate and adapt ASRS 3.3 into Thai language, and Phase 2 is to evaluate the psychometric properties of ASRS-Thai. The flow diagram of the study procedure is provided in Appendix 1.

Phase 1: Translation and cross-cultural adaptation of ASRS 3.3

ASRS 3.3,[21] the most recent version of ASRS, was translated and adapted into Thai by following a standard forward- and backward-translation process[22] with permission from the original developers.

The first stage involved the production of two translations by two independent translators with different backgrounds: an SLP and a professor (linguistic). In the second stage, the two translators synthesized the results of their respective translations to produce one translation. In the third stage, two back-translations based on the synthesized translation were produced by two other independent translators with different backgrounds who were blinded to the original version. The fourth stage involved an expert committee meeting where comparisons were conducted between all the versions of translations and back-translations and the original ASRS 3.3; adjustments were subsequently made to yield a pre-final version. The fifth stage was a cognitive debriefing to test alternative wording and verify the understandability and interpretation of the pre-final Thai ASRS 3.3 among experienced clinicians (SLPs) who were blinded to the original or any English versions. The pre-final version was revised based on the feedback obtained in this stage. The revisions modified and eliminated irrelevancies and generated word substitutes to fit the target's cultural situation while maintaining the general concepts of the items; two back-translations were produced and sent to the developer of the original ASRS 3.3 along with the previous two back-translations for review. Corrections were conducted after reviewing the developer's comments to ensure that the final version would maintain content validity. This step yielded two more back-translations that were sent to the developer for further review. The final version of the ASRS-Thai was finalized after the developer completed the reviewing process.

Adjustments to ASRS-Thai were made when the researcher sent questions seeking explanations from the developer, who then provided clarifications and some examples to be adapted into Thai. Experienced Thai clinicians (SLPs) suggested that the researcher add the evaluation method and rearrange the sequence of items to ensure consistency in the evaluation and scoring method. Thus, items 1-10 use the same scoring criteria, but items 11-13 have different scoring criteria that are specific to each item. The evaluation methods of the ASRS-Thai are presented in Table 1. The brief descriptions of items 1-13 are provided in Table 6.

Table 1 Evaluation methods and scoring criteria of ASRS-Thai.

Evaluation methods of ASRS-Thai
1) Determine speech characteristics from spontaneous speech, repetition, and naming subtests of the Western Aphasia Battery Thai version.
2) Determine AMR, SMR, and duration of the longest vowel prolongation for items 11-13.
Criteria considered for items 1-10
0 = not observable or occurs not more than 1 time.
1 = not observable often or occurs more than 1 time but less than 20% of the whole utterance.
2 = observable often or for 20%-50% of the whole utterance; score not more than 2 if occurs only in the repetition section.
3 = observable almost all the time, but not sufficiently severe to affect overall speech intelligibility.
4 = observable almost all the time or observable all the time with a severe degree that affects speech intelligibility.

Table 1 Evaluation methods and scoring criteria of ASRS-Thai. (continues)

Criteria for item 11	
0 = normal repetition rate	
1 = mild distortion (of placement - manner and/or voiced–voiceless, easily perceived as the target sounds) and occurs a few times	
2 = mild distortion (of placement - manner and/or voiced–voiceless, easily perceived as the target sounds) but occurs often	
3 = moderate distortion (misses the target sound for more than one feature of placement, manner, voiced, voiceless)	
4 = severe distortion (not perceived as the target sounds)	
Criteria for item 12	
0 = normal sequencing phonation rate	
1 = slow (SMR repetitions)	
2 = mild pause between words and/or mild distortion (easily perceived as the target sounds)	
3 = moderate pause between words and/or moderate distortion	
4 = severe pause between words and/or severe distortion (not perceived as the target sounds)	
Criteria for item 13	
Reduced words per breath group	Reduced # of AMR repetitions per breath group
0 = more than 7 syllables	0 = more than 7 times
1 = 6-7 syllables	1 = 6-7 times
2 = 4-5 syllables	2 = 4-5 times
3 = 3-4 syllables	3 = 3-4 times
4 = 2 syllables or less	4 = 2 times or less

At first, ASRS-Thai produced a confusing and less comprehensible result due to an attempt to retain the entire sentence structure and literal meaning of the original version. The suggestions from experienced clinicians matched the suggestions provided by Brislin *et al*. for writing in a short, concise form; providing context; and minimizing the use of colloquialisms, subjunctives, multiple verbs, and vague words in the formulation of the instruments.[23] The ASRS-Thai provides context by adding a few examples: e.g., in item 1, "Speech distortion but target sound still perceived, e.g., distortion of the /s/ of /sà-bùː/ (meaning soap in Thai)"; in item 2, "Substitution with a distorted sound. e.g., substitution with distorted /t/ for /s/ of /sà-bùː/ (meaning soap in Thai)"; in item 10, "use of other words with related meanings," and "/sh../ (shirt) for /kaːŋ-keːŋ/ (pants)" was added due to the confusion caused by translation of the original example into Thai (i.e., "/t͡ɕʰɔ̀ːn/ (spoon) for /sɔ̂ːm/ (fork)") that may be interpreted as unclear speech instead of semantic paraphasias.

Other concerns from experienced Thai clinicians were related to clarifications of scoring criteria, such as those in Strand *et al*.[16] and Wambaugh *et al*.[20] for the specification of the criteria and provision of particular scorings and subtle behaviors (e.g., mildly segmented SMRs; slight voicing error detected in AMRs; and slow, segmented speech in conversation) that could be helpful for ratings among clinicians and researchers. Therefore, the criteria of items 11 and 12 were revised in the ASRS-Thai based on the references from the developer (Table 1). Item 13 was divided into two categories, and quantifying nouns were added to the scorings: 0 = more than seven syllables, 0 = more than seven times. An example of how to count was also added: "count /p/ = 1 time." The final version of ASRS - Thai is presented in Appendix 2.

Phase 2: Psychometric properties evaluation of ASRS-Thai

ASRS-Thai was administered to 30 adults with neurological speech or language disorders in conjunction with ATTA and the Western Aphasia Battery Thai version (WAB-Thai), to determine concurrent validity, sensitivity, specificity, intra-rater reliability, and inter-rater reliability.

Participants

Thirty adults were recruited for this study by following these inclusion criteria:

1. a history of cerebrovascular accidents or acquired brain injury and in a stable condition (vital signs are stable and within normal limits[24]).
2. a rehabilitation physician's or SLP's diagnosis of neurological speech or language problems
3. age greater than 20 years
4. native Thai speakers
5. apparent normal hearing: the hearing was analyzed while the patient was conversing with the researcher at a normal level of loudness; if the researcher had to speak louder or repeat questions or information several times, the patient was not selected.
6. apparent normal vision or having appropriate visual aids: patients were asked if they wore glasses and whether they had visual problems that interfered

with their daily activities.
7. could repeat /pə-tə-kə/ 0-8 times within 5 s[12]
8. a score of 4 and above out of a total score of 10 on the comprehension subtest in the Western Aphasia Battery Thai version[25, 26]

Exclusion criteria were as follows:
1. patients with any condition that would limit their ability to participate in the study, such as unstable vital signs, unconsciousness, discomfort, dizziness, drowsiness, inattention, confusion, slow responses to stimulation, unresponsiveness, lack of co-operation, or on a respirator.
2. patients comorbid with Parkinson's disease or other neurodegenerative diseases.
3. refusal to provide informed consent

All participants were considered to have neurological speech or language problems with or without AOS. Written consent was obtained from all participants according to the committee's guidelines. Two participants were excluded due to their having Parkinsonism. Hence, the data of 28 participants were used in this study. Table 2 presents the demographic information of the participants.

Table 2 Demographic information of the participants.

Gender	
Male	21 (75%)
Female	7 (25%)
Age	
Mean (SD)	52.14 (15.59)
Range	26-84 years
Etiology	
1. Cerebrovascular accident	23 (82%)
1.1 Hemorrhagic	8 (28.5%)
1.2 Ischemic	15 (53.5%)
2. Acquired brain injury	5 (18%)
Post-onset (all participants are in stable condition)	
Mean (SD)	2.06 years (2.41)
Range	7 days-10 years 5 months
WAB comprehension score (AQ)	
Mean (SD)	8.16 points (2.02)
Range	4.05–10 points
Diagnosis (the AOS diagnosis is from the agreement of diagnosis among raters, whether presence or absence of AOS)	
1. Dysarthria without AOS	1 (4%)
2. Dysarthria with Aphasia	7 (25%)
3. Aphasia without AOS	7 (25%)
4. Aphasia with AOS	13 (46%)
5. Dysarthria with AOS	0 (0%)
6. AOS alone	0 (0%)

Procedures

Each participant was evaluated by using WAB-Thai (only for the spontaneous speech, repetition, naming, and word-finding subtests), and the ATTA (only for the vowel prolongation, diadochokinetic rate, repetition, spontaneous speech, and automatic speech activities). A video recording was made of the evaluation by the researcher, who used an iPhone XR (Rater #1).

Performances on WAB-Thai, vowel prolongation, and diadochokinetic rate (both AMR and SMR) were used for collecting speech samples to observe the speech performance of each participant and provide a score for ASRS-Thai. ASRS-Thai consisted of 13 items rated on a 5-point scale to determine speech characteristics from the spontaneous speech, repetition, and naming sections of the WAB-Thai. The criteria for scoring are presented in Table 1.

ATTA has words and sentences in Thai language that could be used as supplementary motor speech tasks to reveal patients' speech performances for the clinical diagnosis of AOS. Performance in ATTA was used for the clinical diagnosis of AOS through perceptual judgment. The inter-rater agreement of clinical diagnosis results from the ATTA regarding the presence of AOS was used to analyze the sensitivity and specificity of the ASRS-Thai. Each subtest of ATTA had a scoring system. Vowel prolongation and the diadochokinetic rate subtest were assessed by asking participants to sustain a vowel sound (/a/, /u/, and /i/) as long as possible two times and to produce the syllables /pə/, /tə/, /kə/, and /pə-tə-kə/ as quickly as possible within 15 s. Raters reported the results of vowel prolongation or maximum phonation time (MPT) in s and AMR and SMR by the frequency of the repetition of syllables. The repetition subtest consisted of 34 words or sentences for the participant to imitate after the examiner, which was rated on a 3-point scoring scale. The subtest for spontaneous speech and automatic speech consisted of two tasks that included 6 items. The first task was to produce spontaneous speech by describing the picture; the second task was to assess automatic speech and used a 4-point scoring scale. The criteria for scoring are presented in Table 3.

Table 3 Scoring criteria of the Apraxia Test for Thai Adults (ATTA) in repetition, spontaneous speech, and automatic speech subtest.

Criteria for repetition subtest
2 = correct, prompt, no struggle, no articulatory error
1 = self-correction, significant delay, visible or audible searching, one or more articulatory errors
0 = no response or failed attempts by not producing a word or producing a word by using the wrong number of syllables
Criteria for spontaneous speech and automatic speech subtest
3 = the characteristics of a two-word phrase or four-word sentence, all of which are appropriate and with correct grammar
2 = a partially correct or trial-and-error response
1 = defective speech, visible or audible search, articulatory error
0 = no response

All raters were instructed by the researcher on scoring ATTA for clinical diagnosis and on scoring ASRS-Thai (Rater#1). They were all experienced SLPs: Rater#1 had 7 years of experience as an SLP at the Sirindhorn National Medical Rehabilitation Institute; Rater#2 had 9 years of experience as an SLP at the Rehabilitation Unit, Vejjarak Lampang Hospital; Rater#3 had 21 years of experience as an SLP at the Department of Rehabilitation, Chulalongkorn Hospital; Rater#4 had 23 years of experience as an SLP at the Department of Rehabilitation, Somdejprapinklao Hospital; and Rater#5 had 26 years of experience as an SLP at the Department of Ear Nose Throat, Bhumibol Adulyadej Hospital. All the raters watched the video recordings and independently scored the participants while at their hospitals (in quiet rooms), i.e., independent from the other raters and the researcher (Rater#1). No rater was involved with the original ASRS development or had seen the original version. Raters 2-5 were provided with limited information-age, etiology, onset, and WAB-Thai comprehension scores-without any diagnosis. The etiological information provided to raters was regarding cerebrovascular accidents and hemorrhagic, ischemic, or acquired brain injury, with no information regarding lesions in the brain or MRI or CT scan results. All video recordings were named by using an alphanumeric code instead of the participants' real names. Raters 1-3 were selected for evaluation of intra-rater reliability based on the number of clinical experiences for comparison. Raters 2-3 (the clinicians participating in the research) received new randomly coded video recordings 14 days after the first scoring; the first-score results were collected immediately after the scoring was finished. Rater #1 (the researcher) rescored the video recordings 20 months after the first scoring to avoid the bias from remembering the first scoring since Rater#1 was both the evaluator and recorder of the videos.

Data analysis

Validity of ASRS-Thai was assessed by obtaining the results of all the samples from ATTA and ASRS-Thai to calculate concurrent validity, sensitivity, specificity, and the cut-off point.

Concurrent validity is the correlation between ASRS-Thai and ATTA, an existing well-established scale, calculated by using the Pearson correlation coefficient with IBM SPSS 26. Values near 0 indicate no correlation, and values near ±1 indicate a very strong correlation. A negative sign indicates that the 2 variables are inversely related, that is, as one variable increases, the other variable decreases. A value less than 0.3 indicates a poor correlation; values between 0.3 and 0.5 indicate a fair correlation; values between 0.6 and 0.8 indicate a moderately strong correlation, and values of at least 0.8 indicate a very strong correlation.[27]

Sensitivity refers to the proportion of individuals with AOS who are shown to have AOS on ASRS-Thai, based on the reference standard (clinical judgment of patient's performance on ATTA). Specificity indicates the proportion of individuals without AOS who are shown not to have AOS on ASRS-Thai. The majority diagnosis among the five raters - i.e., at least three of five raters agreed to the presence or absence of AOS -was used for the AOS diagnosis of the reference standard. The diagnosis results were not retrieved from the consensus evaluation to prevent bias; as senior raters might affect the evaluations of junior raters. As five raters (R#1-5) scored the ASRS-Thai of 28 participants, all data scores were collapsed using the most frequently rated score or a majority rating of each item. The scores of three raters who re-scored the ASRS-Thai were used only for the initial scoring. If the raters did not rate the same score or had two frequently rated values, the median score would be used (the average score featuring a decimal would not be applicable for a cut-off value). All selected scores for the 13 items were compiled into each participant's total score to calculate the cut-off score. The maximum value of the Youden index (Sensitivity+Specificity-1) was used to determine the most appropriate cut-off value.[28] The receiver operating characteristic (ROC) curve was plotted using SPSS version 26 (IBM Corp, Armonk, NY, USA) based on the sensitivity versus 1 - specificity of ASRS-Thai. The area under the ROC curve (AUC) indicates the diagnostic accuracy of the test. An AUC value lower than 0.7 indicates low accuracy, values of 0.7 to 0.9 indicate moderate accuracy, and value more than 0.9 indicate high accuracy.[29]

The reliability of ASRS-Thai was assessed by analyzing the results obtained by independent scoring of ASRS-Thai by multiple raters and measuring the inter-rater and intra-rater reliability. To assess inter-rater reliability, five raters with at least 5 years of experience watched the video recordings of all the participants independently and scored the ASRS-Thai without viewing the scoring results obtained by others. To assess intra-rater reliability, three raters rescored ASRS-Thai independently after the first scoring (Rater#2 and Rater#3 rescored after 14 days; Rater#1 rescored 20 months after the first scoring). The percentage of the sample re-measured to assess intra-rater reliability was 100% (28 videos of 28 participants).

Reliability was computed by using ICCs and IBM SPSS 26, based on a two-way mixed-effects model with absolute agreement type. Values less than 0.5 indicated poor reliability; values between 0.5 and 0.75 indicated moderate reliability; values between 0.75 and 0.9 indicated good reliability, and values greater than 0.90 indicated excellent reliability.[30]

Results

The psychometric properties of ASRS-Thai were assessed in all 28 participants aged 26-84 years with neurological speech or language disorders from cerebrovascular accidents or acquired brain injuries. Demographic information of the participants is provided in Table 2.

Concurrent validity of ASRS-Thai total score was estimated by comparing ASRS-Thai average total scores of all raters with the average score of all raters for each part of ATTA by using Pearson correlations. These data are provided in Table 4.

Table 4 Pearson correlations between the Apraxia of Speech Rating Scale Thai version (ASRS-Thai) and Apraxia Test for Thai Adults (ATTA).

	ATTA					
	MPT	AMR	SMR	Repetition	Automatic	Spontaneous
ASRS-Thai total scores	-0.089	-0.323	-0.575**	-0.900**	-0.711**	-0.775**

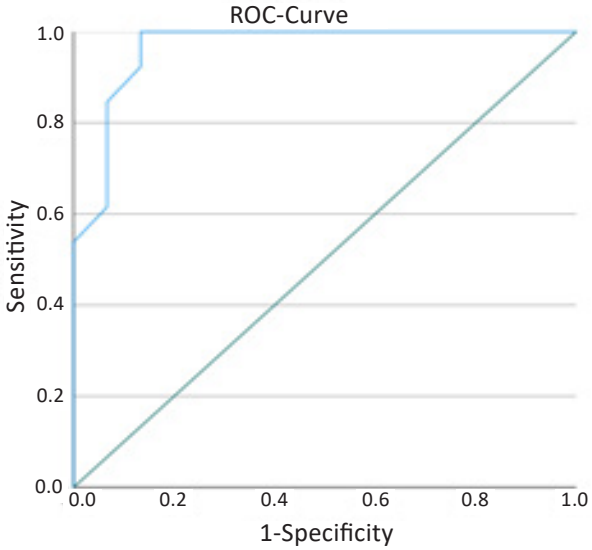
*** Correlation is significant at the 0.01 level (two-tailed).*

The optimal cut-off value for ASRS-Thai according to Youden's index was 16. The sensitivity and specificity of the ASRS-Thai using a cut-off value of 16 were 100% and 86.7%, respectively. In contrast, a cut-off score of 32 yielded a specificity of 100% with a sensitivity of 53.8%. The AUC was 0.964, indicating high diagnostic accuracy (Table 5).

Table 5 Cut-off scores, sensitivities, specificities, crosstabulation between ASRS-Thai and the reference standard, and receiver operating characteristic (ROC) curve.

Cut-off	Sensitivity	Specificity	Youden (Se+Sp-1)
1	100.0%	0.0%	0.000
5	100.0%	6.7%	0.670
6	100.0%	13.3%	0.133
7	100.0%	20.0%	0.200
9	100.0%	26.7%	0.267
10	100.0%	33.3%	0.333
11	100.0%	53.3%	0.533
12	100.0%	60.0%	0.600
13	100.0%	73.3%	0.733
14	100.0%	80.0%	0.800
16	100.0%	86.7%	0.867
19	92.3%	86.7%	0.790
20	84.6%	93.3%	0.779
27	76.9%	93.3%	0.702
31	69.2%	93.3%	0.625
32	53.8%	100.0%	0.538
33	38.5%	100.0%	0.385
48	23.1%	100.0%	0.231
52	15.4%	100.0%	0.154

Crosstabulation		Reference standard		Total
		Yes	No	
ASRS-Thai	Yes	13 (100%)	2 (13.3%)	15
	No	0 (0%)	13 (86.7%)	13
Total		13	15	28



Area under curve (95% CI) = 0.964 (0.901, 1.000)

Reliability was computed by using ICC values. The intra-rater ICCs were 0.96, 0.968, and 0.976, and the inter-rater ICC was 0.927 for the total score (Table 6).

Table 6 Intra-raters and inter-rater intraclass correlations (ICC).

ASRS-Thai (brief description)	Intra-rater Rater#1			Intra-rater Rater#2			Intra-rater Rater#3			Inter-rater Rater 1-5		
	ICC	95% CI		ICC	95% CI		ICC	95% CI		ICC	95% CI	
		Lower	Upper		Lower	Upper		Lower	Upper		Lower	Upper
Phonetic Features												
Item 1 Sound distortions	**0.884**	0.748	0.946	**0.742**	0.44	0.881	**0.663**	0.196	0.852	**0.858**	0.749	0.927
Item 2 Distorted sound substitution	**0.876**	0.732	0.942	**0.799**	0.562	0.907	**0.74**	0.315	0.89	**0.8**	0.633	0.9

Table 6 Intra-raters and inter-rater intraclass correlations (ICC). (continues)

ASRS-Thai (brief description)	Intra-rater Rater#1			Intra-rater Rater#2			Intra-rater Rater#3			Inter-rater Rater 1-5		
	ICC	95% CI		ICC	95% CI		ICC	95% CI		ICC	95% CI	
		Lower	Upper		Lower	Upper		Lower	Upper		Lower	Upper
Item 3 Distorted sound additions	**0.723**	0.402	0.872	**0.788**	0.548	0.901	**0.832**	0.634	0.922	**0.718**	0.518	0.853
Item 4 Increased distortions with increased length or complexity	**0.765**	0.489	0.892	**0.875**	0.731	0.942	**0.746**	0.426	0.885	**0.917**	0.857	0.957
Prosodic Features												
Item 5 Syllable segmentation within words	**0.941**	0.874	0.973	**0.82**	0.609	0.917	**0.937**	0.864	0.971	**0.774**	0.593	0.885
Item 6 Syllable segmentation across words in phrases/sentences	**0.862**	0.7	0.936	**0.832**	0.634	0.922	**0.953**	0.898	0.979	**0.742**	0.543	0.868
Item 7 Slow overall speech rate	**0.866**	0.71	0.938	**0.973**	0.941	0.987	**0.855**	0.688	0.933	**0.869**	0.775	0.932
Item 8 Lengthen segments independent of overall speaking rate	**0.782**	0.533	0.898	**0.75**	0.468	0.883	**0.903**	0.792	0.955	**0.638**	0.385	0.809
Other												
Item 9 Groping	**0.926**	0.808	0.969	**0.896**	0.762	0.953	**0.979**	0.956	0.99	**0.875**	0.777	0.936
Item 10 False starts/restarts	**0.82**	0.606	0.917	**0.936**	0.861	0.97	**0.969**	0.933	0.985	**0.858**	0.753	0.926
Item 11 Off-target speech AMRs	**0.826**	0.616	0.92	**0.868**	0.716	0.939	**0.889**	0.759	0.949	**0.869**	0.769	0.933
Item 12 Slow/segmented/distorted SMRs	**0.836**	0.644	0.924	**0.906**	0.799	0.956	**0.877**	0.736	0.943	**0.854**	0.745	0.924
Item 13 Reduced words/AMRs per breath group	**0.912**	0.811	0.959	**0.99**	0.978	0.995	**0.782**	0.526	0.899	**0.794**	0.616	0.897
Total score	**0.96**	0.914	0.982	**0.968**	0.932	0.985	**0.976**	0.945	0.989	**0.927**	0.867	0.963
Diagnosis	**0.884**	0.749	0.946	**0.964**	0.923	0.983	**0.926**	0.84	0.965	**0.901**	0.829	0.949

Discussion

The current translation is based on the developers' unpublished update of ASRS 3.3.[21] It can be assumed that the newest version of ASRS-English, the ASRS-3.3, inherits the high validity of the previous version. However, the validity of ASRS-English version 1.0 was evaluated in a group of adults with neurodegenerative and language disorders (progressive aphasia and/or progressive apraxia of speech). In contrast, ASRS-Thai was studied in adults with neurological speech or language disorders resulting from cerebrovascular accidents and acquired brain injuries in conjunction with ATTA, another AOS test available in Thai. Thus, the translation and the differences in the study population, including the types of diseases, ethnicities, and language-related contexts, may affect the validity. ASRS-Thai underwent systematic forward-translation and back-translation processes with culturally relevant alterations. The alterations included the addition of the evaluation method, rearrangement of the items' sequence, adoption of simpler words to improve understanding, maximization of the clarity of wordings, familiarization of word usage for the target users, and creation of appropriate Thai examples. The back translations were sent to the original developer and expert SLPs to verify content validity. The results indicated that the ASRS-Thai is consistent with the original ASRS-3.3 and evaluates the same aspects.

The results of correlational analyses demonstrated moderate-to-strong negative correlations between the

three ATTA subtest scores and the total ASRS-Thai scores. ASRS-Thai total score increased, reflecting an increased prevalence of the symptoms observed. However, in the three subtests of ATTA, the score increased, reflecting the absence of a struggle or articulatory error. A strong correlation was observed between the repetition subtest and ASRS-Thai: -0.900, with significance at 0.01. Because both ATTA subtests and ASRS-Thai focus on speech performance, moderate correlations were observed between the automatic speech and spontaneous speech subtests and ASRS-Thai: -0.711 and -0.775, respectively (p=0.01 for both). A poor correlation of -0.089 was observed between MPT and ASRS-Thai. The MPT is used to evaluate breath function and increased or decreased MPT does not reflect the symptoms of AOS but instead the symptoms of dysarthria. Individuals with dysarthria may have short MPT because of reduced breath support. Individuals with AOS may not have short MPT but do have short phrases even though they show no evidence of breathing difficulty.[31] A poor correlation of -0.323 was also observed between AMR and the ASRS-Thai. The AMR subtest in ATTA counts the frequency of syllable repetition without considering articulation errors. ASRS-Thai includes two AMR-associated items: off-target speech AMRs as item 11 and reduced words/AMRs per breath group as item 13, for which the scoring criteria of articulation errors were included. Fair correlations were observed between SMR and ASRS-Thai: -0.575, with significance at 0.01. Increased or decreased frequency of sequenced syllable repetition may be prompt suspicion of AOS. Individuals with AOS are unable or show difficulty in maintaining the correct sequence at a normal rate, as evidenced by, for example, item 12 (Slow/segmented/distorted SMRs). Individuals with dysarthria may produce a correct sequence at a slow rate or an incorrect sequence due to misarticulation.[8] Considering these findings, ASRS-Thai is comparable with the currently used test, ATTA. ASRS-Thai is also superior to the AMR subtest and the MPT subtest of ATTA in scoring criteria specific to AOS characteristics.

The results of the sensitivity and specificity analyses suggest that the most appropriate cut-off value of the ASRS-Thai according to Youden's index is 16 (100% sensitivity and 86.7% specificity). The scores used in the cut-off analysis were obtained from the total score of the 28 participants, which combined scores from the most frequent rated score of each item (majority rating) - not the consensus rating. Although the consensus rating was more accurate than the individual ratings, senior raters or persuasive raters might affect junior or passive raters. The consensus rating did not differ significantly from the majority rating.[32] As the inter-rater reliability in this study based on the agreement of scoring ASRS-Thai among five raters, yielded moderate-to-excellent inter-rater reliability for all 13 items, basing the score on the majority rating was appropriate.

A cut-off score of 16 on the ASRS-Thai is higher than the cut-off value of 8 in the original ASRS 1.0. The deviation in cut-off values may be attributed to many factors, including the number of items, scoring criteria, and population. The number of items and scoring criteria of ASRS 1.0 were revised to yield the ASRS 3.3, which was translated and adapted into the ASRS-Thai in this study. The original developers reported that ASRS is best suited to describe the nature and severity of AOS when present. It is not yet validated as a tool for discriminating AOS from dysarthria or aphasia, and a cut-off score for the ASRS 3.3 has yet to be established. The developers have had some success in using it to detect AOS in patients with degenerative conditions with or without aphasia.[21] The participants in this study were adults with neurological speech or language disorders, mostly from cerebrovascular accidents (82%), without pure AOS (Table 2). The AOS of all 13 participants co-occurred with aphasia. Nonetheless, the clinicians should employ discretion when using this cut-off in rendering a diagnosis of AOS and include diagnostic criteria and related variables that may not be reflected in the rating scale.

The reliability was excellent. The intra-rater ICC for Rater #1 was 0.96 for the total score and ranged from 0.723 to 0.941 for individual items. The intra-rater ICC for Rater #2 was 0.968 for the total score and ranged from 0.742 to 0.99 for individual items. The intra-rater ICC for Rater #3 was 0.976 for the total score and ranged from 0.663 to 0.979 for individual items. The inter-rater ICC for Raters 1-5 was 0.927 for the total ASRS score and ranged from 0.638 to 0.917 for individual items.

Comparable with the ASRS 1.0 and the ASRS 3.0, the inter-rater reliability for the total score of the ASRS-Thai was excellent. Although the inter-rater ICC for individual items of ASRS 3.0 ranged from 0.034 to 0.789, that of the ASRS-Thai ranged from 0.638 to 0.917. The highest levels of agreement for both versions differ. The feature of slow overall speech rate (item 7, ICC=0.789) showed the highest ICC in ASRS 3.0, but the feature of increased distortions with increased length or complexity (item 4, ICC=0.917) was the highest in the ASRS-Thai.

However, some features showed similar ICC values for ASRS 3.0 and ASRS-Thai, such as syllable segmentation within words (ICC=0.737 for ASRS 3.0 and ICC=0.774 for ASRS-Thai), syllable segmentation across words (ICC=0.646 for ASRS 3.0 and ICC=0.742 for ASRS-Thai), and slow overall speech rate (ICC=0.789 for ASRS 3.0 and ICC=0.869 for ASRS-Thai). Features that showed poor rating agreement for both ASRS 3.0 and ASRS-Thai were lengthened vowel and/or consonant segments independent of overall speaking rate (ICC=0.355 for ASRS 3.0 and ICC=0.638 for ASRS-Thai) and distorted sound additions (ICC=0.368 for ASRS 3.0 and ICC=0.718 for ASRS-Thai).

Additional explanations of item 3 (distorted sound additions) may improve agreement among the raters. Furthermore, differentiating the guidelines of prosodic features (items 5-8), modification of scoring, and training to identify each feature's characteristics through the use of video examples could also help achieve rater score agreement, as suggested by Strand *et al*. in ASRS 1.0.[16]

Although the ASRS-Thai was carefully translated from the most recent version of the ASRS by using the backward-translation approach and included the original developer in the translation process to improve the translation accuracy, recommendations for the use of the ASRS-Thai will include further revisions and improvements, the use of an instruction manual, and identification of severity judgment indicators.

Furthermore, the ASRS-Thai is only available for stroke patients and needs to be used in conjunction with the WAB-Thai. The AOS group in this study was small and featured no cases of pure AOS; all AOS participants also presented with aphasia due to cerebrovascular accidents. Additional data collection in future studies will require testing in a larger sample size with a wide range of severities, including pure AOS if possible.

Conclusion

In conclusion, the ASRS-Thai is a reliable and valid tool to describe the characteristics of speech features and rate the severity of AOS in clinical use. These features are anticipated to benefit Thai clinicians since existing AOS-related data are lacking in contexts specific to Thai language.

Ethical approval

This study was approved by the Research Ethics Committee of Faculty of Associated Medical Sciences, Chiang Mai University (Approval ID: AMSEC-61EX-038); the Research Ethics Committee of Faculty of Medicine, Chiang Mai University (Approval ID: NONE-2561-05641); and the Research Ethics Committee of Chiang Mai Neurological Hospital (Approval ID: EC 004-62).

Conflict of interest

The authors have declared that no competing interests existed at the time of publication.

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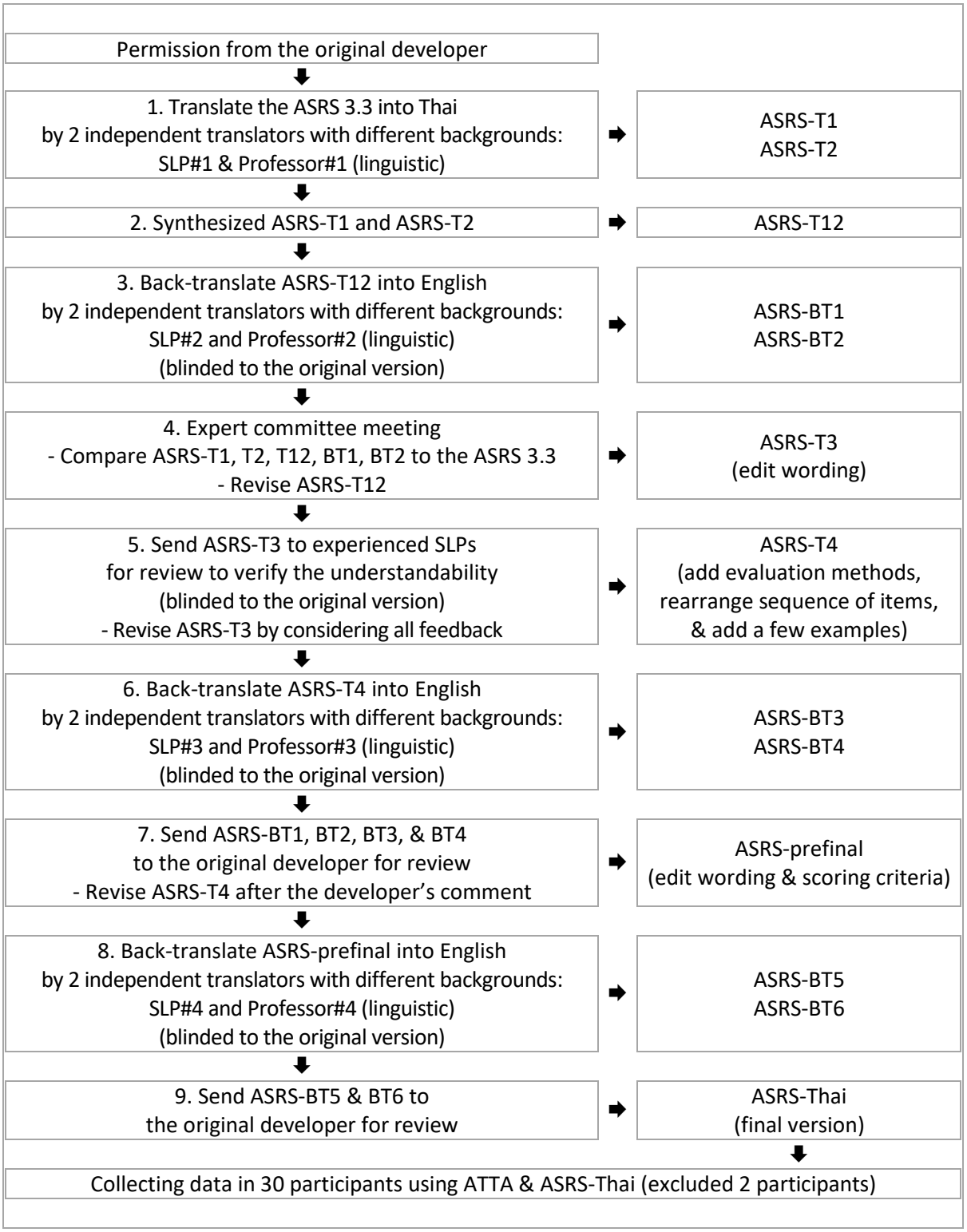
Appendix 1. Flow diagram of the study procedure



Appendix 2. The Apraxia of Speech Rating Scale Thai Version

ชื่อผู้ป่วย:_____เลขประจำตัวโรงพยาบาล:_____วันที่:_____ ผู้ประเมิน:_____

มาตรวัดภาวะเสียการรู้ปฏิบัติด้านการพูด

วิธีการประเมิน: 1) พิจารณาลักษณะการพูดจากการประเมิน Western Aphasia Battery ด้านการพูดเอง การพูดตาม และการเรียกชื่อ
2) พิจารณาอัตราการออกเสียงซ้ำ ๆ อัตราการออกเสียงตามลำดับ และระยะเวลาการออกเสียงสระที่นานที่สุด เฉพาะข้อ 11-13

เกณฑ์การให้คะแนนสำหรับข้อ 1-10

0 = ไม่สังเกตเห็น หรือ เกิดขึ้นไม่เกิน 1 ครั้ง
1 = สังเกตเห็นไม่บ่อย หรือ เกิดขึ้นมากกว่า 1 ครั้ง แต่น้อยกว่าร้อยละ 20 ของถ้อยความทั้งหมด
2 = สังเกตเห็นได้บ่อยครั้ง หรือ ร้อยละ 20-50 ของถ้อยความทั้งหมด โดย*ให้คะแนนไม่เกิน 2 คะแนน หากปรากฏเฉพาะในการพูดตาม*
3 = สังเกตเห็นเกือบตลอดเวลา แต่ไม่รุนแรงมากพอที่จะกระทบต่อการฟังเข้าใจคำพูดโดยรวม
4 = สังเกตเห็นเกือบตลอดเวลา หรือสังเกตเห็นได้ตลอดเวลา และรุนแรงมากพอที่จะกระทบต่อการฟังเข้าใจคำพูด

สัทลักษณ์		
1.	มีเสียงผิดเพี้ยนที่ยังฟังออกว่าเป็นเสียงเป้าหมาย เช่น “สบู่” โดยเสียง /ส/ เพี้ยน	
2.	มีการใช้เสียงอื่นแทนที่ผิดเพี้ยน เช่น “ตบู่” (สบู่) โดยเสียง /ต/ เพี้ยน	
3.	มีการเติมเสียงที่ผิดเพี้ยน เช่น “ขก้าว” (ข้าว) โดยเสียง /ก/ เพี้ยน (รวมทั้งการแทรกเสียงสระที่ไม่เน้นเสียง เช่น กะวาง (กวาง))	
4.	เมื่อพูดถ้อยความที่ยาวขึ้นหรือเคลื่อนไหวฐานกรณ์ซับซ้อนมากขึ้น จะมีเสียงผิดเพี้ยนหรือการใช้เสียงอื่นแทนที่ผิดเพี้ยนเพิ่มขึ้น	
ลักษณะสัทสัมพันธ์		
5.	มีการหยุดระหว่างพยางค์ในคำ (มีช่วงเงียบสั้น ๆ และ/หรือ มีการเน้นเสียงทุกพยางค์เท่ากันอย่างไม่เหมาะสม) เช่น จะ-ตุ-จักร	
6.	มีการหยุดระหว่างพยางค์ในวลีหรือประโยค (มีช่องว่างระหว่างคำ และ/หรือ มีการเน้นเสียงทุกคำเท่ากันอย่างไม่เหมาะสม)	
7.	อัตราการพูดโดยรวมช้า (ไม่รวมการหยุดเพื่อนึกคำ และ/หรือ การเรียบเรียงคำพูด)	
8.	มีการลากเสียงสระและ/หรือพยัญชนะ โดยไม่ขึ้นกับอัตราการพูดช้าโดยรวม	
อื่น ๆ		
9.	มีความพยายามในการจัดรูปปากแบบไม่มีเสียง	
10.	มีการเริ่มออกเสียงผิด หรือมีการเริ่มออกเสียงใหม่อีกครั้ง รวมถึงมีการพูดซ้ำเสียง ยกเว้น การแทรกคำตอนเริ่มประโยค (เช่น อืม คือว่า) และการใช้คำอื่นที่ใกล้เคียงมาพูดแทน (เช่น เสี้...กางเกง ช้อ..ส้อม)	
11.	**ให้คะแนนอัตราการออกเสียงซ้ำ ๆ** (เช่น ออกเสียง เพอะ เพอะ เพอะ ซ้ำเร็ว ๆ) ตามความรุนแรงของการออกเสียงผิดเพี้ยน 0 = อัตราการออกเสียงซ้ำ ๆ ปกติ 1 = ออกเสียงผิดเพี้ยนเล็กน้อย (ใน ฐาน กรณ์ และ/หรือ โฆษะ/อโฆษะ ที่ฟังออกว่าเป็นเสียงเป้าหมายได้ง่าย) และเกิดน้อยครั้ง 2 = ออกเสียงผิดเพี้ยนเล็กน้อย (ใน ฐาน กรณ์ และ/หรือ โฆษะ/อโฆษะ ที่ฟังออกว่าเป็นเสียงเป้าหมายได้ง่าย) แต่เกิดบ่อยครั้ง 3 = ออกเสียงผิดเพี้ยนปานกลาง (ผิดจากเป้าหมายมากกว่า 1 ด้านใน ฐาน กรณ์ โฆษะ/อโฆษะ) 4 = ออกเสียงผิดเพี้ยนรุนแรง (ไม่สามารถฟังเป็นเสียงเป้าหมายได้)	
12.	**ให้คะแนนอัตราการออกเสียงตามลำดับ** (เช่น ออกเสียง เพอะ เทอะ เคอะ ซ้ำเร็ว ๆ) เทียบกับอัตราการออกเสียงซ้ำ ๆ โดยให้คะแนนครั้งที่ทำได้ดีที่สุด ตามความรุนแรงของการหยุดระหว่างคำ และ/หรือ การออกเสียงผิดเพี้ยน 0 = อัตราการออกเสียงตามลำดับปกติ 1 = ช้า 2 = มีการหยุดระหว่างคำเล็กน้อย และ/หรือ ออกเสียงผิดเพี้ยนเล็กน้อย (ฟังออกว่าเป็นเสียงเป้าหมายได้ง่าย) 3 = มีการหยุดระหว่างคำปานกลาง และ/หรือ ออกเสียงผิดเพี้ยนปานกลาง 4 = มีการหยุดระหว่างคำรุนแรง และ/หรือ ออกเสียงผิดเพี้ยนรุนแรง (ไม่สามารถฟังเป็นเสียงเป้าหมายได้)	
13.	ประเมินข้อใดข้อหนึ่ง หรือ ทั้ง 2 ข้อต่อไปนี้: 1) มีจำนวนคำพูดใน 1 ช่วงลมหายใจลดลง ซึ่งสัมพันธ์กับระยะเวลาการออกเสียงสระที่นานที่สุด 2) โดยให้คะแนนจากจำนวนพยางค์ใน 1 ช่วงลมหายใจโดยเฉลี่ย 0 = มากกว่า 7 พยางค์ 1= 6-7 พยางค์ 2 = 4-5 พยางค์ 3 = 3-4 พยางค์ 4 = 2 พยางค์หรือน้อยกว่า 3) มีอัตราการออกเสียงซ้ำ ๆ ใน 1 ช่วงลมหายใจลดลง โดยไม่มีความสามารถในการหายใจที่ลดลง 4) ให้คะแนนจากจำนวนครั้งของการพูดซ้ำใน 1 ช่วงลมหายใจโดยเฉลี่ย (เช่น นับ “เพอะ” = 1 ครั้ง) 0 = มากกว่า 7 ครั้ง 1= 6-7 ครั้ง 2 = 4-5 ครั้ง 3 = 3-4 ครั้ง 4 = 2 ครั้งหรือน้อยกว่า	
	คะแนนรวมทั้งหมด	