

Development of phonemically balanced word lists in Tamil language for adults

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Abstract

Objective: Speech audiometry testing procedure encompasses the assessment of individual's speech recognition abilities. Standardized words are utilised for the assessment procedures which are commonly phonemically balanced. The present study aimed to develop a large set of 25 phonemically balanced bisyllabic word lists in Tamil language for adults and also standardized the same on individuals with normal hearing sensitivity and different degrees of hearing impairment. **Participants:** One hundred individuals with normal hearing sensitivity and 40 individuals with different degrees of hearing loss were assessed. **Methods:** A pool of 1015 bisyllabic Tamil words was sourced and these were subjected to familiarity rating and content validation. After these, 760 words were selected for phonemic balancing and 25 word lists were prepared with 25 words each. All the 25 word lists were presented to 100 individuals with normal hearing sensitivity at 40 dB SL. A PI- PB function was obtained on 30 among these 100 individuals. The lists were validated on 40 individuals with different degree of hearing impairment. **Results:** The results of the present study revealed a mean SIS in adults with normal hearing sensitivity ranged from 99.72% to 100%. There was no significant difference ($p > 0.05$) across the 25 word lists in adults with normal hearing sensitivity. All 25 word lists provided similar scores indicative of list equivalency. A performance-intensity function in adults with normal hearing sensitivity revealed that SIS score increased as the sensation level increased from 10 dB SL to 40 dB SL. A significant decrease in SIS was observed as the degree of hearing loss increased ($p < 0.05$). **Conclusion:** The 25 word lists can be utilised for SIS testing in Tamil language for adults during routine audiological evaluation including assessment hearing aid benefit and for research purpose.

INTRODUCTION

Speech audiometry is a collection of behavioral hearing assessment procedures that uses speech as the stimulus. One of the tests in speech audiometry is establishing speech identification score (SIS). SIS reflects the ability of an individual to identify speech at supra-threshold levels and it is generally assessed using phonemically balanced (PB) words. SIS can be useful in finding out the degree of communication handicap, differential diagnosis, and selection of amplification devices. In addition, SIS can be used to trace the benefits of hearing aid and to monitor rehabilitation (Gelfand, 2009).

The first few materials developed for obtaining SIS were PAL PB-50 word list (Egan, 1948), CID W-22 test and NU-6 test (Tillman & Carhart, 1966) and all the above were in English. Later, speech audiometry materials were developed in different languages such as Russian (Aleksandrovsky, McCullough, & Wilson, 1998), Spanish (Christensen, 1995), Italian (Turrini et al., 1993), Portuguese (Harris, Goffi, Pedalini, Gygi, & Merrill, 2001) etc. These developed material followed criteria postulated by Hudgins, Hawkins, Karlin, & Stevens (1947) over the years with slight modifications in the terminology and a few additions. The original criteria as well as the modifications are discussed below.

1.1 Criteria for development of speech material

Hudgins et al. (1947) had deemed four criteria to be essential for developing a speech audiometry material. They are as follows:

- 1.1.1 Item familiarity
- 1.1.2 Phonetic dissimilarity
- 1.1.3 Normal sampling of speech sounds
- 1.1.4 Homogeneity with respect to basic audibility

1.1.1 Item Familiarity

The familiarity of the test items should be important as the developed material will be evaluated on a wide range of individuals from varied distribution of levels of education and social standards (Ashoor & Prochazka, 1982). Almost all the developed word lists utilise the familiar items in their test lists. However, there were several ways in which the familiar items in the test list can be utilised. In foreign languages, few developed word lists were prepared by employing the words which are published in a word corpus based on their frequency of occurrence of words in that language (Fu, Zhu, & Wang, 2011; Wang, Mannell, Newall, Zhang, & Han, 2007). These word lists obtained from word corpus doesn't employ the phonetic/ phonemic balancing of the word list. The next method is the most commonly employed procedure, in which the test items are sourced from school textbooks, daily newspapers, magazines, novels, storybooks and dictionaries. After sourcing of the test items, the words need to be refined using various levels of familiarity rating scales to filter out the words to maintain the familiarity of the word perception to be similar across the test items which is rated by a wide range of individuals across all levels of education and social status.

1.1.2 Phonetic Dissimilarity

Hudgins et al. (1947) claimed that the speech audiometry test is not a test of intelligence or vocabulary rather it is a test of speech intelligibility and hence the test items employed should be simple and familiar. Phonetic dissimilarity is the term used when the words don't share phonetic elements such as rhyming (Nissen et al., 2011). Having minimally different or similar words in the test item will increase only the difficulty of the test and not the effectiveness of the test. Use of monosyllabic words in the development of word list may incur this difficulty, that the test item may be phonetically similar which at times create confusion to the listeners. Hence to overcome this, few of the researchers had

come up with the idea of developing the word lists with bisyllabic words which reduced the occurrence of phonetically similar units in the test items.

1. 1.3 Normal sampling of speech sounds

Hudgins et al. (1947) reported that representing all of the speech sounds in the English language for developing the word list is essential and termed this step as normal sampling of speech sounds. The construction of any speech audiometry material should be concerned about the phonetic composition of the language as an effort to replicate the sounds of everyday language (Hirsh et al., 1952). While developing a speech audiometry material a most frequently faced issue is that the material should be balanced phonetically or phonemically. According to Causey, Hood, Hermanson and Bowling, (1984), phonetic and phonemic balances were two different concepts. Phonetic balance refers to the occurrence of phonemes in each word lists that mimic that of the frequency of occurrence of phonemes in the representative sample of the language. Phonemic balance, on the other hand, indicates that the frequency of occurrence of phonemes are equal across all the lists in the set.

Phonetic balanced material should quantitatively represent all the phonemes in the spoken language, i.e., the frequency of phonemes in the word list to be similar in terms of frequency of occurrence of phonemes in that particular language in which the word list is being developed (Lyregaard, 1997). The reason for this balance was that the amount of frequent phoneme employed in the test lists was more likely to represent the everyday listening environment. It also quantifies the outcome better than using an infrequent phoneme of a particular language. There were many word lists that employ phonetic balance (Egan, 1948; Fu et al., 2011; Han et al., 2009; Hirsh et al., 1952; Nielsen & Dau, 2009).

Phonemic balancing is also being employed commonly in speech audiometry materials (Boothroyd, 1968; Lau & So, 1988; Yiap Kim Hong, 1984). Arthur Boothroyd

(AB) word lists used the term 'isophonemic' instead of phonemic balance, however, the concept is the same. An advantage of using phonemic balance instead of phonetic balance is that it allows for shorter lists while still having phonemic content that is representative of the language (Boothroyd, 1968).

1.1.4 Homogeneity with respect to basic audibility

The homogeneity of the test item to be obtained by choosing the test item that reaches the listener's ear at the same level of audibility when spoken in a similar tone of the voice or adjusting the intensity level during the recording of the test items (Hudgins et al., 1947).

Homogeneity of a word list is of due importance to keep all the test item to be the same in terms of both the perception by the listener and production by the speaker as it is to believe that the homogeneity of the test item will increase the precision probability of performance intensity.

The development of word lists in any language should incorporate these criteria to attain a good testing material. If these criteria were employed to prepare a word list then the word list will be familiar, phonemically balanced, and homogenous.

1.2 Speech audiometry test materials available in foreign language

The use of word lists at the early 1940s for speech audiometry testing was the basis for further development of speech audiometry material. PAL Auditory Test No. 9 was a recorded test material developed by Hirsh (1947). It consisted of spondaic words. However, these words did not meet all the essential criteria (section 1.1.1. to 1.1.4) (Hudgins et al., 1947; Young, Dudley, & Gunter, 1982) especially the homogeneity criteria.

Hence, Hirsh et al. (1952) improvised Auditory Test No 9 based on the above mentioned four criteria. The modified material developed by Hirsh et al. (1952) consists of three sets of word lists: CID Auditory Test W - 1, Test W-2 and Test W-22. Following this, there are several studies assessing the homogeneity of the developed word tests and creating sublists to achieve the same (Bilger, Matthies, Meyer, & Griffiths, 1998; Wilson & Strouse, 1999; Young et al., 1982). It was later put forth that psychometric functions could be used to arrive at words that have homogeneity with respect to audibility (Bilger et al., 1998). In 1959, Lehiste & Peterson, developed a set of CNC word lists which were phonemically balanced i.e., the frequency of occurrence of the phoneme in each list will be same. The set was made up of 50 monosyllabic consonant-nucleus-consonant (CNC) in each of the ten lists. Causey et al. (1984) had obtained the normative data of this revised CNC list based on the performance-intensity (PI) functions on individuals with normal hearing sensitivity and individual with hearing impairment by presenting the stimuli between 4 and 40 dB SL intensity levels. The result depicting correct scores at different presentation level was depicted in the PI curve, in that 50% word recognition score was taken as their thresholds while the speech discrimination level was depicted through the level at which the maximum score was obtained. In Mandarin language, a psychometrically equivalent bisyllabic speech discrimination material was developed by Nissen et al. (2005). The speech material consisted of four full lists of 50 words each which were psychometrically equivalent, these lists were further made into eight half lists with 25 words each. Wang et al. (2007) developed bisyllabic speech audiometry material in Mandarin language. The main difference between the material developed by Nissen et al. (2005) is that the one by Wang et al., (2007) was phonetically balanced while the one by Nissen et al. (2005) was not. There were also materials for SRT and SIS available in high quality recordings in a variety of foreign

languages other than English such as Spanish (Christensen, 1995), Italian (Greer, 1997), Japanese (Mangum, 2005), French (Nelson, 2004), and in several Indian languages.

1.3 Speech audiometry materials available in Indian language

India is a multicultural and multilingual country constituting a diverse population. Therefore, having a single common test representing all the languages is impossible. Hence, the need for developing and standardizing test materials has been recognized by the researchers and several materials have been developed in Indian languages. Commonly used tests in Indian languages are given in Table 1.1.

Table 1.1: Speech audiometry word materials in different native languages in India

Language	Stimuli used	Number of lists developed	Author
Indian English	Bisyllabic words	2 lists	Swarnalatha (1972)
Tamil	Monosyllabic words	2 lists	Dayalan (1976)
	Spondee (Bisyllabic words)	1 list	
	PB word list	8 lists	Mahima and Muthuselvi (2017)
Kannada	Bisyllabic words	8 lists	Yathiraj and Vijayalakshmi (2005) Manjula, Antony, Sharathkumar and Geetha (2015)
	Bisyllabic words	21 lists	
Hindi	Monosyllabic words	6 lists	De (1973)
Manipuri	Multisyllabic words	4 lists	Tanuja (1985)
Oriya	Bisyllabic words and Monosyllabic words	2 lists of each	Smeeta (2004)
Bengali	Multisyllabic words	3 lists	Gosh (1988)
Telugu	Paired Bisyllabic words	1 list	Sreedhar, Venkatesh, Nagaraja and Srinivasan (2011)
Malayalam	Bisyllabic words	1 list	Kapur (1971)
Konkani	Monosyllabic words	2 lists	Dias, Devadas and Rajashekhar (2015)
Telugu	Bisyllabic words	4 lists	Kumar and Mohanty (2016)
Marathi	Bisyllabic words	4 lists	Kumar, Mohanty, Ujwane, Huzurbazar (2016)

Even though there is an availability of speech audiometry tests in various native languages of India, several attempts have been made to newly develop or revise some of the speech audiometry material due to numerous reasons. Yathiraj and Vijayalakshmi (2005)

developed eight phonemically balanced word lists in Kannada consisting 25 bisyllabic words in each of the lists. These lists were standardized on individuals with normal hearing sensitivity and also validated on individual with hearing impaired. These lists are used in everyday clinical assessment and this material possesses good test-retest reliability. However, Manjula, Antony, Kumar, and Geetha (2015) later developed and standardized 21 phonemically balanced word lists in Kannada with 25 bisyllabic words in each of the lists so that many conditions can be assessed using different lists without having to repeat any of the lists in research studies.

Sreedhar, Venkatesh, Nagaraja, and Srinivasan (2005) developed a test material in Telugu for estimating the speech recognition thresholds using paired words and compared it with the existing bisyllabic words developed by Padmaja (1987). The researchers have reported that the words in the earlier material were unfamiliar to the listeners and hence, it was difficult for the listeners to repeat back the words. There are a few testing materials in Tamil language. The current study aimed to develop speech audiometry material in Tamil, hence, the existing materials in Tamil have been describe in detail along with the need to develop new test material in Tamil.

1.4 Speech materials in Tamil language

Tamil is a commonly spoken language in Tamil Nadu and Puducherry, which is also a recognized language of Indian constitution and it is of Dravidian origin. Tamil is one of the classical longest surviving languages in Tamil and it dates back to 300 BC. Tamil is “Diglossic” in nature (Matiki, 2010) because the languages have its spoken variety which is the sentamizh (ancient Tamil) and the colloquial Tamil with dialectal variations across the districts of the state. However, the written form follows the classic earlier era of Sentamizh.

Tamil language consists of 12 vowels and 18 consonants, both the vowel and consonants combine to form 216 compound characters. Along with these a special character called “aaytham” is added forming 217 individual Tamil alphabets in the language. The language also has a unique liquid which is not significantly present in the other language sounds “zh” (Vasanthakumari, 1989).

In Tamil, only a few speech audiometry materials have been developed for both children and adult populations. First of which was developed by Dayalan (1976). The test consists of Tamil PB and spondee word lists for adult listeners. The author developed four lists of monosyllabic PB words with 25 words in each list. All the syllables were in CNC combination. Along with this the author also developed one list of spondee words with equal stress on both the syllables in the words and the list consist of 38 spondee words in it. To standardize the word list the developed material was administered on 30 individuals with normal hearing aged 19 and 20 years. The study did not validate the developed material on individuals with hearing impairment.

For children, two speech audiometry materials were developed in Tamil. Boominathan and Yathiraj (1999) developed the picture speech identification test for children in the Tamil language. The lists consist of two lists of phonetically balanced Tamil bisyllabic words with 25 words each. All the words were picturable words and the developed material was standardized on 40 children in the age of 2 to 6 years who were normal hearing. The task given was a forced-choice paradigm with four pictures placed in front of the children and the target words were presented to the children and the children were asked to respond to the target word by identifying the correct picture. This speech audiometry material was also not standardized on children with hearing impairment.

Tamilmani (2002) developed the Early Speech Perception test for children in Tamil language. This test aimed at testing children with hearing aids and cochlear implants. The test has two versions. The lower version consists of syllable categorization in the Tamil language for children aged between 2 to 3 years. The lower version of the test consists of nine monosyllabic, nine bisyllabic and nine trisyllabic words in a picturable form in the word list. The higher version contains the pattern perception test for children aged 3 to 5 years. In this, it consists of three lists with eight polysyllabic words per list. Among the three lists, two lists were presented auditorily and one list was presented audio-visually.

Sinthiya and Sandeep (2009) developed and standardized high-frequency speech identification test for adults in the Tamil language. The material consists of three word lists with two word lists containing bisyllabic words and one list with trisyllabic high-frequency words in it. All the words in the word lists contain the phonemes with predominant high frequency energy such as /s/, /ʃ/, /tʃ/, /dz/, /k/ in it. The developed word lists aimed to assess adult with high-frequency sloping hearing loss. However, the developed material was assessed only on individuals with normal hearing not on the individual with high-frequency hearing loss.

Mahima and Muthuselvi (2017) developed and standardized four lists of phonemically balanced word lists in CVCV combination in Tamil and randomized these lists to make a total of eight word lists. The clinical utility was assessed on individual with different degree of sensorineural hearing loss.

1.5 Need of the study

India is a culturally and linguistically diverse country and hence, having a single common assessment material for evaluation of speech perception abilities cannot be accepted. Hence, there is an increasing need to develop a material which is sensitive

culturally and linguistically. Some of the speech audiometry materials available in Indian languages were Indian English (Swarnalatha & Rathna, 1972), Hindi (De, 1973), Kannada (Yathiraj & Vijayalakshmi, 2005), Tamil (Dayalan, 1976), Telugu (Rathna Kumar & Mohanty, 2012) and Malayalam (Kapur, 1971). A few researchers realized the need to modify, revise or newly develop speech audiometry materials across different Indian languages to overcome the limitations of earlier developed materials (Dias, Devadas, & Rajashekhar, 2015; Manjula et al., 2015; Sreedhar et al., 2005). Some of the limitations of existing word lists being inclusion of unfamiliar words, lesser number of test items to assess different conditions, lack of validity on clinical population, lack of validity on usage of test items in noise condition and not considering the effect of dialect variations (Lehiste & Peterson, 1959).

The development of first word list in Tamil language is dated back to late 1970s. This word list comprises of four phonetically balanced lists with 25 monosyllabic Tamil words each (Dayalan, 1976). The validation of the developed material was done only on individuals with normal hearing sensitivity and not on the clinical population. Carhart (1951) recommended that speech audiometry materials should be validated in an experimental setting on a test population to get appropriate test results.

In addition to the not including hearing impaired population, Dayalan (1976) utilised monosyllables for constructing the word lists. The number of frequently occurring familiar monosyllabic words with consonant endings are very less in Tamil. In addition, some of the words in the lists are not in everyday use and hence, not familiar (e.g. /pi:r/, /su:l/, /sa:r/, /ja:n/, /va:r/) to the listeners. The word lists also contain some borrowed words (e.g. /bus, /ha:l/, /tin/) and unparliamentarily words (eg. /pe:i/, /de:i/). Zubick (1983) states that the use of unfamiliar words in a speech audiometry material will affect the accuracy of the testing

procedure which heavily relies on the subject knowledge towards the test items. Hence, it is essential to develop test items which consist of words which are familiar, frequently occurring in the environment and can easily be produced or repeated back by the listener.

The use of monosyllabic words are common for assessing speech recognition scores. Reason being the monosyllables are a minimum meaningful unit of a language and are non-redundant. Nevertheless, in South Indian languages like Tamil, Kannada, Telugu and Malayalam, the availability of familiar monosyllable is very scarce and hence, Kumar and Mohanty (2012) employed bisyllables in their PB word lists in Telugu. With this as a support, Mahima and Muthuselvi (2017) developed a phonemically balanced bisyllabic word list to overcome a few of the shortcoming of earlier developed word list developed by Dayalan (1976).

Mahima and Muthuselvi (2017) developed four lists of 25 words each. After standardisation, the developed four lists were randomized to make eight lists. However, randomizing the word list without accounting for homogeneity of audibility makes the word list lack validity and also the listener might perform better than expected during assessment due to repetition of test items.

Hence, the present study aimed to develop over 20 word lists with familiar words used in an everyday context. Since Tamil is considered as a vowel ending language, this study intends to develop PB word lists using bisyllabic words. The developed words lists will be standardized on a larger number of adults with normal hearing sensitivity. The effectiveness of the word list will be assessed in the clinical population with hearing impairment.

1.5.1 Aim of the study

The aim of the study was to develop and standardize a large set of phonemically balanced bisyllabic word lists in Tamil for assessing speech identification scores in adults with normal hearing sensitivity; and to assess the clinical utility of the developed word lists.

1.5.2 Objectives of the study

- To develop 25 Phonemically Balanced word list in Tamil for adults,
- To standardize and assess the consistency of speech identification scores among different word lists on adults with normal hearing sensitivity,
- To assess the homogeneity of audibility, and
- To evaluate the clinical utility of the developed Phonemically Balanced word lists in adults with hearing impairment.

Method

The present study was carried out with objectives of development and standardization of Tamil phonemically balanced word lists, and assessment of the clinical utility of the developed word lists. The study was structured in three phases. Phase I involved the development of PB word lists in Tamil. Phase II involved standardization of the word lists, and phase III involved assessing the clinical utility on individuals with hearing impairment. A normative research method was followed to conduct the study.

2.1 Phase I: Development of Phonemically Balanced word lists in Tamil

Development of phonemically balanced word lists was done using many steps. The

steps followed were collection of words, familiarity rating, content validation, preparation of phonemically balanced words and recording.

2.1.1 Collection of words

Initially, a pool of 1015 bisyllabic words were collected. These words were collected from various sources including newspapers, magazines, textbooks, novels, storybooks, and dictionary. It was ensured that proper nouns or words creating conflict were not selected in the study.

2.1.2 Familiarity rating

The collected pool of words was subjected to familiarity rating on 20 native Tamil speakers from different socio-economic status and different levels of education. The words were rated using a five-point rating scale in Tamil and the ratings are as follows:

- **5 – Most familiar** (words are well known and used more frequently in conversation)
- **4 – Familiar** (words well known but used less in conversation)
- **3 – Familiar but not used every day** (known words but not used in conversation)
- **2 – Not Familiar** (words heard but meaning not known)
- **1 – Unknown** (words never heard)

The ratings from all the participants were collected and averaged. The words with the average rating of 3 to 5 were considered for the next step. At the end of this exercise, 930 words had a rating of 3 to 5 and hence were considered for content validation.

2.1.3 Content validation

Content validation of the selected words were carried out using the assistance of five experts working in the field of audiology, speech language pathology, linguistics and psychology. The experts were asked to check if those words met the criteria regarding familiarity, absence of emotional overlay, cultural and religious overlay. They were requested to mark these 930 words as highly relevant or not relevant. The responses from each individual were collected and considered if applicable to the present study. The words which were not relevant based on the aforementioned criteria i.e. unfamiliar words, and words relating to social, political, religion and war were excluded from the list. At the end of this process, 170 were considered irrelevant and hence, were excluded. Hence, only a total of 760 words were considered for the preparation of word lists. In order to objectively assess if the elected words are relevant, content validity index (CVI) was computed. The computation includes I-CVI and S-CVI. I-CVI is computed as the number of experts giving a rating of “very relevant” for each item divided by the total number of experts. S-CVI is calculated using the number of items in a tool that have achieved a rating of “very relevant”. There are two methods to calculating S-CVI, one is the Universal Agreement (UA) among experts (S-CVI/UA), and the second is the Average CVI (S-CVI/Ave). S-CVI/UA is calculated by adding all items with I-CVI equal to 1 divided by the total number of items, while S-CVI/Ave is calculated by taking the sum of the I-CVIs divided by the total number of items. A I-CVIs of 0.78 or higher and S-CVI/UA and S-CVI/Ave of 0.8 and 0.9 or higher, respectively (Shi, Mo & Sun, 2012) are suggestive of very good content validity. In th present study, The I-CVI ranged between 0.8 to 1, S-CVI/UA and S-CVI/AVG were found to be 0.92 and 0.98.

2.1.3 Preparation of Phonemically Balanced words

Out of 760 words, 625 words were utilised to construct 25 lists of 25 words each. The constructed word lists were phonemically balanced to match the frequency of occurrence of

phonemes in Tamil. The phonemic balancing was performed based on the data on frequency of occurrence of phonemes in Tamil given by Sakkan, (2008). In Sakkan's study, the frequency of occurrence of phonemes in Tamil language was computed from a Tamil corpus which had an aggregated amount of approximately three million words across all genres. Initially, the number of individual phonemes in the 760 words were computed. The computed number of phonemes were compared with the corpus frequency of occurrence. This is done to maintain similar phonemic representation across the lists and also to ensure that the frequency of occurrence of phoneme to be equal to the corpus frequency of occurrence.

2.1.4 Recording

The constructed word lists were recorded in an acoustically treated room (ANSI S 3.1, R2013) using a personal laptop loaded with Adobe Audition version 3.0 software with an installed Motu Micro Book II software. The laptop was connected to a condenser microphone and kept at a distance of 10 cm from the speaker's mouth through an external Motu Micro Book II USB sound card. A sample of 50 words were spoken by seven native Tamil speakers. These recorded sample words were presented randomly to five experts in the field of audiology and five native Tamil speakers across different educational and socioeconomic status. They rated the recorded words in terms of naturalness, clarity, pronunciation, pleasantness in a four-point rating scale with 0 being poor and 3 being the best. The sample words were presented to the listeners in a randomized fashion among the experts and general public. The identity of the speaker was not revealed to the listeners. The response rating was compiled and a female speaker with the maximum rating was chosen for the final word list recording. The speaker was instructed to pronounce the words naturally, clearly in a neutral intonation with a constant vocal effort throughout the recording. The recorded waveforms were digitized with a 16 bit A/D converter at a sampling frequency of 44,100 Hz. Each of the

recorded words was normalized to 0 dB using Adobe Audition version 3.0 software. A calibration tone of 1000 Hz was generated in Adobe Audition version 3.0 software, normalized to 0 dB, and added at the beginning of each of the word lists. The typed word lists in International Phonetic Alphabet and Tamil are enclosed in Appendix 1. The audio recorded version of the stimuli in .wav format along with the calibration tone is enclosed in Appendix 2.

2.2 Phase II: Standardization of word lists

2.2.1 Participants

The recorded word lists were presented in quiet on 100 individuals with normal hearing sensitivity in the age range between 18 to 50 years (mean = 29.48; SD = 8.22), after a routine audiological evaluation. A calibrated dual-channel audiometer (Inventis Piano) coupled with acoustically matched TDH 39 headphones housed in MX- 41 AR ear cushions and B71 bone vibrator was utilized to estimate the pure tone thresholds, speech recognition threshold with Tamil Spondee words and speech identification score with a phonetically balanced word list in Tamil (Dayalan, 1976). A calibrated GSI Tymstar middle ear analyzer was used for obtaining tympanogram and acoustic reflex threshold. The test stimulus was presented using a laptop (64 bit Dell Inspiron 15 3000 Series laptop) and delivered through the same audiometer utilized for hearing testing.

Pure tone air conduction thresholds for each of the participants were established in octave frequencies from 250 Hz to 8000 Hz, using the modified Hughson and Westlake method (Carhart & Jerger, 1959). Bone conduction thresholds were also established using the same method for octave frequencies from 250 Hz to 8000 Hz. The tympanometric measurements were done using a probe tone of 226 Hz at 85 dB SPL to evaluate the status of the middle ear. For acoustic reflex measurement, reflex eliciting tones of 500, 1000, 2000 and

4000 Hz were presented both ipsilaterally and contralaterally to track the acoustic reflex thresholds. A significant change of admittance value of greater than 0.03 ml was considered as the criterion for the presence of reflexes (Cohen and Prasher, 1992). The calibration tone was played and the gain of external stimulus was adjusted such that VU meter deflection was maintained at '0'.

2.2.2 Administration of developed word lists

All the 100 participants listened to all the 25 lists in quiet at 40 dB SL (Ref: PTA). The words were routed through a personal laptop and delivered through Senheisser HDA 200 headphones of a calibrated audiometer. The participants were instructed to repeat the words and the responses were recorded on a scoring sheet. Every correct response was given a score of 1 and a score of 0 was given for incorrect responses or failure to repeat the words. The word lists were also presented at 0 dB SL, 10 dB SL, 20 dB SL and 30 dB SL to 30 out of 100 individuals with normal hearing sensitivity in order to obtain a psychometric function of performances with the word lists across intensity levels (PI-PB function). The order of presentation of word lists was randomized in order to avoid the order effect. In order to avoid practice effect, the word list was first presented at 0 dB SL and then at 10 dB SL. The testing was done at 20 dB SL and 30 dB SL after a break of five days.

2.3 Phase III: Assessing the clinical utility in individuals with hearing impairment

The individuals with acquired sensorineural hearing impairment consisted of 10 individuals with age ranging from 18 to 55 years (mean = 36.07 ± 9.07 years) in each of the different degrees of hearing loss i.e., mild (40.2 ± 6.98 years), moderate (36.6 ± 7.19 years), moderately-severe (33 ± 11.53 years) and severe (34.5 ± 9.50 years). The ears were selected randomly if the loss was bilateral or the ear having the required degree of hearing loss was selected for the study. If masking was required, the maximum effective masking was

provided in the contralateral ear. The configuration of audiogram was restricted to flat type. The speech identification scores were in agreement with the degree of hearing loss, suggesting a cochlear hearing loss (Duhno, Lee, Klein, Matthews, & Lam, 1995). All the participants had 'A' type tympanogram and reflexes were appropriate to their degree of hearing loss. All the participants had normal speech and language abilities as reported and observed. The participants listened to all the 25 lists in quiet at 40 dB SL (Ref: PTA). The words were routed through a personal laptop and delivered through Senheisser HDA 200 headphones of a calibrated audiometer. The participants were instructed to repeat the words and the responses were recorded on a scoring sheet. Every correct response was given a score of 1 and a score of 0 was given for incorrect responses or failure to repeat the words.

2.4 Analysis

The data were tabulated and statistically analysed in Statistical package for the Social Sciences (SPSS) software version 21. The Shapiro Wilks test of normality revealed that the data obtained from the individuals with normal hearing sensitivity were not normally distributed and the data obtained from the individuals with hearing impairment were distributed normally. Hence, Non-parametric statistics (Friedman test) were carried out for data obtained from the individuals with normal hearing sensitivity and whereas ANOVA and Bonferroni pairwise comparison were done on the data obtained from the individuals with hearing impairment. Cronbach's alpha measures were carried to assess the homogeneity and the intra-class correlation coefficient. To assess the test- retest reliability 10% from individual with normal hearing group were tested again with all the 25 word lists developed. To statistically measure the reliability a Cronbach's alpha measure was measured.

Results

The study aimed at developing and standardising a Tamil word test in individuals with normal hearing sensitivity. The clinical utility of the developed word lists on individuals with hearing impairment was also assessed.

3.1 Development of word lists

A pool of 1015 bisyllabic words in Tamil language were collected through various resources. All the words were subjected to familiarity rating and content validation. After familiarity rating and content validation, 760 words were finalised for the preparation of 25 phonemically balanced word lists. Each developed list has 25 words.

3.2 Standardization of the developed word lists and assessing the consistency of the lists in individuals with normal hearing sensitivity

Twenty five word lists were administered on 100 individuals with normal hearing sensitivity at 40 dB SPL. The number of correctly identified words, here after referred to as speech identification scores (SIS), for each list was calculated. The mean and standard deviation (SD) of the SIS at 40 dB SL are given in Table 3.1.

Table 3.1 Mean and SD of speech identification scores for 25 lists at 40 dB SL obtained on individuals with normal hearing sensitivity

Lists	Mean	SD	Lists	Mean	SD	Lists	Mean	SD
List 1	24.96	0.19	List 11	24.97	0.17	List 21	24.98	0.14
List 2	24.93	0.25	List 12	24.97	0.17	List 22	24.94	0.23
List 3	24.96	0.19	List 13	24.99	0.10	List 23	24.99	0.10
List 4	24.95	0.19	List 14	24.95	0.26	List 24	24.99	0.10
List 5	24.98	0.14	List 15	24.98	0.14	List 25	24.99	0.10
List 6	24.98	0.14	List 16	24.96	0.19			
List 7	24.95	0.26	List 17	24.96	0.19			
List 8	24.97	0.17	List 18	24.94	0.23			
List 9	24.98	0.14	List 19	24.96	0.19			
List 10	24.94	0.23	List 20	24.94	0.23			

Note. Maximum possible score = 25.

For the standardization of the 25 developed word lists, the SIS was obtained at 40 dB SL (ref: hearing threshold) on 100 normal hearing individuals. From the Table 3.1, it can be observed that the minimum and the maximum scores obtained across all the lists in individuals with normal hearing sensitivity are 24.93 (99.72 %) and 25 (100%). The grand mean average across the lists is found to be 99.77% in individuals with normal hearing sensitivity. Shapiro-Wilks test of normality revealed non-normal distribution of the data and hence, non-parametric measures were used for further analyses. Friedman test was carried out to see whether there is a significant difference in the SIS of individuals with normal hearing sensitivity across 25 words lists. The results of Friedman test revealed no significant difference ($\chi^2 = 28.527, p > 0.05$) across the 25 word lists.

To assess the test-retest reliability of the developed word lists, out of 100 individuals with normal hearing sensitivity, ten individual were assessed again with all the word lists after a month. The data were statistically compared using Cronbach's alpha measure to check the reliability of the developed word lists. Cronbach's alpha of ($\alpha = 0.86$) was obtained which denotes that the developed word lists have high test-retest reliability.

3.2.1 Assessment of homogeneity in terms of audibility

To assess whether all the lists are homogenous in terms of difficulty level, across different intensities, a psychometric function was drawn using Performance Intensity-Phonemically Balance function (PI-PB) test. The PI- PB test was carried out on 30 individuals with normal hearing sensitivity across five different sensation levels (0, 10, 20, 30 and 40 dB SL) and psychometric function was established for all the 25 word lists (Figure 3.1).

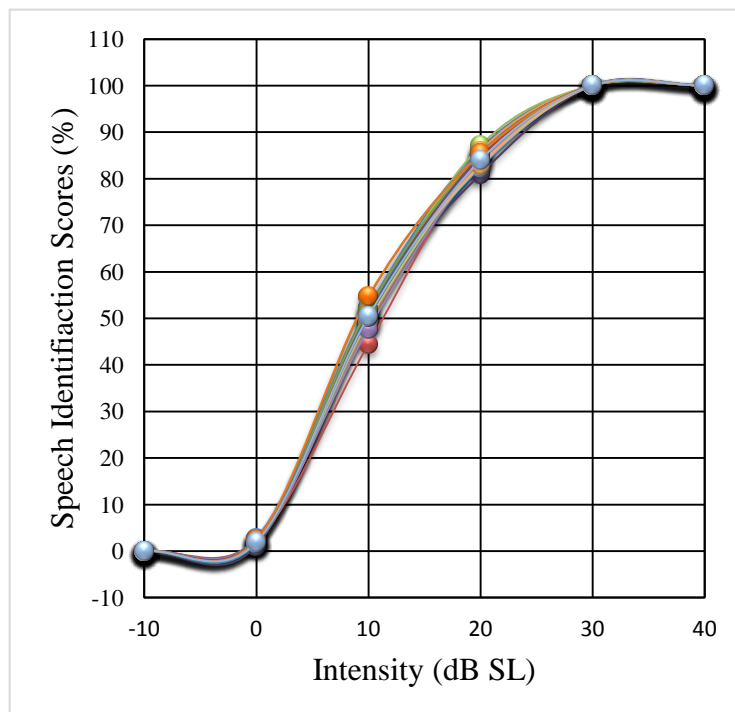


Figure 3.1 Graph representing the psychometric function curves for 25 word lists depicted in different colours

From the Figure 3.1, it is clear that with a gradual increase in intensity level there is a gradual increase in the SIS with a poor score of 0 to 4% at 0 dB SL and a 100% scores after 30 dB SL suggesting that the difficulty decreases as the intensity increases. The same is followed by all the lists indicative of homogeneity across lists.

Homogeneity of audibility was also measured using Cronbach's alpha test. Alisaputri (2006) reported that the measure of Cronbach's alpha value using intraclass coefficient at the 50% and 100% performance level provide information on the homogeneity of the word lists in terms of audibility. In the present study, the 50% percentage score was obtained at 10 dB SL and the ceiling was observed above 30 dB SL. Hence, SIS at these two levels was employed for homogeneity assessment in individuals with normal hearing sensitivity using Cronbach's alpha. The results are given in Table 3.2.

Table 3.2 Results of test of homogeneity in terms of audibility across all the word lists at 10 and 40 dB SL in individuals with normal hearing sensitivity

Group	α – value
Normal (10 dB SL)	0.984
Normal (40 dB SL)	0.987

From Table 3.2, it is evident that all the word lists are found to be in strong agreement in terms of audibility at 10 dB SL. The same results were found even at 40 dB SL.

3.2 Assessment of clinical utility on individuals with different degrees of hearing impairment

To assess the clinical utility of the developed word lists, the word lists were presented at 40 dB SL (ref: threshold of hearing) on 40 individual with hearing impairment with mild, moderate, moderately-severe and severe degree of hearing loss, with ten individuals in each degree of loss. The minimum and the maximum scores obtained across all the lists and all the groups are 14 (56%) and 25 (100%), respectively (Table 3.3). The grand mean average among all the groups and across the lists in the group with normal hearing sensitivity is 24.94 (99.77%), in the group with mild degree of hearing loss is 22.22 (88.88%), in the group with moderate degree of hearing loss is 19.76 (79.04%), in the group with moderately-severe degree of hearing loss is 16.33 (65.32%) and in the group with severe degree of hearing loss

is 14.58 (58.32%).

Table 3.3 Mean and SD of speech identification scores for 25 lists of PB words for all the groups

Groups	List 1		List 2		List 3		List 4		List 5	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Normal	24.96	0.19	24.93	0.25	24.96	0.19	24.95	0.19	24.98	0.14
Mild HL	21.8	1.55	22	1.41	22.3	1.70	22.2	1.55	22.5	1.27
Moderate HL	20.3	1.06	19.6	0.97	19.8	1.40	19.4	1.07	19.7	1.25
Moderately Severe HL	16.9	1.73	16.1	1.73	16.6	1.71	16.1	1.52	16.6	1.58
Severe HL	14	1.25	15.1	1.19	14.4	1.07	14.1	1.85	14.7	1.57
Groups	List 6		List 7		List 8		List 9		List 10	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Normal	24.98	0.14	24.95	0.26	24.97	0.17	24.98	0.14	24.94	0.23
Mild HL	22.5	1.18	21.8	1.03	22.7	1.70	22.4	1.50	22.1	1.66
Moderate HL	19.6	1.71	19.9	1.20	19.9	1.29	19.9	0.99	19.8	1.69
Moderately Severe HL	15.9	1.91	16.7	2.00	16.5	1.84	16.7	2.21	16.6	1.65
Severe HL	14.4	1.07	14.3	1.41	14.9	1.45	14.5	1.78	14.7	1.50
Groups	List 11		List 12		List 13		List 14		List 15	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Normal	24.97	0.17	24.97	0.17	24.99	0.10	24.95	0.26	24.98	0.14
Mild HL	21.9	1.37	22.3	1.49	22	1.56	22.7	1.63	22.4	1.43
Moderate HL	19	1.33	19	1.70	19.9	1.66	19.9	1.29	20.3	1.57
Moderately Severe HL	16	2.10	15.3	3.49	16.8	1.47	16.4	2.06	16.5	1.58
Severe HL	14.3	1.42	14.4	1.58	14.8	1.32	14.5	1.65	14.5	1.08
Groups	List 16		List 17		List 18		List 19		List 20	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Normal	24.96	0.19	24.96	0.19	24.94	0.23	24.96	0.19	24.94	0.23
Mild HL	21.7	1.57	21.6	1.35	21.9	1.66	22.7	1.06	22.3	1.06
Moderate HL	19.9	1.20	20.1	0.99	20.1	0.88	20	1.56	20	1.63
Moderately Severe HL	16.5	1.71	16.4	1.34	16	1.49	16.3	1.64	16.7	0.95
Severe HL	14.6	1.43	14.8	1.40	14.8	1.62	15	1.05	14.5	0.97
Groups	List 21		List 22		List 23		List 24		List 25	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Normal	24.98	0.14	24.94	0.23	24.99	0.10	24.99	0.10	24.99	0.10
Mild HL	22.8	1.40	22.6	0.97	21.9	1.20	22.4	1.50	22	1.15
Moderate HL	19.5	1.90	19.7	1.49	19.3	0.82	19.5	1.18	20	1.25
Moderately Severe HL	15.9	1.52	16.1	1.96	15.8	1.75	16.3	1.34	16.6	1.07
Severe HL	14.7	1.33	14.8	1.62	14.5	1.18	14.6	1.17	14.8	1.23

Note. Maximum possible score = 25.

3.2.1 With-in group assessment of consistency of the lists in individuals with hearing impairment

The normality results using Shapiro-wilks test of normality revealed normal distribution of the data and hence, parametric test were employed for further analysis. A repeated measure ANOVA was carried out to compare the performance of individuals with hearing impairment across each lists and the result of the same is given in Table 3.4.

Table 3.4 Within-Group Comparison of Speech Identification Scores of Individuals with Hearing Impairment across 25 Word Lists.

Groups	F value
Mild	$F_{(24,216)} = 1.118, p > 0.05$
Moderate	$F_{(24,216)} = 1.136, p > 0.05$
Moderately Severe	$F_{(24,216)} = 1.143, p > 0.05$
Severe	$F_{(24,216)} = 0.627, p > 0.05$

It can be seen in the Table 3.4 that there was no significant difference in the performance across the word lists in any of the groups. Therefore, the word lists can be used interchangeably in individuals with hearing impairment for assessing speech identification ability in Tamil language.

3.2.2 Assessment of clinical utility of the developed word lists to different degrees of hearing loss

Between-group comparison was done across the lists to check how the performance of speech identification varied across different degrees of hearing loss using one-way ANOVA. The results of one way ANOVA are given in Table 3.5.

Table 3.5 Between-group comparisons of speech identification scores across 25 lists

Lists	F value	Lists	F value
List 1	$F_{(4,135)} = 729.97, p < 0.001$	List 11	$F_{(4,135)} = 649.13, p < 0.001$
List 2	$F_{(4,135)} = 741.87, p < 0.001$	List 12	$F_{(4,135)} = 350.36, p < 0.001$
List 3	$F_{(4,135)} = 656.39, p < 0.001$	List 13	$F_{(4,135)} = 632.63, p < 0.001$
List 4	$F_{(4,135)} = 688.59, p < 0.001$	List 14	$F_{(4,135)} = 507.76, p < 0.001$
List 5	$F_{(4,135)} = 719.75, p < 0.001$	List 15	$F_{(4,135)} = 720.94, p < 0.001$
List 6	$F_{(4,135)} = 703.31, p < 0.001$	List 16	$F_{(4,135)} = 655.00, p < 0.001$
List 7	$F_{(4,135)} = 665.10, p < 0.001$	List 17	$F_{(4,135)} = 852.93, p < 0.001$
List 8	$F_{(4,135)} = 564.83, p < 0.001$	List 18	$F_{(4,135)} = 680.88, p < 0.001$
List 9	$F_{(4,135)} = 523.15, p < 0.001$	List 19	$F_{(4,135)} = 752.74, p < 0.001$
List 10	$F_{(4,135)} = 531.57, p < 0.001$	List 20	$F_{(4,135)} = 952.52, p < 0.001$
Lists	F value		
List 21	$F_{(4,135)} = 647.10, p < 0.001$		
List 22	$F_{(4,135)} = 595.69, p < 0.001$		
List 23	$F_{(4,135)} = 1002.92, p < 0.001$		
List 24	$F_{(4,135)} = 906.77, p < 0.001$		
List 25	$F_{(4,135)} = 1043.67, p < 0.001$		

From Table 3.5, it can be seen that there exists a significant difference in SIS on all the lists across different degrees of hearing impairment. Hence, Bonferroni pair-wise comparison was carried out to further analyse the groups having significant difference. The results of Bonferroni pair-wise comparison are given in Table 3.6. The results revealed a significant difference between all the groups across all the lists.

Table 3.6 Bonferroni Pairwise comparison between groups across different lists

Group (A)	Group (B)	Mean difference (A-B)									
		List 1	List 2	List 3	List 4	List 5	List 6	List 7	List 8	List 9	List 10
Normal	Mild HL	3.16***	2.93***	2.66***	2.76***	2.48***	2.48***	3.15***	2.27***	2.58***	2.84***
	Moderate HL	4.66***	5.33***	5.16***	5.56***	5.28***	5.38***	5.05***	5.07***	5.08***	5.14***
	Moderately Severe HL	8.06***	8.83***	8.36***	8.86***	8.38***	9.08***	8.25***	8.47***	8.28***	8.34***
	Severe HL	10.96***	9.83***	10.56***	10.86***	10.28***	10.58**	10.65***	10.07***	10.48***	10.24***
Mild HL	Moderate HL	1.50**	2.40***	2.50***	2.80***	2.80***	2.90***	1.90**	2.80***	2.50***	2.30***
	Moderately Severe HL	4.90***	5.90***	5.70***	6.10***	5.90***	6.60***	5.10***	6.20***	5.70***	5.50***
	Severe HL	7.80***	6.90***	7.90***	8.10***	7.80***	8.10***	7.50***	7.80***	7.90***	7.40***
Moderate HL	Moderately Severe HL	3.40***	3.50***	3.20***	3.30***	3.10***	3.70***	3.20***	3.40***	3.20***	3.20***
	Severe HL	6.30***	4.50***	5.40***	5.30***	5.00***	5.20***	5.60***	5.00***	5.40***	5.10***
Moderately Severe HL	Severe HL	2.90***	1.00*	2.20***	2.00***	1.90***	1.50***	2.40***	1.60***	2.20***	1.90***
		List 11	List 12	List 13	List 14	List 15	List 16	List 17	List 18	List 19	List 20
Normal	Mild HL	3.07***	2.67***	2.99***	2.25***	2.58***	3.26***	3.36***	3.04***	2.26***	2.64***
	Moderate HL	5.97***	5.97***	5.09***	5.05***	4.68***	5.06***	4.86***	4.84***	4.96***	4.94***
	Moderately Severe HL	8.97***	9.67***	8.19***	8.55***	8.48***	8.46***	8.56***	8.94***	8.66***	8.24***
	Severe HL	10.67***	10.57***	10.19***	10.45***	10.48***	10.36***	10.16***	10.14***	9.96***	10.44***
Mild HL	Moderate HL	2.90***	3.30***	2.10***	2.80***	2.10***	1.80***	1.50***	1.80***	2.70***	2.30***
	Moderately Severe HL	5.90***	7.00***	5.20***	6.30***	5.90***	5.20***	5.20***	5.90***	6.40***	5.60***
	Severe HL	7.60***	7.90***	7.20***	8.20***	7.90***	7.10***	6.80***	7.10***	7.70***	7.80***
Moderate HL	Moderately Severe HL	3.00***	3.70***	3.10***	3.50***	3.80***	3.40***	3.70***	4.10***	3.70***	3.30***
	Severe HL	4.70***	4.60***	5.10***	5.40***	5.80***	5.30***	5.30***	5.30***	5.00***	5.50***
Moderately Severe HL	Severe HL	1.70***	0.90	2.00***	1.90***	2.00***	1.90***	1.60***	1.20**	1.30**	2.20***
		List 21	List 22	List 23	List 24	List 25					
Normal	Mild HL	2.18***	2.34***	3.09***	2.59***	2.99***					
	Moderate HL	5.48***	5.24***	5.69***	5.49***	4.99***					
	Moderately Severe HL	9.10***	8.84***	9.19***	8.69***	8.39***					
	Severe HL	10.30***	10.14***	10.49***	10.39***	10.19***					
Mild HL	Moderate HL	3.30***	2.90***	2.60***	2.90***	2.00***					
	Moderately Severe HL	6.90***	6.50***	6.10***	6.10***	5.40***					
	Severe HL	8.10***	7.80***	7.40***	7.80***	7.20***					
Moderate HL	Moderately Severe HL	3.60***	3.60***	3.50***	3.20***	3.40***					
	Severe HL	4.80***	4.90***	4.80***	4.90***	5.20***					
Moderately Severe HL	Severe HL	1.20*	1.30**	1.30***	1.70***	1.80***					

Note: *** = $p < 0.001$, ** = $p < 0.01$, * = $p < 0.05$

3.2.3 Assessment of homogeneity of the word lists in individuals with hearing impairment

Homogeneity in terms of audibility was assessed in individuals with hearing impairment using the Cronbach's alpha. The Cronbach's alpha measured in the individual with hearing impairment are given in the Table 3.7.

Table 3.7 Measure of homogeneity across the word lists among different degree of hearing loss

Group	α – value
Mild Hearing loss	0.955
Moderate Hearing loss	0.966
Moderately severe Hearing loss	0.947
Severe Hearing loss	0.947

From the Table 3.5 it is clear that the developed word lists have a high alpha value. Hence, the developed material is highly homogenous even in individuals with hearing impairment.

Discussion

Researchers have developed word lists in several Indian languages and a few among them have been revised due to numerous reasons (Kapur, 1971; De, 1973; Dayalan, 1976; Tanuja, 1985; Gosh, 1988; Smeeta, 2004; Sreedhar, Venkatesh, Nagaraja and Srinivasan, 2011; Manjula, Geetha, Sharathkumar and Geetha, 2015; Dias, Devadas and Rajashekar, 2015; Kumar and Mohanty, 2016; Kumar, Mohanty, Ujwane and Huzurbazar, 2016; Mahima and Muthuselvi, 2017). The present study aimed to develop over 20 PB word lists in Tamil language and standardize them in normal and clinical population as currently there is no test that has these many lists in Tamil.

4.1 Development and standardization of word lists in individuals with normal hearing sensitivity

SIS of 25 words lists were compared on 100 individuals with normal hearing sensitivity in quiet and the overall mean combining all the 25 word lists was 99.8%. These scores are comparable with that obtained in many other word lists. The mean score of Kannada PB word lists was 98% (Manjula et al., 2015). Mahima and Muthuselvi (2017) reported a mean SIS of 98% for the four PB words lists developed in Tamil. Ullrich and Grimm (1976) administered NU-6 word lists in individuals with normal hearing and reported of 99.7% score at most comfortable level. Whereas Beattic, Edgerton and Svihovccc (1977) assessed CID W-22 and NU-6 test material to evaluate SIS in individuals with normal hearing and obtained approximately a score of 95% at 32 dB SL. The reason for such high scores at most comfortable level in individual with normal hearing sensitivity is the intact auditory system and attention. Hence, above the most comfortable listening level, almost all the individuals with normal

hearing sensitivity will achieve a 100% (Davis & Silverman, 1960) and the same has been found in the present study.

It is very important that consistency assessment is done as the measure of consistency guarantees that the SIS is comparable irrespective of the list used (Wilson & Margolis, 1983). The mean SIS across the lists in the current study is comparable in the group of individuals with normal hearing. This was reflected in the results of Friedman test where there was no significant difference across 25 word lists. This indicates that the SIS obtained with different word lists developed in the current study is comparable and hence, they are interchangeable.

A psychometric equivalency of the lists was also assessed across different intensities. All the sigmoid curves were coinciding for all the lists suggestive of homogeneity of word lists. . The scores at 10 dB SL revealed a score of 50.56% with ceiling in scores above 30 dB SL. Manjula et al. (2015) also obtained a near to 50% score at 10 dB SL and observed a plateau after 30 dB SL when they assessed in individual with normal hearing across different intensity levels. The trend is similar in the study done by Mahima and Muthuselvi (2017) with a ceiling in the scores after 30 dB SL and near to 50 % scores at 10 dB SL. Even though the PI function curve act as measure to assess the list equivalency of a developed test lists, assessment of homogeneity in terms of audibility will strengthen the consistency of the developed word lists. Hence, the homogeneity of audibility was measured statistically using Cronbach's alpha measures with the support from a study done by Alisaputri (2006). Alisaputri (2006) measured SIS at two dial settings i.e., at 15 dB and 40 dB SL, in Malay language. The homogeneity of audibility of Malay PB word lists was assessed using Cronbach's alpha and the results revealed a high alpha value of 0.81. The results of the study were in agreement to the study done on developing word lists.

Hence, it is to be believed that 25 PB word lists in Tamil developed in the current study is found to be useful to assess SIS in quiet, and the lists are interchangeable during the course of testing as there is homogeneity between the lists in terms of difficulty and audibility.

4.2 Clinical utility of the developed word lists

Evaluation of clinical utility of the 25 word lists on adults with different degrees of hearing impairment showed significant differences in the performance among individuals with hearing impairment of varying degrees. The grand mean SIS was 22.2 (88.8%), 19.76 (79.05%), 16.32 (65.32%) and 14.58 (58.35) for mild, moderate, moderately-severe and severe hearing loss, respectively. The performance reduced as the degree of hearing loss increased. The result of the study is in agreement with that of Manjula et al. (2015), Muthuselvi and Mahima (2017) and Dias et al. (2015).

The possible reason for the decrement in the performance of SIS as the loss increases is due to the loss of cochlear nonlinearity, decreased frequency selectivity and temporal resolution, increased upward spread of masking and possible presence of dead region as the loss progresses (Plomp, 1994; Moore, Lynch & Stone, 1992; Moore et al., 2000). Because of the aforementioned factors with an increase in the degree of hearing impairment impairs the individual's speech perception abilities (Pekkerinan, Salmivalli, & Suompa, 1990). Hence, 25 PB word lists developed in the present study is sensitive to different degrees of hearing loss and hence, can be administered on clinical population. In addition, the test re-test reliability assessment revealed a high alpha value indicating a strong agreement between the test and re-test scores for all 25 word lists. The results of the study is in agreement with other research findings on the development of word lists revealing a high test re-test reliability measure ($\alpha = < 0.96$) using Tamil PB word list

(Muthuselvi & Mahima, 2017) and in Konkani language also test re-test reliability was measured on 20 individual with normal hearing a strong agreement was established between both the measures (Dias, Devadas & Rajashekhar, 2015).

Summary and Conclusions

Speech audiometry has become an essential component in the audiological test battery. Various speech audiometry materials have been developed in different languages and also revised later to meet the criteria such as familiarity of the words, phonetic/ phonemic balance, number of test items and dialectal variations. The current study focussed on developing multiple PB word lists in Tamil language for adults. The study was structured in three phases. Phase I involved the development of PB word lists in Tamil. Phase II involved standardization of the developed word lists, and phase III involved assessing the clinical utility of the lists on individuals with hearing impairment.

A pool of 1015 bisyllabic Tamil words were sourced and these were subjected to familiarity rating and content validated. After these, 760 words were selected for phonemic balancing and 25 word lists were prepared with each list consisting of 25 words each in it. SIS was assessed on 100 individuals with normal hearing sensitivity using all the 25 word lists at 40 SL. Thirty of these 100 individuals were presented the word lists at different intensity levels to obtain PI- PB function. After which the same lists were validated on individuals with hearing impairment. For validation, 40 individuals with different degree (mild, moderate, moderately-severe and severe) of hearing impairment were included.

The mean SIS in adults with normal hearing sensitivity ranged from 99.72% to 100%. The SIS of adults with normal hearing sensitivity revealed no significant difference ($p > 0.05$)

across the 25 word lists indicating list equivalency. The performance-intensity function in adults with normal hearing sensitivity revealed that SIS score increased as the sensation level increased from 10 dB SL to 40 dB SL for all the lists which is suggestive of homogeneity among all the lists. Mean SIS scores for adults with mild, moderate and severe hearing loss were found to be 88.88%, 79.04%, 65.32%, and 58.32% respectively. A significant decrease in SIS was observed as the degree of hearing loss increased ($p < 0.05$). The developed 25 bisyllabic word list in Tamil has a high test re-test reliability in individuals with normal hearing sensitivity as well as in hearing impairment.

Hence these developed 25 word lists can be utilised for SIS testing in Tamil language for adults during routine audiological evaluation. These developed word list can also be used for assessing hearing aid benefit and for research purpose in normal hearing individuals as well as in clinical population.

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APPENDIX 1

S.NO	List 1		List 2		List 3		List 4		List 5	
1	கீற்று	kitrU	கூழல்	sUla	துணி	tUnI	புதர்	pUdər	சடை	səḍaɪ
2	வளம்	valəm	திகில்	ḍiḡil	துறை	tUraɪ	விலை	vilaɪ	நத்தை	naṭṭaɪ
3	ரம்பம்	rəmbəm	மடை	məḍaɪ	வினை	viṇaɪ	பாசி	pa:si	வீரர்	viṛər
4	தலை	talaɪ	பயிர்	pəjir	பயம்	bəjəm	சித்தாள்	siṭṭa:l	நகம்	naḡəm
5	தச்சன்	tṭəṭṭən	குல்லா	ḡuḷḷa:	மழை	məḷaɪ	நேயர்	nejər	வெப்பம்	veppəm
6	நாணம்	na:ṇəm	தாயம்	ḍa:jəm	மாடு	ma:ḍU	கத்தி	kaṭṭi	தரம்	tā:rəm
7	வாசல்	va:səl	புள்ளி	puḷḷi	நெடில்	neḍil	மல்லி	mālḷi	சீட்டு	siṭṭu
8	தமிழ்	tamiḷ	கப்பம்	kaḡḡəm	சோளம்	soləm	ரூபாய்	rūba:j	கொல்லன்	kaḷḷan
9	நண்பன்	naṇḡbən	மேதை	meḍaɪ	கனல்	kaṇəl	மோகம்	mogaḡəm	சிப்பி	sippi
10	கண்மாய்	kaṇḡma:j	வங்கி	vaṅḡi	துச்சம்	tUṭṭəm	முட்டை	mUṭṭaɪ	கட்டம்	kaṭṭəm
11	செடி	ṭeḍḍi	வீடு	viḍḍu	நலம்	naḷəm	சேனை	senai	குட்டி	kuṭṭi
12	கனா	kaṇa:	காளை	ka:ḷaɪ	மிதி	miḍḍi	புகை	puḡaɪ	யூகம்	juḡəm
13	சண்டை	saṇḍaɪ	பஞ்சை	paṇḍaɪ	கஷ்டம்	kaṭṭəm	மங்கை	maṅḡaɪ	பள்ளம்	paḷḷəm
14	காற்று	ka:ṭru	விந்தை	viṇḍaɪ	குளிர்	kuḷḷir	தோசை	ḍosaɪ	சுழி	sUḷi
15	பேதை	peḍaɪ	துண்டு	tUṇḍu	தீங்கு	tīṅḡu	ரயில்	raɪl	மன்னன்	maṇṇən
16	பொம்மை	paṃmaɪ	கண்டம்	kaṇḍəm	புலன்	puḷan	கம்பம்	kaṃḡbəm	பானம்	pa:ṇəm
17	கோழி	koḷi	நெற்றி	neṭṭri	தினை	tinaɪ	வேட்டி	veṭṭi	திடல்	tḷḍəl
18	காடை	ka:ḍaɪ	சிரி	siṭṭi	பூச்சி	puṭṭi	கூட்டு	kuṭṭu	குறள்	kuṛəl
19	யுத்தம்	juṭṭhəm	செவி	sevi	ராகம்	ra:ḡəm	சிறுறுர்	siṭṭurur	தயிர்	təjir
20	பள்ளி	paḷḷi	நேற்று	neṭṭru	சிரம்	siṛəm	நெறி	neṛi	லுங்கி	luṅḡi
21	வடை	vaḍaɪ	மணி	maṇi	மையம்	maɪəm	தணல்	tṭanəl	சவால்	sa:val
22	கதை	kaḍaɪ	பேச்சு	peṭṭu	வெற்றி	veṭṭri	வள்ளல்	vaḷḷəl	பூமி	bumi
23	மரம்	maṛəm	முனை	muṇḡaɪ	வானம்	va:ṇəm	அனல்	anəl	மறை	maṛaɪ
24	சில	silē	குலம்	kuḷəm	குடல்	kuḍḍəl	புதர்	pUdər	துளை	tUḷaɪ
25	யானை	ja:ṇaɪ	ரதம்	raḍḍəm	சபா	saḡa:	விலை	vilaɪ	தோணி	tōṇi

S.NO	List 6		List 7		List 8		List 9		List 10	
1	மிகை	migaɪ	சுண்டல்	sUndəl	கிளை	kɪɻɪ	சரண்	səɻən	கூந்தல்	kundəl
2	கோடை	koḍaɪ	மௌனம்	məUnəm	சொத்தை	soṭṭaɪ	மயிர்	maɻɪɻ	பிறர்	piɻəɻ
3	நிரை	niraɪ	காயம்	ka:jəm	ரத்தம்	ɻəṭṭəm	கவி	kəvi	காரம்	ka:ɻəm
4	கோதை	koḍaɪ	வேந்தன்	vendən	தண்ணீர்	ṭəṇṇiɻ	புதிர்	pUḍiɻ	வெள்ளம்	vēḷəm
5	கோபம்	kobəm	சூழல்	sUḷəl	வெல்லம்	vēḷəm	சூளை	sulaɪ	கதி	kəḍi
6	வேளாண்	vela:n	துளி	ṭḷɪ	முழம்	mUḷəm	சின்னம்	siṇṇəm	ரேகை	regaɪ
7	கொள்ளை	koṻɻɪ	பணம்	pəṇəm	தளம்	ṭələm	கால்வாய்	ka:lva:j	நெடி	neḍi
8	வேம்பு	vembU	நகை	nəgaɪ	முகாம்	mUga:m	கோழை	koḷaɪ	படை	pəḍaɪ
9	சாயம்	sa:jəm	சிமிழ்	siṁiḷ	யாகம்	ja:gəm	பேரன்	perən	சமம்	səməm
10	தறி	ṭəɻi	ஞானம்	ṇa:nəm	சரம்	səɻəm	நலன்	nələn	செயல்	sejəl
11	மைனா	maɻna:	சாலை	sa:lɻɪ	வடு	vəḍU	மதி	məḍi	பொதி	poḍi
12	மடல்	məḍəl	பீடம்	piḍəm	குயில்	kuɻiḷ	முற்றும்	mUṭṭrUm	மைந்தன்	məiṁḍən
13	வண்ணம்	va:ṇṇəm	கரை	kəɻaɪ	செல்வம்	selvəm	நங்கை	nəṅka:j	நாணல்	na:nəl
14	சினை	siṁaɪ	புறா	pUɻa:	கும்பம்	kuṁbəm	சினம்	siṁəm	கொலை	koḷaɪ
15	தட்டை	ṭəṭṭaɪ	வண்டு	vəṁḍU	கதிர்	kəḍiɻ	பலம்	bələm	வன்மம்	vəṅməm
16	நந்தி	nəṁḍi	சுள்ளி	sUṻi	சீப்பு	siṭṭpU	தென்றல்	ṭēṁḍrəl	பட்டம்	pəṭṭəm
17	கோப்பை	koṭṭaɪ	வேலை	velaɪ	மன்னர்	məṇṇəɻ	கணை	kəṅaɪ	பாலை	pa:lɻɪ
18	சிலிர்	siḷiɻ	நாட்டம்	na:ṭṭəm	பாண்டி	pa:ṁḍi	தளிர்	ṭələiɻ	கொள்கை	koḷgaɪ
19	சிறை	siɻaɪ	பித்தம்	piṭṭəm	முறம்	mUɻa:m	வயல்	vəɻəl	கோர்வை	koɻva:j
20	யுக்தி	juḷṭi	சத்து	saṭṭU	நிறை	niɻa:i	பசி	pəsi	சுற்றம்	sUṭṭṛəm
21	மதம்	məḍḍəm	கொக்கு	koḷḷU	சோலை	soḷaɪ	பொடி	poḍi	தேனீ	ṭeni
22	முழு	mUḷU	முதல்	mUḍəl	தங்கை	ṭəṅkaɪ	கெண்டை	kēṁḍaɪ	துளிர்	ṭḷiɻ
23	பாம்பு	pa:ṁbU	பறை	pəɻaɪ	போட்டி	poṭṭi	தொடை	ṭoḍaɪ	செழி	seli
24	லிங்கம்	liṅgəm	முகில்	mUgɪḷ	நாடு	na:ḍU	தொண்டு	ṭoṁḍU	சட்டம்	saṭṭṭəm
25	ராசி	ɻa:si	தேரை	ṭeɻaɪ	பனி	pəni	முகம்	mUgəm	மனை	məṅaɪ

S.NO	List 11		List 12		List 13		List 14		List 15	
1	நோம்பு	nombU	வெள்ளி	vēI	பலன்	pəɻən	தொண்டை	t̪oŋɖaɪ	தேங்காய்	tenga:j
2	சிகை	siɖaɪ	தோன்று	t̪oŋɖrU	களி	kəɻI	சுழல்	sUɻəɻ	மகள்	məɖəɻ
3	விளை	viɻaɪ	கபம்	kəbəm	தென்னை	t̪ēŋɖaɪ	கனி	kəni	தோகை	t̪oɖaɪ
4	புயல்	pUɻəɻ	கிளி	kiɻI	பசை	pəsəɻaɪ	வாலி	va:ɻI	மூன்று	muŋɖrU
5	திசை	t̪iɻaɪ	பணை	pəŋɖaɪ	சாவி	sa:vi	மகம்	məɖəm	பெயர்	pəjəɻ
6	தேமல்	t̪eməl	மேகம்	megəm	தீட்டு	t̪iṭṭa	பனை	pənaɪ	படம்	pəɖṭəm
7	செய்யுள்	səjjuɻ	சேட்டை	sēṭṭaɪ	புழு	pUɻU	கரி	kəɻI	யானம்	ja:nəm
8	பன்னிர்	pəŋiɻ	சூலை	sulaɪ	தெரு	t̪ēɻU	சரி	səɻI	குடம்	kUṭṭəm
9	துன்பம்	t̪uŋbəm	குனி	gUŋi	யோகம்	jogəm	துகில்	t̪uɖiɻ	நெய்தல்	nejṭṭəl
10	சுத்தம்	sUṭṭəm	மயில்	maɻiɻ	போற்றி	poṭṭiɻ	மந்தை	məŋɖaɪ	தலம்	t̪ələm
11	குலை	kUɻaɪ	நிகர்	niɖəɻ	வசி	vəsi	நெகிழ்	neɖiɻ	குரல்	kUɻəl
12	ரகம்	rəɖəm	பிறை	piɻaɪ	திரி	t̪iɻI	சாபம்	sa:bəm	செம்மல்	sēmṭəl
13	கொண்டை	koŋɖaɪ	வரன்	vəɻən	மகிழ்	məɖiɻ	பலி	pəɻI	தொழில்	t̪oɻiɻ
14	கேணி	keŋi	தோட்டா	t̪oṭṭa:	கோடி	koṭṭi	திட்டம்	t̪iṭṭəm	சூரன்	surən
15	குளம்	kUɻəm	விசை	viɻaɪ	தொடர்	t̪oṭṭəɻ	திணி	t̪iŋi	பன்மை	pəŋmaɻ
16	நரை	nəɻaɪ	சிலை	siɻaɪ	கன்னி	kəŋi	காசி	ka:si	வெண்பா	vəŋpa:
17	முறை	muɻaɪ	சுடர்	sUṭṭəɻ	குமிழ்	kUmiɻ	களம்	kəɻəm	வண்ணான்	vəŋa:n
18	பறி	pəɻI	பக்தி	bəkt̪i	பிணி	piŋi	புளி	pUɻi	பிள்ளை	piɻṭṭaɪ
19	மாந்தர்	ma:ŋɖəɻ	கட்டில்	kəṭṭiɻ	கோட்டை	koṭṭaɪ	சீற்றம்	siṭṭəm	வெள்ளை	vēṭṭaɪ
20	மலை	məɻaɪ	மின்னல்	miŋṭṭəl	செம்மை	sēmṭaɪ	நபர்	nəbəɻ	குடில்	kUṭṭiɻ
21	தசை	t̪əsəɻaɪ	பழம்	pəɻəm	மாற்றம்	ma:t̪rəm	பன்றி	pəŋɖri	தட்டு	t̪əṭṭU
22	வண்டி	vəŋɖi	தன்மை	t̪əŋmaɻ	வதம்	vəṭṭəm	வெயில்	vəjɻiɻ	சனி	səni
23	குழாய்	kUɻa:j	துக்கம்	t̪uɻkəm	ஞாலம்	ŋa:ləm	தாய்மை	t̪a:jmaɻ	சேர்க்கை	serkəɻaɪ
24	வினா	viŋa:	துயர்	t̪uɻəɻ	நீளம்	niɻəm	விடை	viṭṭaɪ	சான்று	sa:ŋɖrU
25	பீடா	biṭṭə	நூரை	nuɻaɪ	நஞ்சு	nəŋɖu	முயல்	muɻəɻ	நிலம்	niɻəm

S.NO	List 16		List 17		List 18		List 19		List 20	
1	மனம்	mənəm	மக்கள்	məkkaḷ	நிகழ்	nigal	மூர்க்கம்	murkəm	தேர்தல்	terdəl
2	கூடம்	kudəm	கட்டை	kaṭṭai	தெப்பம்	tēppəm	நொடி	noḍi	பண்ணை	paṅṅai
3	தடை	tṭadai	கோணம்	koṇəm	விழி	viḷi	தளிர்	tṭalir	பூனை	punai
4	மதில்	māḍil	குயில்	kuḷil	யுகம்	juḡam	சிக்கல்	siḱkal	மொழி	moḷi
5	நாற்று	na:ṭru	தாரம்	tā:ṛam	கலம்	kaḷam	கொய்யா	kojja	சூறை	sura:j
6	பூட்டு	puṭṭu	பிசின்	piṣin	மூட்டு	muṭṭu	கடை	kaḍai	கம்மாய்	kaṁma:j
7	சித்தர்	siṭṭar	தோப்பு	tōppu	பூட்டு	puṭṭu	முட்டாள்	muṭṭa:ḷ	காடு	ka:ḍu
8	கிழி	kiḷi	தாளம்	tā:ḷam	கடை	kaḍai	கறை	kaṛai	புதை	puṭai
9	சர்க்கார்	saṛka:ṛ	மயில்	maḷil	தானம்	dā:nəm	தூரம்	duṛam	தண்டல்	tṭandəl
10	சேவல்	seval	நிலை	nilai	கன்று	kaṇḍru	வழி	vaḷi	சுளை	suḷai
11	பண்டம்	paṇḍam	பீடி	biḍi	நரி	naṛi	நாளை	na:ḷai	காலை	ka:ḷai
12	புலி	puḷi	வலம்	valam	தொய்வு	tōjvu	சிறு	siṛu	விறல்	viṛal
13	வேந்தர்	veṇḍar	சேட்டை	seṭṭai	சாணம்	sa:nəm	ரொட்டி	roṭṭi	சட்டை	saṭṭai
14	சம்பா	saṁba:	பிழை	piḷai	மேற்கு	meṛku	பொய்மை	pojmai	துயர்	tṭujar
15	வேட்டி	veṭṭi	சத்தம்	saṭṭam	சின்னம்	ciṇṇam	செவ்வாய்	sevva:j	வயம்	vaḷam
16	கேடு	keḍu	குறை	kuṛai	தொட்டில்	tōṭṭil	மணல்	maṇal	கனல்	kaṇal
17	தேக்கம்	tēkəm	தினம்	ḍinam	கொள்ளி	koḷḷi	பல	paḷa	வெறி	veṛi
18	குறி	kuṛi	களம்	kaḷam	சளி	saḷi	பதம்	paḍam	நகர்	naḡar
19	பிணம்	piṇam	நாவல்	na:val	சிப்பாய்	siṭpa:j	பீங்கான்	piṅga:n	தொகை	tōḡai
20	மாலை	ma:ḷai	காட்சி	ka:ṭṭi	முல்லை	muḷḷai	தானம்	dā:nəm	நெஞ்சம்	neṇḍam
21	தக்கை	tṭakai	தோற்றம்	tōṭṛam	வீரம்	viṛam	சிப்பாய்	siṭpa:j	செம்மை	seṁmai
22	நேரம்	neram	மேசை	mesai	மறு	maṛu	தீனி	tīni	கள்ளி	kaḷḷi
23	யாளி	ja:ḷi	வனம்	vaṇam	தலா	tāla:	வேங்கை	veṅḡ ai	படி	paḍi
24	மூளை	muḷai	சுரி	suṛi	தாயார்	tā:ja:ṛ	சாயல்	sa:jal	பேரூர்	perur
25	ரசம்	ṛasam	மேடை	meḍai	பிடி	piḍi	தயை	tajaj	மலர்	maḷar

S.NO	List 21		List 22		List 23		List 24		List 25	
1	காலம்	ka:ləm	மறை	məṛaɪ	புள்ளி	pUḷi	நன்று	nəndrU	சாறு	sa:rU
2	நிலா	nila:	சேனை	senai	கரி	kəri	ரகம்	rəgəm	கன்னி	kəṇi
3	நீளம்	niləm	கோடி	koḍi	தடி	təḍi	நஷ்டம்	nəḷṭəm	சோர்வு	soṛvU
4	மாயம்	ma:jəm	பயிர்	paɪr	கரு	kəru	கொடு	koḍa	பண்டம்	pəṇḍəm
5	மூட்டை	muṭṭai	கூர்மை	kurmai	ரோமம்	roməm	வளி	vəḷi	பய்யன்	paɪjəm
6	பன்னீர்	pəṇṇir	வெண்மை	venmai	குழை	kuḷai	குடை	kuḍai	மூடி	muḍi
7	பொருள்	poruḷ	நயம்	naɪm	துயர்	tuyar	மாதம்	ma:ḍəm	கோவில்	kovil
8	சணல்	ṣəṇal	திடம்	tiḍəm	சிற்பம்	siṛppəm	செய்தி	seɪṭi	தரம்	taram
9	சக்கை	ṣəkai	ரொக்கம்	rokkəm	சினம்	sinəm	தென்னை	tēnnai	கிழி	kiḷi
10	சுக்கு	ṣukku	பற்று	paṭru	வன்மை	vanmai	பசு	paṣu	முறம்	muṛəm
11	மொட்டை	moṭṭai	பொது	potu	மடை	maḍai	கன்னம்	kannəm	சொத்து	ṣoṭṭu
12	சொந்தம்	ṣoṇḍəm	கண்கள்	kaṅkaḷ	நுங்கு	nuṅku	பகல்	paḡal	கலை	kaḷai
13	குறில்	kuṛil	சின்னம்	ṣinnəm	கள்ளம்	kaḷḷəm	சொள்ளு	ṣoḷḷu	தயை	tai
14	வரம்	vaṛəm	நிழல்	niḷal	முத்தம்	mutṭəm	சுற்றம்	ṣuṭṭrəm	தூண்டில்	tūṇḍil
15	கள்ளம்	kaḷḷəm	தரை	tarai	பந்து	paṇḍu	தேர்வு	tērvu	கீரி	kiṛi
16	பழி	paḷi	சுடு	ṣuḍu	பீடை	pidai	விழா	viḷa:	கோலம்	koləm
17	சட்டி	ṣaṭṭi	சிலர்	ṣilar	சிதை	ṣidai	துலாம்	tula:m	பணி	paṇi
18	தனி	ṭani	துணை	tunai	கதர்	kaṭar	மடம்	maḍəm	நீச்சல்	niṭṭal
19	தோற்று	toṭru	மூளை	mulai	சன்னம்	ṣannəm	மாரி	ma:ri	பாடம்	pa:ḍəm
20	கும்பு	kumba	தடம்	tḍəm	வர்ணம்	vaṛṇəm	சுயம்	ṣujəm	விண்மீன்	vinmim
21	தையல்	ṭaiyal	பூர்த்தி	puṛṭṭi	பலா	pala:	மேகம்	megəm	நேர்மை	nermai
22	தப்பு	ṭappa	சாக்கு	ṣa:kku	வலை	valai	குணம்	guṇəm	பாளை	pa:ḷai
23	தவில்	ṭavil	வலி	vali	கயம்	kaɪm	லாபம்	la:bəm	தூளி	tulṭi
24	மடி	maḍi	கேப்பை	keppai	நிறம்	niṛəm	பயன்	paɪṇ	கனம்	kaṇəm
25	வாய்க்கால்	va:ɪka:l	வள்ளல்	vaḷḷal	சாட்டை	ṣa:ṭai	பதில்	paḍil	மதி	maṭi