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Development and preliminary investigations of a language-specific trisyllabic word set for assessing speech recognition threshold in school-aged children

Nikolaos Trimmis [1,2]*, Fotini Feida [1], Angelos Papadopoulos [3] and Panagiotis Plotas [1,2]

[1] Department of Speech & Language Therapy, University of Patras, 26504 Rion, Greece.
[2] Primary Healthcare Laboratory, School of Health Rehabilitation Sciences, University of Patras, 26504 Rion, Greece.
[3] Department of Speech and Language Therapy, School of Health Sciences, University of Ioannina, 45500 Ioannina, Greece.
***** Correspondences: nicktrimmis@upatras.gr; Tel.: +30-2610962809

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Abstract: The purpose of this study was to develop a set of three-syllable words suitable for assessing the Speech Recognition Threshold (SRT) in school-aged children (6 to 12 years old), as there is a gap in the Greek population. Word selection was based on four key criteria: syllabic structure (trisyllabics), age-appropriate vocabulary familiarity, phonemic differentiation, and homogeneity in relation to audibility. Words were recorded and processed in accordance with the International Organization for Standardization (ISO) 8253-3:2022 for speech audiometry. A total of 20 children participated in the word homogeneity evaluation. For each word, the presentation level required to achieve 50% correct recognition was determined. Next, recognition rates were measured across a range of intensities to determine recognition from 20% to 80%, during which the steepest rise in the Performance-Intensity (PI) function occurred. Findings indicated that all words that are homogeneous in terms of recognition rate are not homogeneous in terms of recognition threshold, and vice versa. Therefore, to optimise homogeneity, only words falling within a range of +1 Standard Deviation (SD) in both recognition rate and recognition threshold were selected. Results are consistent with previous studies in other languages that developed trisyllabic material for the SRT test. In conclusion, a list of 40 trisyllabic words was developed that will increase the reliability of audiological pediatric testing and can serve as a foundation for further research and clinical application across Greek-speaking populations.

Keywords: Language development; Speech audiometry; Speech recognition threshold; Greek; Children

1.0 INTRODUCTION

A clinical speech audiometric evaluation usually includes two measures. The first is the Speech Recognition Threshold (SRT), which identifies the threshold for speech material. The second is the Word Recognition Score (WRS), achieved at suprathreshold intensities (American Speech-Language-Hearing Association [ASHA], 1979, 1988; Martin, 1997). Different speech materials are used to achieve each of these measurements with maximum accuracy. The SRT is the lowest level of hearing at which speech is barely understood (ASHA, 1979, 1988; Martin, 1997). Most audiologists agree that speech should be so soft that it is recognised at a rate of almost 50% with repetition of verbal stimuli. For various reasons, the speech recognition threshold has become more popular with audiologists and is thus the preferred speech recognition threshold test (Martin, 1997).

The speech detection threshold (SDT) is the minimum hearing level at which an individual can discern the presence of speech material 50% of the time (ASHA, 1988). There is a high correlation between SRT and pure tone average (PTA); PTA is the average of a person's pure-tone thresholds at the frequencies of 500, 1000, and 2000 Hz (Martin, 1997). The difference between PTA and SRT can help clinicians identify potential speech perception problems (ASHA, 1979, 1988; Martin, 1997).

Speech recognition thresholds are measured with a variety of speech materials, using both continuous speech, as in the SDT measurement, and single words such as monosyllables, disyllables, and polysyllables, due to language restrictions (Martin, 1997). However, monosyllabic word lists often yield shallower Performance Intensity (PI) functions and greater variability than disyllabic spondaic words (Martin, 1997).

Therefore, the linguistic stimulus most recommended and used for testing speech recognition is spondaic words (ASHA, 1979, 1988; Martin, 1997; Wilson & Margolis, 1983). A spondaic word is a two-syllable word with equal intonation on both syllables. **Table 1** lists the spondaic words used for the pediatric population whose native language is English (ASHA, 1988; Frank, 1980). If the testing materials used are not spondaic words, the clinician should report the testing material used (ASHA, 1979, 1988).

Both syllables of the spondaic word must peak at zero on the volume unit (VU) meter of the audiometer, whether presented through a microphone, CD or any other recorded material (International Organization for Standardization [ISO], 2022). Many audiologists, through practice, have achieved an equivalent peak on the audiometer's VU meter using controlled live voice (CLV). Of course, CLV causes a great deal of variability compared to recorded material due to inter-talker and intra-talker variability (ASHA, 1988; Martin, 1997; Wilson & Margolis, 1983).

Table 1. Examples of spondaic words used to measure SRT in children with a native language of English (ASHA, 1988; Frank, 1980).

Airplane	Cupcake	Ice-cream	Seesaw
Baseball	Fire-truck	Mailman	Shoelace
Bathtub	Flashlight	Popcorn	Snowman
Bluebird	Football	Reindeer	Toothbrush
Cowboy	Hotdog	Sailboat	Toothpaste

When a recorded word list is used, it is common to have a calibration tone recorded in a specific frequency band. The calibration signal, which typically lasts 60 seconds, is presented as long as needed to allow the audiometer's VU meter to adjust to zero. Take care when selecting the recording level of the calibration signal and its relationship to the recorded material in the lists. In some recorded lists with spondaic words, an introductory phrase precedes each word, for example, "repeat the word........" followed by the stimulus word. Although some people prefer the use of an introductory phrase, many do not use it because no real advantage of using it has been demonstrated (Martin & Dowdy, 1986; Martin, 1997).

In international contexts and across languages, SRT test development should be population- and language-specific. This specificity matters because phonological structure and lexical familiarity may affect psychometric properties. As the literature has shown in the equivalent lists in several languages, such as Mandarin (Slade, 2006), Cantonese (Kim, 2007), Spanish (Keller, 2009), Fante (Honu-Mensah, 2015), and Cebuano (Graham, 2016), there is a specific need for linguistic stimuli appropriate for these languages rather than a translation.

In Modern Greek, validated speech audiometry materials for the SRT test are lacking, particularly for children. This is because children have different levels of lexical familiarity than adults. Moreover, such an instrument with age-appropriate stimuli would help clinicians identify hearing loss more accurately. Furthermore, although validated disyllabic lists have been developed for speech audiometry, particularly for WRS testing, no materials are available for SRT assessment (Trimmis et al., 2006, 2008, 2023).

Therefore, developing materials for children and adults seems necessary. SRT testing is vital for pediatric audiologists and clinicians. Most importantly, it validates pure-tone thresholds and, in some cases, enables children with developmental disorders to respond reliably to pure tones. In the Greek context, the audiologists or related clinicians lack a standardised test.

To fill this gap, the present study aimed to develop and validate a homogeneous set of three-syllable words for SRT testing in Greek-speaking school-aged children (6 to 12 years). In addition, the absence of two-syllable compound words further supports the use of three-syllable words as suitable because it creates a balance between the child's vocabulary familiarity and minimal language repetition, as supported by the literature (Burke & Coady, 2014; Dispaldro et al., 2009, 2013).

Specifically, this balance is essential, and studies have shown that children's familiarity with longer, multisyllabic words can improve their ability to process and reproduce these structures. Finally, this could affect children's language proficiency (Burke & Coady, 2014; Dispaldro et al., 2009, 2013). For example, Dispaldro et al. (2013) concluded that when children with specific language impairment are more familiar with longer words, they complete nonword repetition tasks more effectively.

2.0 MATERIALS AND METHODS

Examination of classic and modern speech audiometry test development led to the adaptation of the following four criteria for generating an SRT word list (Hirsh et al., 1952; Hudgins et al., 1947; Nissen et al., 2007; Trimmis et al., 2006, 2008; Wilson & Margolis, 1983). The criteria used to develop words for school-aged children (6 to 12 years old) were: (1) three-syllable words, (2) familiarity in relation to vocabulary, (3) phonetic dissimilarity so that one word cannot be easily confused with another word, and (4) homogeneity with respect to audibility, i.e., the thresholds for different words are acquired at similar intensities

2.1 Trisyllabic words

The material used in different languages for the SRT test includes phonemes, syllables, words (monosyllabic, disyllabic, and polysyllabic), phrases, and sentences. In English, we use spondaic words (**Table 1**). We notice that these spondaic words are both two-syllable and compound. Each word consists of two subjects (airplane = Air + plane, Baseball = Base + ball). No part of the spondaic word is acoustically weaker, since both syllables are equally stressed. Equal stress improves reliability. This provides more consistent threshold measurements by making words easier to recognise at lower intensity levels.

With two equally stressed syllables, recognition requires hearing both parts of the word clearly. This reduces the chance that a listener guesses correctly based on partial hearing (compared to single-syllable words). This acoustic balance makes spondaic words ideal for establishing the SRT. Spondaic words are also familiar, common words in the listener's language.

Modern Greek has no spondaic words. The majority of content words are two-syllable and three-syllable words. Also, compound words are formed in two ways: (1) A word takes at its beginning an inseparable particle, e.g., avrastos (unboiled): a = not + vrastos = boiled. (2) Two or more words are joined into one, e.g., Democracy: demos = people + -cracy = rule.

Therefore, in Modern Greek, there are no two-syllable words that are also compound words. The shorter-syllable compound words are trisyllabic, but they are also formed with inseparable particles. However, too few of these words exist to create a complete list for speech audiometry. Moreover, most of the pediatric population is not familiar with these words. Compound words, consisting of two words, are at least four syllables (chionobala = snowball, meronichto = day and night, protathlitis = champion), which results in these words having high redundancy. Phonemes are the least material type, and sentences are the most redundant. Therefore, the use of compound words requires at least four-syllable words in Modern Greek, increasing the linguistic redundancy of the test. A pilot study revealed that PI-Functions of trisyllabic words are similar to the steepness of slopes for spondaic words in English.

Greek words can only be stressed on one syllable. Therefore, two-syllable words cannot be equally stressed. The same is true for three-syllable words with the stress on the first or the third syllable. However, three-syllable words with the stress on the second syllable present better acoustic balance. This creates symmetry, with one unstressed syllable before and one after, thus enhancing perceptual clarity and making such words acoustically stable for SRT testing. In addition, words with the stress on the middle syllable are the most common across Greek trisyllables. Moreover, we observed that with trisyllabic words stressed on the second syllable, all trisyllabics could peak at 0 on the audiometer's VU meter without compromising the naturalness of production. This was not achievable with bisyllabic words or with trisyllables carrying stress on the first or third syllable.

For these reasons, simple three-syllable words, with the least amount of phonemes in order to control redundancy, and stress on the suffix (middle syllable) were chosen for better homogeneity of audibility as the material of the SRT. They are highly familiar, acoustically balanced, and similarly stressed, allowing for accurate measurement of the softest level at which speech can be recognised.

2.2 Familiarity

The stimulus words used in speech audiometry should be included in the vocabulary of the children being tested. To meet the criterion of familiarity, 464 three-syllable words with accentuation in the middle syllable were initially selected from the two volumes of the 'Language' textbook for the first grade of primary school. Then, to reduce redundancy, words containing phonemic clusters were removed, leaving 242. Words containing a consonant digraph were not removed. A consonant digraph is a two-letter consonant combination representing a single consonant phoneme, such as the letters «μπ» representing the consonant phoneme /b/, as in the word /buˈkali/.

A three-choice questionnaire (very familiar, moderately familiar, unknown) was then administered to 10 primary school teachers (10 female, Mean (M) = 41.84 years old, Standard Deviation (SD) = 6.83) with at least 5 years of teaching experience in Grade 1, and 10 mothers (M = 33.82 years old, SD = 4.65) who had a child/children with normal hearing in Grade 1.

To further fulfil the criterion of word familiarity, a two-choice (known, unknown) questionnaire was administered to 300 children aged 6 to 12 years (50 children per class - 25 boys, 25 girls; M=8.98 years, SD=1.74), including only the three-syllable words selected as very familiar by the teachers and parents. Only the words selected as "known" by the 300 children were used to develop the final lists.

2.3 Phonetic dissimilarity

It is important not to use phonetically similar words because recognition of the target word is more difficult, especially for hearing-impaired persons whose ability to recognise phonemes is diminished (Bell & Wilson, 2001). Words must differ in at least two phonemes so that they are not acoustically similar to each other.

2.4 Homogeneity

The words used to measure SRT should be relatively homogeneous and exhibit steep PI functions. If words are homogeneous, it limits the pool of suitable words for SRT testing (Hudgins et al., 1947). To reduce testing time and to improve reliability, the words with the steepest slopes are used (Wilson & Carter, 2001). In English, spondaic words are preferred in the SRT test because of their homogeneity in acoustic properties.

Egan (1948) reported that, when different types of words were presented to experienced listeners, spondees had the highest homogeneity of acousticity (Egan, 1948). This matters because it enables accurate SRT measurements within a narrow intensity range. If words are homogeneous, then they should be recognised at the same level of presentation. Therefore, the words are interchangeable (Carhart, 1951). Homogeneity of words, in terms of intelligibility, is critical because it increases the accuracy of SRT measurement. It also allows for the use of fewer words, resulting in reduced testing time and test-taker fatigue (Brandy, 1966; Carhart, 1951).

2.5 Speaker

Initial recordings were made using three female professional speakers of Modern Greek. All speakers were native speakers of Modern Greek from Athens. Then, 2 raters, one male and one female (speech therapists), assessed each speaker's performance on dialect, voice quality, speech flow, and articulation (**Table 2**). We selected the highest-ranked speaker for the final recordings.

To ensure a fair speaker evaluation that reflects the multidimensional nature of speech performance, we gave equal weight to four parameters: Dialect, Voice Quality, Speech Flow, and Articulation (**Table 2**). These are key speech components and equally important in a standard clinical speech pathology evaluation, contributing to overall intelligibility and communicative competence (Barkmeier-Kraemer & Clark, 2017). This equal weighting of all parameters ensured that no single parameter dominated the assessment.

Table 2. Speaker evaluation form.

Dialect	0	1	2	3	4	5
Voice quality	0	1	2	3	4	5
Speech flow	0	1	2	3	4	5
Articulation	0	1	2	3	4	5
Dialect	0	1	2	3	4	5

2.6 Recording

The CLV presentation, even when monitored via a sound level meter, results in volume variability, both within each list and between different lists (Brandy, 1966; Silman & Silverman, 1991). Also, male and female voices are quite different, causing differences in recognition scores for the same material and listener (Hirsh et al., 1954). These problems are avoided by presenting recorded material rather than CLV for audiometry purposes. The use of recorded material ensures that the material is of equal difficulty, which means reproducible PI-Functions (ASHA, 1988; Carhart, 1951; Martin, 1997).

The words were recorded in a soundproof booth (Industrial Acoustic Company - Model 402-A) meeting American National Standards Institute standard (American National Standards Institute, 2013). We used a condenser microphone (AKG C-1000-S) with wind protection, placed at the optimal distance from the speaker, and editing software (Adobe Audition, Version 3, Adobe Systems Incorporated, San Jose, CA).

Each word was produced several times, with minimal suprasegmental elements (prosodic features), to approximate the spondaic configuration. The judges, one male and one female (speech therapists), assessed each word's repetitions for perceived production quality, and the best production of each word was selected. Each word (sampling frequency 44,100K Hz, single channel, and 16-bit resolution) was saved in a file for further processing.

2.7 Processing

The words were processed according to ISO 8253-3 for speech audiometry to balance their loudness (ISO, 2022). ISO 8253-3 suggests two methods for equalising the level of material in a speech test. The material will be equalised according to either the speech level equalisation method or the equal reference method for the level of the speech recognition test (ISO, 2022; Martin, 1997). The first method requires that all test material have equal sound pressure levels, while the second requires that each test item have an equal recognition threshold.

In this study, we equalised word acoustic stress according to the first method. We processed each word using the Root Mean Square (RMS) equation for signal amplitude, scanned with a 50-ms window. Specifically, each average RMS power value, which represents the average power of the entire selected waveform and is a good measure of overall loudness, was measured and then multiplied by an appropriate dB factor to achieve an equal average RMS power value. This gave each word an equivalent loudness level.

A single tone of 1000 Hz and 60 seconds duration was calibrated to the RMS level of all words and placed at the top of the list. The duration of the tone should be sufficient to allow enough time for the audiometer to adjust, which means that it should have a minimum duration of 60 seconds (Silman & Silverman, 1991). No carrier phrase was used.

2.8 Population

In Greece, primary school includes six grades with children aged 6-12 years. We recruited children from public primary schools in the city of Patras, following personal communication with school directors. We provided schools with all necessary study information, and children were invited to participate voluntarily. Written informed consent was obtained from the parents.

Initially, 26 children volunteered to participate in this study. However, after audiological assessment, three children were excluded because they had at least one air-conduction threshold above the inclusion criterion of ≤15 dBHL. In addition, we excluded another three children to ensure a symmetrical distribution between sexes. Finally, 20 children (10 boys and 10 girls) participated in the assessment of homogeneity of three-syllable words in Greek. Their age ranged from 6.2 to 11.7 years (M = 8.91, SD = 1.76). We selected this broad age range (6–12 years) because it covers the full age span of children attending primary school in Greece, which represents the target population for developing SRT materials.

All 20 children had hearing thresholds ≤15 dBHL in all octaves from 125 to 8000 Hz (**Table 3**) and static auditory conductance between 0.4 and 1.4 mmhos, with a peak pressure between -25 and +30 daPa. In addition, each child had present unilateral Acoustic Reflexes (AR) (≤90 dBHL) at 500, 1000, and 2000 Hz in the tested ear.

Table 3. Hearing scores of pure tones of 20 children.

Frequency	Mean	Minimum	Maximum	SD
125 Hz	8.17	5	15	3.07
250 Hz	6.83	5	15	2.78
500 Hz	5.67	0	10	2.86
1000 Hz	4.50	-5	15	5.31
2000 Hz	4.33	-5	15	4.10
4000 Hz	4.17	-5	10	3.96
8000 Hz	4.00	-5	15	4.43

Pure-tone average (PTA) of 500, 1000 and 2000 Hz = 4.83.

2.9 Material

The three-syllable words, selected as known after assessment of teachers, parents, and finally 300 children, were 206. From these, the verbs were removed, and 120 nouns remained, which were used as the material for the final development of the test for SRT in school-age children, as presented in **Table 4**. Only nouns were chosen for two reasons: firstly, their development and number precede those of verbs in childhood, and secondly, they show much more iconification than verbs (Trimmis et al., 2025). Therefore, they can also be used with individuals who cannot participate orally.

2.10 Procedure

Before the test, the necessary instructions were given. Children were encouraged to repeat each word and to guess when they were unsure. The children were not familiar with the trisyllabic words prior to testing. Before presenting the words, the audiometer was adjusted to 0 volume units on the VU meter using the 1000 Hz calibration tone. Each word was presented at -10 dBHL and increased in 2 dBHL increments, with 5-second silent intervals between words, until the child recognised the word. A 5-second interval separated the presentation of each word.

Subjects repeated words verbally, which were scored as being correct or incorrect. Each stimulus word was presented once at each intensity level. The order of word presentation was randomised for each subject. This randomised word order yields more reliable and valid results (Nissen et al., 2007). All participants were tested unilaterally (right ear) in a sound isolation chamber (IAC - Model 402/A), using a laptop computer to provide the verbal stimuli, connected to an audiometer (Orbiter 922 Version 2), wearing TDH-49 headphones.

2.11 Institutional review board statement

This study was conducted in accordance with the Declaration of Helsinki. Informed consent was attained from every parent/legal guardian of the participating adolescents. All measures for keeping anonymity and protecting personal data were taken, while the researchers followed the rules of Research Ethics and Deontology. Ethical review and approval were not required for the study on human participants in accordance with the local legislation (Law 4957/2022, Article 279, Paragraph 2[b]) and institutional requirements of the University of Patras.

Table 4. The 40 trisyllabic words within +1 SD in terms of both recognition rate and recognition threshold.

Trisyllabic Word (Greek Script)	Phonetic Transcription (IPA)	English Translation
Αλάτι	/aˈlati/	Salt
Βαλίτσα	/vaˈlitsa/	Suitcase
Βελόνα	/veˈlona/	Needle
Γουρούνι	/ɣuˈruni/	Pig
Ελάφι	/eˈlafi/	Deer
Καλάθι	/kaˈlaθi/	Basket
Καμπάνα	/kamˈbana/	Bell
Καντήλι	/kanˈdili/	Oil lamp
Καπέλο	/kaˈpelo/	Hat
Καράβι	/kaˈravi/	Ship
Καρότο	/kaˈroto/	Carrot
Κατσίκα	/kaˈtsika/	Goat
Κεφάλι	/ceˈfali/	Head
Κιθάρα	/ciˈθara/	Guitar
Κορίτσι	/koˈrici/	Girl
Κουλούρι	/kuˈluri/	Bread ring / bagel
Λαμπάδα	/lamˈbaða/	Candle
Λεμόνι	/leˈmoni/	Lemon
Μαχαίρι	/maˈçeri/	Knife
Μπαλόνι	/baˈloni/	Balloon
Μπουκάλι	/buˈkali/	Bottle
Ντομάτα	/doˈmata/	Tomato
Παπούτσι	/paˈpuci/	Shoe
Πατέρας	/paˈteras/	Father
Πιρούνι	/piˈruni/	Fork
Ποντίκι	/ponˈdici/	Mouse
Ποτάμι	/poˈtami/	River
Ποτήρι	/poˈtiri/	Glass
Σαλάτα	/saˈlata/	Salad
Σαπούνι	/saˈpuni/	Soap
Σελίδα	/seˈliða/	Page
Σεντόνι	/seˈdoni/	Sheet
Σημαία	/siˈmea/	Flag
Τσιμέντο	/tsiˈmento/	Cement
Φανάρι	/faˈnari/	Traffic light
Φασόλι	/faˈsoli/	Bean
Φεγγάρι	/feŋˈgari/	Moon
Χειμώνας	/çiˈmonas/	Winter
Χελώνα	/çeˈlona/	Turtle
Χωράφι	/xoˈrafi/	Field

3.0 RESULTS

The results from this survey were used to construct the PI-Function for each of the 120 words. At low intensity levels, few children recognised any words, but as intensity gradually increased, the recognition rate increased linearly. At the highest intensity levels, almost all children could repeat the words. For each word, we determined the intensity level required for 50% correct recognition. These levels were obtained from the PI-Functions and can be considered the "recognition threshold" for each of the three-syllable words. The recognition thresholds are presented in **Table 5** in Appendix A, in which the words are ordered in terms of intensity level (from the word that required the lowest intensity level to be recognised/paˈtata/ to the word that required the maximum intensity level /kaˈriði/).

Two key findings emerge from **Table 5**. First, if all 120 words were presented at the average intensity (10.8 dBHL) to a group of school-aged children with normal hearing, then we would expect a 50%-word recognition rate. Therefore, this average intensity is comparable to the SRT that would have been obtained if we had presented the entire word list to all children. Second, the levels of word recognition ranged from 7.2 dBHL /paˈtata/ to 14.6 dBHL /kaˈriði/.

Recognition rates for each word were then measured across the 20%–80% range, during which the steepest rise in PI-Function is shown. These percentages, obtained from the PI-Function, are presented in **Table 5**. The words in the shaded cells fall within +1 SD of the Mean. We observe that the word that had the most progressive slope is /paˈtata/, and the word that had the steepest slope is /moˈlivi/. We can conclude that 44 words can be considered homogeneous based on the rate of increase in recognition.

One challenge in finding a subset of highly homogeneous words is determining what constitutes homogeneity. If we set the only criterion of homogeneity as the word recognition threshold, then we must decide what the acceptable range of intensity will be. A logical solution is to spread around the mean value, such as +1 SD, as used in **Table 5** regarding the word recognition threshold.

In **Figure 1**, we observe the recognition rates of three different three-syllable words. Although they require different intensities for 50% recognition, the recognition rates of the first two (A and B) are almost the same, while the rate between words A and C is quite different. More specifically, the PI-function of the C word is much steeper than the A word. Therefore, changes in intensity will cause a greater effect on the C word than on the A word. Such effects of intensity change present problems, especially considering the 5 dBHL steps used clinically for the SRT test. Therefore, the recognition rate of each word should also be a criterion for homogeneity.

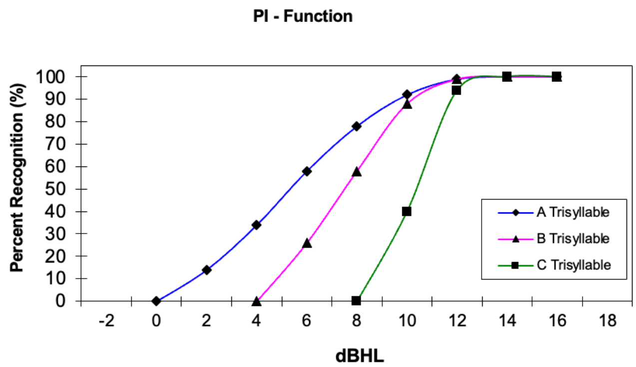

Figure 1. PI-Function of three trisyllabic Greek words.

In **Table 5**, we observe the recognition rate per dBHL, ranging from 20% to 80%, for the 120 words. The words in the shaded cells show a recognition rate within +1 SD of the Mean value. Using the threshold criterion, we have 88 homogeneous words from **Table 5**. In contrast, using the recognition rate criterion (**Table 5**), we have 44 words.

From the two columns, it follows that all words that are homogeneous in terms of recognition rate are not homogeneous in terms of recognition threshold, and vice versa. Therefore, for better homogeneity of the words, the words that are within +1 SD, both in terms of recognition rate and in terms of recognition threshold, were selected. **Table 4** shows the 40 three-syllable words that meet both of the above criteria.

Table 5. The intensity (dBHL) required for 50% recognition (mean = 10.8 dBHL, SD = 1.6), and percentage of recognition per dBHL from 20% to 80% recognition (mean = 9.0 dBHL, SD = 1.5), for each of the 120 three-syllable words. Asterisk (*) cells enclose words within +1 SD of the Mean.

Trisyllabic Word (Greek Script)	Phonetic Transcription (IPA)	English Translation	Recognition Threshold (dBHL)	Recognition Rate (%)
Πατάτα	/paˈtata/	Potato	7.2	6.9
Μωράκι	/moˈraci/	Baby	7.4	10.9
Ντουλάπα	/duˈlapa/	Wardrobe	7.8	10.7
Πεπόνι	/peˈponi/	Melon	7.8	7.1
Τιμόνι	/tiˈmoni/	Steering wheel	7.8	**7.6***
Μολύβι	/moˈlivi/	Pencil	8.0	12.0
Σαγόνι	/saˈɣoni/	Jaw	8.2	7.3
Φουγάρο	/fuˈɣaro/	Chimney	8.2	10.6
Φανέλα	/faˈnela/	Jersey / undershirt	8.4	10.6
Παπάκι	/paˈpaci/	Duckling	8.6	10.8
Λιμάνι	/liˈmani/	Port / Harbor	9.0	7.2
Μητέρα	/miˈtera/	Mother	9.0	10.8
Πινέλο	/piˈnelo/	Paintbrush	9.0	7.4
Ρολόι	/roˈloj/	Clock/Watch	9.0	11.0
Σαλάμι	/saˈlami/	Salami	9.0	7.4
Σακούλα	/saˈkula/	Bag	9.0	**7.6***
Πετσέτα	/peˈtseta/	Towel	9.0	**7.6***
Σαλόνι	/saˈloni/	Living room	9.1	**7.8***
Αγκάθι	/aŋˈɣaθi/	Thorn	**9.2***	11.0
Μπαούλο	/baˈulo/	Chest/Trunk	**9.2***	7.2
Πατίνι	/paˈtini/	Skate	**9.2***	7.3
Πιπέρι	/piˈperi/	Pepper	**9.2***	7.4
Σακάκι	/saˈkaci/	Jacket	**9.2***	10.9
Ντομάτα	/doˈmata/	Tomato	**9.2***	**9.6***
Μελάνι	/meˈlani/	Ink	**9.4***	7.4
Χωράφι	/xoˈrafi/	Field	**9.4***	**8.8***
Συνάχι	/siˈnaxi/	Cold (illness)	**9.4***	7.2
Καπέλο	/kaˈpelo/	Hat	**9.6***	**9.0***
Πατζούρι	/paˈdzuri/	Shutter	**9.6***	7.2
Ρουθούνι	/ruˈθuni/	Nostril	**9.6***	7.2
Σιρόπι	/siˈropi/	Syrup	**9.6***	7.3
Τσεκούρι	/tseˈkuri/	Axe	**9.6***	7.4
Λουκούμι	/luˈkumi/	Turkish delight	**9.8***	7.3
Κορίτσι	/koˈrici/	Girl	**9.8***	**9.1***
Μανίκι	/maˈnici/	Sleeve	**9.8***	7.2

Καράβι	/kaˈravi/	Ship	**9.8***	**9.4***
Παλάτι	/paˈlati/	Palace	**9.8***	7.3
Παπούτσι	/paˈpuci/	Shoe	**9.8***	**10.2***
Πιπίλα	/piˈpila/	Pacifier	**9.8***	10.9
Ρακέτα	/raˈketa/	Racket	**9.8***	7.4
Βαλίτσα	/vaˈlitsa/	Suitcase	**10.0***	**9.8***
Κοπέλα	/koˈpela/	Young woman/girl	**10.0***	10.8
Κοτούλα	/koˈtula/	Hen	**10.0***	11.1
Καλάθι	/kaˈlaθi/	Basket	**10.2***	**8.9***
Μαντίλι	/manˈdili/	Handkerchief	**10.2***	7.3
Μασέλα	/maˈsela/	Molar (tooth)	**10.2***	7.3
Καρότο	/kaˈroto/	Carrot	**10.2***	**8.2***
Φασόλι	/faˈsoli/	Bean	**10.2***	**9.2***
Χελώνα	/çeˈlona/	Turtle	**10.2***	**9.3***
Ζωάκι	/zoˈaci/	Little animal/pet	**10.4***	10.9
Σεντόνι	/seˈdoni/	Sheet	**10.6***	**8.6***
Κιθάρα	/ciˈθara/	Guitar	**10.8***	**9.5***
Τηγάνι	/tiˈɣani/	Frying pan	**10.8***	7.4
Σαλάτα	/saˈlata/	Salad	**10.8***	**9.3***
Γορίλας	/ɣoˈrilas/	Gorilla	**10.8***	10.8
Σημαία	/siˈmea/	Flag	**10.8***	**8.8***
Τσιμέντο	/tsiˈmento/	Cement	**10.8***	**9.2***
Φεγγάρι	/feŋˈgari/	Moon	**10.8***	**9.6***
Μπανάνα	/baˈnana/	Banana	**10.8***	10.8
Βελόνα	/veˈlona/	Needle	**11.0***	**8.0***
Ελάφι	/eˈlafi/	Deer	**11.0***	**9.4***
Καμπάνα	/kamˈbana/	Bell	**11.2***	**9.8***
Κυρία	/ciˈria/	Lady/Mrs.	**11.2***	10.8
Λουλούδι	/luˈluði/	Flower	**11.2***	10.8
Λαμπάδα	/lamˈbaða/	Candle	**11.2***	**9.4***
Μαχαίρι	/maˈçeri/	Knife	**11.2***	**9.3***
Μπαλόνι	/baˈloni/	Balloon	**11.2***	**9.4***
Κατσίκα	/kaˈtsika/	Goat	**11.4***	**8.6***
Κεφάλι	/ceˈfali/	Head	**11.4***	**9.0***
Γατάκι	/ɣaˈtaci/	Kitten	**11.4***	10.6
Λεμόνι	/leˈmoni/	Lemon	**11.4***	**8.7***
Μπουκάλι	/buˈkali/	Bottle	**11.4***	**9.7***
Πατέρας	/paˈteras/	Father	**11.4***	**9.8***
Πιρούνι	/piˈruni/	Fork	**11.4***	**9.2***

Γυναίκα	/ʝiˈneka/	Woman	**11.6***	11.0
Γουρούνι	/ɣuˈruni/	Pig	**11.6***	**7.8***
Πινέζα	/piˈneza/	Thumbtack	**11.6***	7.3
Ποντίκι	/ponˈdici/	Mouse	**11.6***	**9.6***
Ποτάμι	/poˈtami/	River	**11.6***	**8.9***
Ποτήρι	/poˈtiri/	Glass	**11.6***	**10.2***
Αγόρι	/aˈɣori/	Boy	**11.8***	10.9
Αμπέλι	/amˈbeli/	Vineyard	**11.8***	7.3
Κουλούρι	/kuˈluri/	Bread ring/bagel	**11.8***	**9.7***
Αλάτι	/aˈlati/	Salt	**11.8***	**8.4***
Ζακέτα	/zaˈketa/	Cardigan	**11.8***	10.9
Σελίδα	/seˈliða/	Page	**11.8***	**9.2***
Καλύβα	/kaˈliva/	Hut	**11.8***	10.7
Κασέρι	/kaˈseri/	Kasseri cheese	**11.8***	7.3
Φανάρι	/faˈnari/	Traffic light	**11.8***	**9.0***
Χειμώνας	/çiˈmonas/	Winter	**11.8***	**9.3***
Κουνέλι	/kuˈneli/	Rabbit	**11.8***	10.8
Κουρέλι	/kuˈreli/	Little haircut	**11.8***	7.3
Καντήλι	/kanˈdili/	Oil lamp	**11.8***	**9.4***
Βαρέλι	/vaˈreli/	Barrel	**12.0***	10.6
Γεράκι	/ʝeˈraci/	Hawk	**12.0***	10.9
Σαπούνι	/saˈpuni/	Soap	**12.0***	**8.9***
Δωράκι	/ðoˈraki/	Little gift	**12.0***	10.7
Ζυμάρι	/zʝaˈmari/	Dough	**12.0***	10.7
Καλάμι	/kaˈlami/	Reed / cane	**12.0***	7.4
Κοχύλι	/koˈçili/	Seashell	**12.0***	7.3
Κανάτα	/kaˈnata/	Pitcher	**12.2***	11.1
Καπάκι	/kaˈpaki/	Lid/cap	**12.2***	7.4
Καρότσι	/kaˈrotsi/	Stroller/cart	**12.2***	7.3
Κολόνα	/koˈlona/	Column	**12.2***	7.2
Κουδούνι	/kuˈðuɲi/	Bell	**12.2***	10.6
Κουνούπι	/kuˈnupi/	Mosquito	**12.2***	10.7
Κεράσι	/ceˈrasi/	Cherry	12.6	7.4
Κουβάρι	/kuˈvari/	Ball (of yarn)	12.6	7.3
Κουζίνα	/kuˈzina/	Kitchen	12.8	10.6
Κουφέτο	/kuˈfeto/	Candy	12.8	7.4
Κανόνι	/kaˈnoni/	Cannon	13.0	10.7
Κασέτα	/kaˈseta/	Cassette	13.0	7.3
Κουτάκι	/kuˈtaki/	Small box	13.0	7.4

Αγγούρι	/aˈɣuri/	Cucumber	13.2	7.4
Κουρέας	/kuˈreas/	Barber	13.2	7.4
Βαγόνι	/vaˈɣoni/	Wagon/Carriage	13.8	10.7
Εικόνα	/iˈkona/	Picture	14.2	10.9
Αγκώνας	/aɣˈɣonas/	Elbow	14.4	7.4
Κυνήγι	/ciˈnici/	Hunting	14.4	7.2
Καρύδι	/kaˈriði/	Walnut	14.6	7.4
		Mean	10.8	9.0
		SD	1.6	1.5
		Minimum	7.2	6.9
		Maximum	14.6	12.0

4.0 DISCUSSION

The goal of developing a list of trisyllabic Greek words for SRT testing in school-aged children was successfully achieved through a rigorous selection process. The resulting 40-word list aligns with international practices in speech audiometry and addresses a critical gap in Greek pediatric audiology in both clinical practice and research.

In English and other languages, SRT testing relies on spondaic words, but direct adaptation is not linguistically possible for Greek due to its different stress system and syllable structure. Greek lacks validated SRT materials designed for both children and adults. The absence of spondaic words and the linguistic characteristics of the Greek language, specifically the stress system and syllable structure, necessitated the development of this language-specific trisyllabic word list for SRT testing in Greek-speaking pediatric populations. By selecting trisyllabic words with stress on the middle syllable, the test aligns with the most frequent and natural prosodic pattern of Modern Greek, ensuring stimuli are representative and perceptually balanced.

Assessment of SRT in the pediatric population is essential for identifying hearing impairments, which can significantly affect speech and language abilities. This SRT test, developed for the Greek language, is crucial for obtaining reliable results and will enhance early intervention, thus improving long-term outcomes for children with hearing loss.

Because Greek literature is limited, we could not compare our findings with existing Greek SRT materials. However, our results are consistent with previous studies in other languages that have developed language-specific SRT trisyllabic materials (Anderson, 2016; Graham, 2016; Honu-Mensah, 2015; Keller, 2009; Kim, 2007; Mangum, 2005; Nissen et al., 2007; Slade, 2006). These studies emphasise the importance of creating equivalent word lists to ensure SRT testing remains relevant across diverse linguistic populations. Specifically, in 2007, Kim identified and provided trisyllabic SRT words for Cantonese across specific dialects and phonetic systems, highlighting the language's unique phonetic properties (Kim, 2007). Similarly, Keller's 2009 study examined Spanish-speaking speakers (Keller, 2009), and Slade's 2006 study examined Mandarin in Taiwan (Slade, 2006).

Furthermore, Anderson et al. (2016) and Graham et al. (2016), for native Cebuano speakers and Spanish pediatric speakers, respectively, emphasised the need for psychometric equivalency across populations and highlighted that careful consideration of linguistic backgrounds is necessary to enhance SRT test methodology. Finally, in Honu-Mensah's 2015 study (Honu-Mensah, 2015) on the Fante language, a final list of 25 familiar homogeneous words with the same tone patterns and slopes greater than 7%/dB was selected, highlighting similar challenges in developing SRT materials for a language that is not commonly used. In conclusion, these studies indicate a growing recognition of the connection between language structure and auditory processing abilities.

From a clinical perspective, an age-appropriate SRT word list in Greek is a vital tool that serves numerous clinical purposes. It provides more reliable threshold estimation in children and enables the evaluation of the relationship between speech and pure tones by providing a check on the validity of pure tone thresholds necessary for speech recognition (Carhart, 1951). It provides a referential intensity level for checking the WRS (ASHA, 1979; Wilson & Margolis, 1983). It provides an assessment of acoustic sensitivity across the range of speech frequencies in difficult-to-screen patients (e.g., children with mental retardation, developmental disorders, etc.) who are unable to respond to pure-tone stimuli due to their condition (ASHA, 1988; Wilson & Margolis, 1983). It helps to assess performance with auditory amplification and progress in auditory rehabilitation (ASHA, 1979; Wilson & Margolis, 1983).

From a research perspective, this work contributes to cross-linguistic audiology by demonstrating how language-specific properties (e.g., stress placement, syllable structure) can shape test design, rather than importing materials from English or other languages. It also provides a tool for future normative studies in Greek-speaking children, which can inform comparisons across dialects, ages, and clinical groups (e.g., children with hearing impairment, language disorders, or cochlear implants).

For many years, various methods have been used to predict SRT from pure-tone audiograms. Although some of these procedures are quite sophisticated, most audiologists agree that the SRT can be predicted by averaging the two lowest thresholds at 500, 1000, and 2000 Hz (Fletcher, 1950). Carhart and Porter (1971) found that the SRT can be predicted from the pure tone audiogram by averaging the thresholds at 500 and 1000 Hz and subtracting 2 dBHL (Carhart & Porter, 1971). Although 500, 1000, and 2000 Hz are called "speech frequencies", Wilson and Margolis (1983) noted that such an expression can be misleading if it is stated that this small frequency range is the most necessary for adequate speech discrimination (Wilson & Margolis, 1983).

Two key findings were indicated by the intensity (dBHL) required for 50% recognition and the percentage of recognition per dBHL from 20% to 80% recognition, for each of the 120 three-syllable words. First, if we presented all 120 words at the average intensity (10.8 dBHL) to a group of school-aged children with normal hearing, we would expect a 50% word recognition rate. Therefore, this average intensity is comparable to the SRT that would have been obtained if we had presented the entire word list to all children. Second, the levels of word recognition, shown in **Table 5**, ranged from 7.2 dBHL /paˈtata/ to 14.6 dBHL /kaˈriði/. This range of 7.4 dBHL is in agreement with the ranges of 8.1, 7.4, and 6.4 dBHL reported by Curry & Cox (1966), Beattie et al. (1975), and Young et al. (1982), respectively, for English language verbal words (Beattie et al., 1975; Curry & Cox, 1966; Young et al., 1982). We note that 88 words can be considered homogeneous according to the recognition threshold.

Regarding the recognition rates, each word was then measured across the 20%–80% range, during which the steepest rise in PI-Function is shown. These percentages, obtained from the PI-Function, are presented in **Table 5**. The words in the shaded cells fall within +1 SD of the Mean. We observe that the word that had the most progressive slope is /paˈtata/, and the word that had the steepest slope is /moˈlivi/.

We can conclude that 44 words can be considered homogeneous based on the rate of increase in recognition. The average value of 9%/dBHL obtained in the present study is in agreement with the 10%/dBHL and 8%/dBHL reported by Young et al. (1982) and Hirsh et al. (1952), respectively, for the spondaic words of the English language (Hirsh et al., 1952; Young et al., 1982).

Our findings also align with the literature on PTA/SRT agreement, a key indicator of test reliability and consistency in audiological assessments. In individuals with normal hearing, SRT and PTA typically agree within 5 to 10 dB HL. However, in some cases, the SRT may be much lower (better) than the PTA, such as when the audiogram drops sharply at high frequencies. In other cases, the SRT may be higher (worse) than the three PTA frequencies, for example, in some elderly patients or those with central auditory nervous system disorders.

4.1 Strengths and limitations

The strong points of the current study are a) characterised by a rigorous and child-centred methodology that was employed in word selection and validation, and b) the uniqueness and novelty due to the lack of similar studies in the Greek language. However, this study has several limitations. First, the study included only children with typical hearing abilities, and its application to children with hearing loss remains to be explored. Secondly, the limited sample is another limitation, but the preliminary data are adequate for this scope. Future studies and research should focus on clinical populations to validate the current material and confirm its usefulness. More specifically, possible clinical populations could include children with hearing impairment, or the test could be repeated with different age subgroups or dialects, comparing findings across lists with varying syllabic structures (mono-, di-, and trisyllabic).

5.0 CONCLUSIONS

In conclusion, the current study presents a suitable trisyllabic word list for SRT testing in Greek-speaking children, thereby addressing an important research gap in Greece. Moreover, this tool is expected to enhance the reliability of pediatric audiological assessments and can serve as a foundation for further research and clinical applications across Greek-speaking populations.

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