HIGH FREQUENCY SPEECH IDENTIFICATION TEST IN TAMIL

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Abstract

The present study aimed at developing and standardising a high frequency speech identification test in Tamil. The study was carried out in two phases. Phase I involved the development of High frequency word lists while in phase 2 these words were standardised on 100 normal hearing individuals. Two lists of bisyllabic high frequency words and one list of trisyllabic high frequency words were developed. The mean speech identification scores for all the three lists were above 99%. Comparison across the 3 lists showed that any of the 3 lists can be used to obtain high frequency speech identification scores and can also be used in providing amplification for individuals with high frequency hearing loss.

Introduction

Speech communication is so important that it is rightly considered to be the most characteristic feature of the human race (Plomp, 2002). The two components, speech perception and production are closely related and have been studied extensively for decades.

The acoustic information carried by speech is quite complex and has many dynamic variations. Sounds are by their nature dynamic, changing over time in terms of level and spectral content. In general, consonants contribute primarily to speech intelligibility while vowels contribute to the power of speech (Niemeyer, 1967). Hence, it is important that one identifies consonants properly if have to understand speech better. This requires the identification of place as well as manner of articulation which in turn are cued by dynamic filter cues like closure duration, burst and transition (Dorman, Studdert- Kennedy & Rapheal, 1977). The spectral cues for place and manner of articulation of different speech sounds are given in Table 1.

Table 1: The spectral energy and the major cues for perception of consonants.

Phonemes	Energy spectrum	Place cue	Manner cue
/s/	2000-4000 Hz	Spectral properties – F2 transition, noise duration and amplitude (overall and relative amplitude)	Duration of frication noise, amplitude of noise component and fundamental frequency at vowel onset
/♠/	3500 Hz		
/f/	6800-8400 Hz		
/k/	1500 – 4000 Hz	Frequency position of burst, F2 transition, spectral pattern, voice onset time	Stop gap, silence, closure duration, duration of preceding vowel, F1 cutback
/t□/	Above 4000 Hz		
/d☪/	2500 Hz	Duration of noise segment Rise time of noise segment	Frication duration, closure duration.

The above table represents the spectral energy of the consonants and the major cues for the perception given by Hughes and Halle (1956).

Evaluating a person's ability to understand conversational speech is a difficult task because conversational speech sounds are strung together in a variety of ways. For this reason audiologists traditionally limit their tests to two important measures, which are the speech recognition threshold and speech identification scores. Most of the speech identification tests use phonetically balanced word list that are standardized on individuals having flat audiometric configuration. The performance on these tests may overestimate speech perception in individuals with sloping high frequency hearing loss as the spectral information in the frequency (below 2 kHz) regions where the hearing is normal could help in perception. Furthermore, the speech perception in noise particularly becomes more difficult for these individuals, in the background noise conditions as background noise masks the low frequencies information that was otherwise available in facilitating perception.

Hence there was a need to develop High frequency Speech Identification Test. The first high frequency word list was developed by Gardner (1971). Gardner developed a word list that contained consonants of high frequency spectral energy and used it for testing speech discrimination in cases of high frequency hearing loss. Though it was specifically designed for application of hearing aid selection it was reported to be useful for auditory training as well.

Maroonroge and Diefendorf (1974) administered 3 words lists; North-western Auditory Test No. 6, the California Consonant Test, and Pascoe's High-Frequency Test, in two groups of individuals. Group 1 consisted of individuals with normal hearing up to 2 kHz accompanied by a high-frequency loss, while individuals in Group 2 had normal hearing even between 2 and 8 kHz. Results of the study showed that individuals in the Group 1 scored near normal scores on NU 6 test while scores were significantly lesser than that of normals on Pascoe's high frequency word list. The comparison between the 2 tests showed greater sensitivity of Pascoe's high frequency word list in determining the communicative handicap in the individuals with high frequency hearing loss.

Furthermore, an individual's perception of speech is reported to be influenced by his mother tongue (Singh & Black, 1966). De (1973) found that people consistently had better and optimum discrimination scores in their mother tongue as compared to other languages. On account of this, administering the test in a subject's native language is considered ideal. Since India is a multilingual country, there is a need to develop the tests in each of the languages. Although phonetically balanced speech identification tests have been developed in more than 7 Indian languages, there is a lack of High frequency word lists in all these languages. High frequency speech identification tests are developed only in Kannada (Kavitha, 2002), Hindi (Ramachandra, 2001) and English (Sudiptha, 2006). Speech identification scores obtained for High frequency word list is a better estimate for such individuals. Because such a list is not available in Tamil language the study is attempting to develop the test material.

Objectives

1) To develop high frequency word list in Tamil to determine speech identification scores in individuals with predominantly high frequency hearing loss.
2) Establish a normative for the newly developed material on normal hearing adults, who are native speakers of Tamil.

Method

The study was conducted in the following two phases.

Phase 1: The development of high frequency word list.

Phase 2: Standardization of the test material.

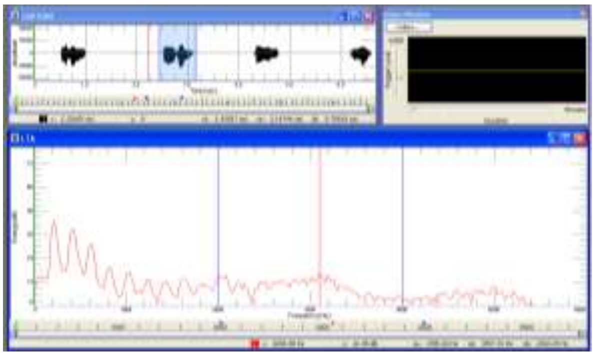
Phase 1: The Development of High Frequency Word List

Selection of the Words and Familiarization

Only the bisyllabic and trisyllabic words were considered to develop the test list as they were the smallest meaningful units and also would provide optimum redundant cues for the identification. The words were selected from different sources like newspapers, books, and magazines. Totally 355 words were collected for the purpose. Words with phonemes /k/, /t🗄/, /s/, /d🗄/, /r/, /d☪/, and /l/ were preferred as these phonemes have spectral energy predominantly distributed in the frequencies above 1 kHz (Hughes & Halle, 1956). These words were tested for familiarity. Thirty adults who were native speakers of Tamil were involved for this task. They were instructed to rate the words according to the frequency of occurrence on a three point scale of familiarity; most familiar, familiar and unfamiliar. Only the words that were most familiar to all of the subjects were selected for the construction of the test list. There were 111 such words out of the 355 selected words.

LTASS on the familiar words

LTASS was done to determine if the most familiar words had spectral information predominantly in the higher frequencies. This was necessary as the spectral information of the phonemes, /k/, /t🗄/, /s/, /d🗄/, /r/, /d☪/, /d/ and /l/ could differ depending on the context, and hence the so called high frequency word may not be having high frequency spectral information. LTASS was derived using CSL 4500 (as shown in figure1) and the spectral information was determined manually. The peak frequency of the spectra was taken as the target parameter. Peak frequency was defined as the frequency having highest energy concentration. Peak frequency in LTASS was also determined for the words in the phonetically balanced speech identification test **(**Prakash, 1998**).** This was required for the comparison of the spectra between the two. A total of 75 words had spectral information at significantly higher frequencies compared to the phonetically balanced words.



Peak frequency

Figure 1 LTASS for a representative word.

Construction of Word Subtest

The 75 words that were available for the construction of high frequency test were further categorised into a bisyllabic and a trisyllabic list. There were 50 words in the bisyllabic list and 25 words in the trisyllabic list. The 50 bisyllabic words were further divided into 2 half lists. The frequency of occurrence of high frequency sounds was maintained same between the two half lists with bisyllabic words.

Recording of the Test Material

The recording was done in a sound treated room where the noise levels were as per the ANSI guidelines (1991). Test words spoken by 4 adult females and 4 adult males, who were native speakers of Tamil were recorded into a computer using Adobe Audition (version 1.0) software. These recorded materials were then perceptually rated and the speaker who spoke with the best clarity was chosen for the audio recording of final test list. The signal was digitized at a sampling rate of 16 kHz using 12 bit analog to digital and digital to analog converter housed within a computer. Each word was saved as a separate file. The recorded material was then edited to carry out noise and hiss reduction. The inter stimulus interval between the two words was set to 5 seconds.

Phase 2: Standardization of the Test Material

The developed test material was standardized by obtaining speech identification scores in 100 native speakers of Tamil. The participants were in the age range of 19-25 years and, had normal hearing sensitivity (< 15 dB HL) in the octave frequencies between 250 Hz and 8 kHz. There was no relevant past or present history of otological dysfunctioning. The information about the past history was collected through case history and results of pure tone audiometry and immittance was used to interpret the current status.

Test Procedure

After estimation of pure tone thresholds, the speech recognition threshold (SRT) was estimated through bracketing method using standardized Tamil words and the high frequency word identification lists developed in the phase I was played (through Philips CD player) at 40 dB SL (ref: SRT). All the participants were tested monaurally with all the three lists. Stimuli were presented through head phones and the order of the list was randomised.

Scoring

The responses were marked either 0 or 1. Each correct response was given a score of 1 and an incorrect response was given a score of 0.

The raw score was then converted to percentage as below

$$\text{Total score (\%)} = \frac{\text{Total number of correct responses}}{\text{Total number of words presented.}} \times 100$$

Statistical analysis

Statistical Package for the Social Sciences (version 10) software was used to carry out the statistical analysis. Descriptive statistics, Independent *t* test, One-way ANOVA and repeated measures ANOVA were the statistical tests used.

Results and Discussion

Development of the High Frequency Word List/s

Selection of the words and their familiarity

Initially a total 355 words were collected for the development of the high frequency speech identification test. These were bisyllabic and trisyllabic words. The words were then rated for their familiarity. The outcome was, of the 355 selected words, 111 words were rated as most familiar. Only those were considered for the development of the final list.

Results of LTASS of Target Words

LTASS of the target words was obtained to validate the spectral information of the words, to be included in the final test list. LTASS was done on 111 words that were reported as most familiar by the representative population. In each word, data of LTASS revealed the frequency range with predominant energy concentration. The spectral parameter that was noted down from the LTASS was peak frequency of the spectrum. The 111 most familiar words were categorized based on their peak frequency (Hz) as given in Table 2. The cut off peak frequencies considered were 1, 1.5, 2, 2.5 and 3 kHz.

Table 2: Mean and standard deviation (SD) of peak frequency in words above different cut off frequencies.

Cut off Frequency (Hz)	Number of words	Mean (Hz)	SD
1.0	111	1960	864
1.5	108	1964	860
2.0	75	2396	803
2.5	54	2790	599
3.0	19	3684	401

From the data given in Table 2, it can be inferred that, all the 111 most familiar words had predominant spectral information above 1 kHz. As the cut off frequency increased, the number words decreased.

LTASS was also administered on phonetically balanced word list in Tamil, developed by Prakash (1998). There were 50 words in the list. The mean peak frequency was 1278 Hz with standard deviation of 880 Hz.

To verify whether the spectral information of the most familiar words of the present study is significantly different from that of phonetically balanced list, the data were statistically compared. The mean peak frequency of phonetically balanced words was compared with that of the most familiar words. This was done separately for the words with spectral information above 1, 1.5, 2 and 2.5 kHz. Because the words with spectral information above 3 kHz were only 19 in number, they were not considered for the comparison.

The results of independent *t* test are given in Table 3. Results show a significant difference ($p<0.01$) between mean peak frequency of phonetically balanced words and mean peak frequency of the most familiar words of the present study. The result was same at all cut off frequencies. Thus, the information in the words of the present study is at significantly higher frequencies compared to that of phonetically balanced list and in turn supports the use of these words for the construction of a high frequency word list.

Table 3*:* Results of independent t test showing the significance of difference between most familiar words and the phonetically balanced words

Cut-off Frequency	*t*	df
1.0 kHz	4.4*	159
1.5 kHz	4.6*	156
2.0kHz	7.3*	123
2.5 kHz	10.2*	102

*Note: * - p < 0.01*

The results showed that there is a significant difference in peak frequency between the phonetically balanced Tamil list and the high frequency list developed at each cut off frequencies. This could be because, standardised phonetically balanced speech identification test has words with phonemes like /m/, /p/, /l/ and /d/ which have energy predominantly at low frequencies while the high frequency word list has phonemes /s/, /t🗄/, /t💧/ and /k/ which have energy predominantly at high frequencies.

Although all the 111 words showed a significant difference in the spectral information, inspection of the *t* values shows that the difference was more as the cut off frequency was higher. Hence, it can be inferred that words with predominant spectral information above 2 kHz are more sensitive in detecting speech perception deficits in individuals with high frequency hearing loss, compared to words with energy above 1 kHz. Considering this, in the present study it was decided to use words with peak frequency above 2 kHz. There were 75 words with peak frequency above 2 kHz, of which 25 were trisyllabic and 50 were bisyllabic words.

Construction of the word subtests

Two separate lists were prepared based on the number of syllables. List 1 had 50 bisyllabic words while the list 2 had 25 trisyllabic words. This was done because the redundancy in trisyllabic words could be more than that in a bisyllabic words and hence may lead to different identification scores (Hirsh, Silverman, Reynolds, Eldert, & Benson 1952). It was presumed that in terms of difficulty these two lists could differ and a normative developed combining these two words within the same list may be erroneous. The list of 50 bisyllabic words was further divided into two half list with 25 words each. This was done to provide a shorter version of the test which could be useful when the complete list cannot be used due to time constraints. While dividing the list, the attempt was made to keep the frequency of high frequency sounds same in the two half lists.

Development of the normative for the high frequency word list in Tamil

Normative was developed on 100 normal hearing individuals who were native speakers of Tamil. Mean and standard deviation of speech identification scores obtained for the two half lists with bisyllabic words and one list in trisyllabic words are given in Table 4.

Table 4: Mean and standard deviation (SD) of high frequency speech identification scores in normals.

Lists	Ears	Mean (%)	Range	1 SD	2 SD
Bisyllabic word- Half list 1	Right	99.7	100-96	1.0	2.00
	Left	99.8	100-96	0.787	1.57
	Total	99.7	200-192	0.914	1.83
Bisyllabic word- Half list 2	Right	99.5	100-96	1.25	2.50
	Left	99.7	100-92	1.11	2.22
	Total	99.6	200-188	1.19	2.38
Trisyllabic words	Right	99.9	100-96	0.40	0.80
	Left	99.9	100-96	0.562	1.12
	Total	99.9	200-192	0.487	0.97

Majority of the normal hearing individuals obtained almost 100% speech identification scores in left as well as right ear. The speech identification scores were first compared between right and left ears separately in the three lists. One way ANOVA (Table 5) was done for this purpose. Results of one way ANOVA showed no significant difference between the identification scores obtained in the two ears. Hence, the data from left and right ear were combined for further statistical analysis.

Table 5: One way ANOVA results across lists

List	F	df	p
Bisyllabic word- Half list 1	0.861	198(1)	0.355
Bisyllabic word- Half list 2	1.420	198(1)	0.235
Trisyllabic list	0.336	198(1)	0.536

The present result of almost 100% identification of high frequency words in normal hearing individuals is in agreement with earlier studies (Schwartz & Surr, 1979; Mascarenhas, 2002; Sudipta, 2006). The lowest score obtained among the 100 subjects was 92%. Thus, it can be inferred that the specificity of the high frequency speech identification test in Tamil is good. The earlier studies (Schwartz & Surr, 1979; Mascarenhas, 2002; Sudipta, 2006) have checked for the sensitivity of the respective tests in identifying perceptual deficits in individuals with high frequency sensorineural hearing loss. However, that was not among the objectives of the present study.

Comparison across the Word Subtests

To verify whether there is a significant difference in the identification scores across the three lists, repeated measures ANOVA was done. The results of repeated measure ANOVA [F (2,398) = 5.402, $p < 0.01$] showed a significant main effect of word list on speech identification scores. To obtain the pair wise comparisons, Bonferroni post hoc test was carried out. Results of post hoc test are depicted in Table 6. Results showed no significant difference between the 2 bisyllabic word half lists. This means, either of the lists can be used to test high frequency speech identification. Also, there was no significant difference ($p>0.05$) between bisyllabic word half list 1 and the trisyllabic word list in terms of speech identification scores. This goes to prove that there is not much difference in the redundancy present in the two lists.

Table 6: Results of Bonferroni post hoc test showing the pair wise comparison across the word subtests.

Lists	Bisyllabic word-Half list 1	Bisyllabic word-Half list 2	Trisyllabic word list
Bisyllabic word-Half list 1	NS	NS	NS
Bisyllabic word-Half list 2	NS	NS	S
Trisyllabic word list	NS	S	NS

Note: S - p<0.05, NS – p>0.05

However, Bonferroni test showed a significant difference between bisyllabic word half list 2 and the trisyllabic word list. Inspection of the mean speech identification scores obtained for the bisyllabic word half list 2 and the trisyllabic word list reveal that, both are above 99%. Therefore, though there is a statistical difference, the magnitude of the mean difference is small and will not have any clinical importance. Hence, it can be concluded that any of the 3 word subtests can be used to assess the high frequency speech identification.

Conclusions

The high frequency speech identification test developed will be useful to identify the speech perceptual deficits in individuals with high frequency hearing loss. This shall give a better estimate of the communicative handicap that these individuals possess compared to phonetically balanced word test. This could also be useful in the selection of amplification devices for individuals with HFHL and auditory training of high frequency words.

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APPENDIX

S.No	Bisyllabic word Half List 1	Bisyllabic word Half List 2	Trisyllabic List
1	🖑■♎☪🖑	🖑❐✌♑⬀	kagid🗄am
2	⬧☜▫✞✌●	s🖑ra🖑	&✞☼✞✞🖑
3	◆🗄✌♎◎✌🖑	◆🗄✌☼✌🖑	&☜▫⬧✌❐🖑
4	⬧♋▫●♋♓	⬧❑◆🗄🖳⬀	✞✌▫☼🖑⬧⬀
5	&✌🖑♎🗄🖑	&✌▫⬧⬀	&✌♎◎🖑♎🗄✌ ❍
6	◆🗄☜▫■♑✌🖑	◆🗄☜■🖳✌🖑	♓er♋❐&♋♓
7	⬧🖑❐❑🖑	⬧🖑●✌🖑	◆🗄✌❐✌▫⬧⬀
8	♓⬧♋♓	♎🗄☜▫⬧✌❍	⬧✌☼&✌☼✌🖑
9	&✞er🖑●	&✌◆🗄🖳🖑	&♋♎◎✌●✌🖑
10	◆🗄☜♎🗄🖑	◆🗄✌☼✌🖑	&✌♎🗄✌✞⬀
11	♎☪♋■🖳♋●	♎☪✌♎🗄🖑	🖑●✌❍✌🖑
12	&✌☼&✌●	◆🗄☜☼&🖳⬀	&✌♎◎🖑◆🗄✌ ❍
13	🖑♎◎✌🖑	🖑☼✞●	✌☼✌⬧♋■
14	⬧☜🖑♎🗄🖑	⬧✌■♎🗄✌🖑	✌☼♋⬧🖑
15	🖑♎◎✌❍	er✌▫■✌🖑	◆🗄✌●✌🖑✞🖑
16	⬧☜♎◎🖑	⬧✞■♎◎✌●	✌❐🖑⬧♓
17	&❑♎🖑	&🖑●🖑	⬧🖑❐✌♑⬀
18	❍☜▫☼&⬀	◆🗄❑❑🖳🖑	◆🗄✌&✌▫●🖑
19	&✌●✞🖑	&❑▫●♓	&✞♎🖑⬧✌🖑
20	&✌◆☼⬀	&✌♎◎✌♓	❖✌❐◆💧✌❍
21	&✌❑🖳✌●	&✌◆◆◎🖑●	❖✌🖑&✌⬧🖑
22	&✌✞✌●	☼☜▫♑✌🖑	&✌●🖳◆▫☼🖑
23	🖑▫❐✌●	🖑♎🗄✌●	&🖑❐✞❍🖑
24	&✌▫❑🖑	&✌■♎☪🖑	&✌☼♋♎◎🖑
25	♎🗄❑▫⬧✌🖑	♎🗄🖑⬧✌	⬧🖑●🖳◎✌❐✌er