HIGH FREQUENCY SPEECH IDENTIFICATION TEST IN TAMIL

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Certificate

This is to certify that this dissertation entitled '**High frequency speech**

DEDICATED TO

MY LORD JESUS CHRIST

&

MY FAMILY

Certificate

This is to certify that this dissertation entitled '**High frequency speech identification test in Tamil'** has been prepared under my guidance and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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Declaration

This Dissertation entitled '**High frequency speech identification test in Tamil'** is the result of my own study and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Place, Mysore **Register No.**07AUD017

Date 25.5.09

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Every good gift and every perfect gift is from above, and comes down from the father

James 1: 17

Whatever you do, do all to the glory of God. 1 Corinthians 10:31

Thank you Jesus for the wonderful blessing you have showered on me at all times. The father who always answers my prayers in a very special way and is close beside me.

…..Choose Knowledge rather than finest gold …. Proverbs 8 :10

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Get all advice you can, and you will succeed and without it you will fail

Proverbs 15 : 22

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No one who achieves success does so without acknowledging the help of others

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Chapter 1

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.

Before the 20 the century, speech recognition was tested informally by having the individuals repeat the words or sentences that were whispered or spoken. Scientists such as Fletcher and Steinberg (1929), French, Carter and Koenig, (1930) and others at the Bell telephone laboratory studied speech as an auditory signal to test new equipment. It was obvious to these early investigators that the study of hearing speech was far more complex than study of hearing tones. In addition to physiologic and acoustic factors, linguistic and psychologic factors had to be considered during the interpretation of the results.

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 reasons audiologists traditionally limit their tests to two important measures, which is the speech recognition threshold and speech identification scores.

In a conventional audiological evaluation, the pure tone audiogram gives an estimate of the signal detection at different stimulus frequencies. But, it may not provide an estimate of speech perception. Earlier studies have reported the presence of normal or near normal puretone audiogram in individuals with auditory dyssynchrony in whom the speech perception is seriously affected. One of the basic and the earliest method to assess speech perception is speech audiometry. Basic speech audiometric tests include speech detection threshold (SDT) speech recognition threshold (SRT), speech identification scores (SIS), most comfortable level (MCL) and uncomfortable level (UCL). The purpose of the speech audiometry is three fold. First, it is a validation of the pure tone air- conduction thresholds (Carhart, 1952; Chaiklin & Ventry, 1964). Second, it provides an index of hearing sensitivity for speech. Third, it provides an estimate of suprathreshold speech perception (Hannley, 1986).

Acoustically, conversational speech has the most energy approximately between 500 and 3000 Hz. This midfrequency region is important for understanding speech, particularly when speech is meaningful (Pavlovic 1987; Studebaker, Pavlovic & Sherbecoe 1987; Sherbecoe & Studebaker 2002). The, speech energy above 3000 Hz is reported to offer listeners important linguistic information. One needs to have normal hearing sensitivity at all these frequencies for good speech recognition. Any pathology of the ear that causes hearing loss will reduce the audibility, in turn leading to affected speech recognition

Need for the Study

Individuals with sensorineural hearing loss (SNHL), particularly the elderly, tend to have the greatest amount of hearing loss in the higher speech frequencies (above 2 kHz), which generally corresponds to more extensive pathophysiological changes in the corresponding regions of the inner ear (Liberman & Dodds, 1984; Williott, 1991). Because pure tone thresholds does not allow for complete understanding of a person's communication deficit, speech idenfication tests are generally used to determine the extent of communicative handicap. Most of the speech identification tests are phonetically balanced and 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 due to inherent redundancy in natural speech. The spectral information in the frequency (below 2 kHz) regions where the hearing is normal could help in perception by auditory closure. To further support this notion, the speech perception in presence of background noise. This is because in the presence of background noise low frequencies information that was otherwise available in facilitating perception is masked. Hence, speech identification scores obtained for High frequency word list is a better estimate of communication handicap for such individuals. Because such a list is not available in Tamil language the study attempted to develop the test material. Approximately 7,00,00,00 population exists just in the state of Tamil Nadu and significant percentage of them can communicate only in Tamil. Also, De (1973) reported that identification scores are maximum in the individual's native language. Hence a separate list is required in Tamil.

Objectives of the Study

The objectives of the present study were:

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

Chapter 2

REVIEW OF LITERATURE

2.1 Importance of high frequencies in speech intelligibility

Speech communication is unique to human beings. 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 2.1.

Additionally the speech energy above 3000 Hz offers important linguistic information Niemeyer, 1967). The standardised speech intelligibility index (SII-ANSI) allocates 21 % of the importance of the average speech to the $1/3^{rd}$ octave bands at 3150 Hz and above. The importance of the same high frequency region further increases for more difficult types of speech (less redundant) such as nonsense syllables. Thus, it is important that one perceives the spectral cues in the higher frequencies for 100% speech understanding. It is logical to expect the individuals with hearing loss to have poor speech intelligibility due to reduced audibility. High-frequency hearing loss (HFHL) is the most common configuration seen in individuals with sensorineural hearing loss, particularly in Presbycusis. In individuals with a high-frequency sloping audiogram, the audibility of higher-frequency consonant energy are sacrificed, often being completely inaudible. Hence, the client with this configuration of hearing loss usually presents with complaints of difficulty understanding or recognizing conversational speech. This is particularly true if the speaker is talking softly or is in the presence of background noise.

Table2.1: *The spectral energy and the major cues for perception of consonants*

<table>
<tr><th>Phonemes</th><th>Energy spectrum</th><th>Place cue</th><th>Manner cue</th></tr>
<tr><td>/s/</td><td>2000-4000 Hz</td><td rowspan="3">Spectral properties – F2 transition, noise duration and amplitude (overall and relative amplitude)</td><td rowspan="3">Duration of frication noise, amplitude of noise component and fundamental frequency at vowel onset</td></tr>
<tr><td>/□/</td><td>3500 Hz</td></tr>
<tr><td>/f/</td><td>6800-8400 Hz</td></tr>
<tr><td>/k/</td><td>1500 – 4000 Hz</td><td rowspan="2">Frequency position of burst, F2 transition, spectral pattern, voice onset time</td><td rowspan="2">Stop gap, silence, closure duration, duration of preceding vowel, F1 cutback</td></tr>
<tr><td>/t□/</td><td>Above 4000 Hz</td></tr>
<tr><td>/d□/</td><td>2500 Hz</td><td>Duration of noise segment
Rise time of noise segment</td><td>Frication duration, closure duration.</td></tr>
</table>

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

Miller (1951) stated that the weakness in intensity of the consonant sounds is unfortunate because the consonants are more critical for the correct interpretation of speech. Earlier studies have shown deficits in the perception of different classes of sounds like stops and fricatives. Sher and Owens (1974) reviewed the evidence that acoustic cues above 2 kHz are necessary for discriminating isolated words containing certain high frequency phonemes. Owens, Benedict and Schubert (1972) reported specific difficulties in /s, □, t□, dz, t & □ /. Similar findings have been reported in the perception of sibilants by Bilger and Wang (1976)

Lawrence and Byers (1969) studied identification of voiceless fricatives in five male adults (aged 25 – 55 yrs) with HFHL. The ear with best sensitivity for pure tones was selected as the test ear. The stimuli used were 16 CV syllables by combining each of the fricative /□, □, f, □ / with four vowels /i, e, o, u/. The percentage correct identification of fricatives was /□/ - 87 %, /□/- 77%, /□/ - 72 % and /f/- 83%. The subjects showed idiosyncratic confusion pattern. Importantly, there were no vowel confusions. However, the fricatives were most often confused in association with front vowel /i/ and /e/, than with back vowel /u/ and /o/. Even /□/ was confused for /s/ and, /f/ for /□/. Examination of fricatives suggested the low frequency energy, intensity and duration of fricatives sounds as well as formant transition of vowels were available to subjects to serve as possible cues for fricative identification. Although the study showed fairly good identification, the scores will probably reduce drastically in the presence of noise, due to masking of low frequency cues. Sher and Owens (1974) reported that cues above 2 kHz are necessary to extract meaning even from rather highly contextual sentences when the redundant nature of acoustic, grammatical, lexical, linguistic, and prosodic content of such sentences is reduced by distortion. It was noticed that, greater the distortion, the higher the frequencies required for maximum understanding.

Zeng and Turner (1990) reported that adults with sensorineural hearing loss were less able to use transition cues to identify voiceless fricatives than were normal-hearing listeners, even when the transition was clearly audible. They attributed this finding to poorer than normal discrimination ability for the dynamic spectral cues involved in the transition.

Dubno, Dirks& Schaefer (1987) carried out study to evaluate the utility of short term spectral cue for recognition of initial plosive consonant by both normals and hearing impaired listeners, including listeners with flat, gradually sloping audiometric configurations. The results indicate that the hearing impaired do not perform well with short duration stimuli as they are unable to make use of the cues present with the magnitude of difference present depending on the audiometric configuration.

Prawin and Yathiraj (2008) studied perception of speech simulating different configurations of hearing loss. Phonetically balanced monosyllable words were used. The errors patterns seen depend on the configuration of hearing loss. In the rising pattern voicing errors were maximum, but place errors were less. In gradually falling pattern manner and place errors were evident while sharply falling patterns only place errors were evident. Thus subjects with high frequency hearing loss have difficulty perceiving place cues. However, simulation of high frequency hearing loss is not equivalent to the actual hearing loss. Dubno, Dirks and Ellison (1988) studied the contribution of certain frequency regions to consonant place perception for normal hearing listeners and listeners with high frequency hearing loss, and to characterize the differences in stop consonant place perception among these listeners. Stop consonant recognition and error patterns were examined at various speech presentation levels and under low and high pass filtering. Differences in stop consonant recognition between normal hearing and hearing impaired listeners observed for low pass filtering at 2800 Hz and for the unfiltered condition indicate that low pass filtering effects on normal hearing listeners stop consonant recognition are not comparable to the changes in recognition resulting from HFHL. In other words, changes in recognition resulting from threshold elevation were more pronounced compared to that seen during the elimination of high frequency spectral energy. The additional deficits in speech perception in individuals with SNHL have been attributed to reduced frequency resolution (Festen & Plomp, 1983) and the increased upward spread of masking. Sensorineural hearing loss, particularly cochlear hearing loss, is associated with broader-than-normal auditory filters in turn leading to reduced frequency selectivity.

Furthermore, Horwitz, Dubno and Ahlstrom (2002) reported similar findings and purported reduction in audible high-frequency speech information to be the reason. In addition, high-frequency hearing loss may reduce the contribution from the ‘‘tails’’ of high-frequency auditory nerve fibers, resulting in diminished availability of lower frequency speech cues. This study was designed to determine if high-frequency hearing loss results in speech-understanding deficits beyond those accounted for by reduced high-frequency speech information. Recognition of speech, both low-pass filtered and unfiltered, was measured for subjects with normal hearing and those with hearing loss limited to high frequencies. Nonsense syllables were presented in three levels of noise that was spectrally shaped to match the long-term spectrum of the speech. Scores for subjects with impaired high-frequency hearing were significantly poorer than scores for subjects with normal hearing. In the case of the low-pass-filtered speech, Performance differences between groups could not be attributed to differences in speech audibility, as high-frequency speech cues were absent for all subjects which is necessary for contributing to speech intelligibility. Listeners with HFHL had deficits in recognition of unfiltered speech in noise compared to normal hearing listeners. This was attributed to the reduction in the high frequency audibility. Listeners with impaired high frequency loss also showed difficulty in the perception of low frequency speech in noise compared to normal hearing subjects.

2.2 Speech Perception in the Presence of Noise

In the presence of noise, the critical range of frequencies which have a significant effect on word recognition are those between 2500 and 6300 Hz (Pascoe, 1975). Hornsby and Ricketts (2003) examined the contribution of speech information in various frequency regions to speech understanding in noise by comparing persons with flat SNHL with that of listeners with normal hearing. Speech understanding in noise was assessed using multiple low- and high-pass filter cut off frequencies for all groups of listeners. Access to high frequency information resulted in comparable improvements in speech understanding for listeners with flat SNHL and normal hearing (Hornsby & Ricketts, 2003). Similarly, Turner and Henry (2002) found that amplified high-frequency speech information improved speech understanding in noise of listeners with sloping SNHL, regardless of the degree of hearing loss.

Cohen and Keith (1976) attempted to determine whether word recognition scores obtained in quiet as well as in noise varied with the pattern of hearing loss. Subjects with high frequency cochlear hearing loss and flat cochlear hearing loss were tested in quiet and in the presence of a 500 Hz low- pass noise in 2 signal- to- noise (SNR) conditions (-4dB & -12dB). The results indicated that, while the word recognition scores were similar between the two groups in quiet, in the presence of noise scores deteriorated with SNR for the high frequency hearing impaired participants as compared to those with flat cochlear hearing loss.

2.3 Sensitivity of High Frequency Speech Identification Tests in Identifying Communicative Handicap

Maroonroge and Diefendorf (1984) 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 upto 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. Similar results have been reported by Gardner (1971), Pascoe (1975) and, Owens and Schubert, (1977).

2.4 Review of High Frequency Speech Identification Tests

A review of the earlier studies on high frequency speech identification tests revealed many tests. The difference among these tests is either in terms of the length of the speech material (syllables or words or sentences) or in the language of the test material. The length of the speech material has been varied basically to maintain the redundancy at optimum levels. Attempts are also made to develop speech material in the respective native languages. Particularly in a country like India where almost each state has its own native language and the large number of individuals in the state know only their native language, there arises a need for developing separate test list in each language.

2.4.1 High Frequency Speech Identifications Tests in English

The high frequency word list was first 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 (Gardner, 1971). The drawback of Gardner Test was that, no standardisation information was reported for the different talker's presentation modes or randomised lists. Therefore the sensitivity of test was doubted.

Pascoe High Frequency Word List developed by Pascoe (1975) was meant to assess the speech perception abilities of individuals who are hearing impaired. The list included fifty monosyllable words that emphasize phonemes that are difficult for hard of hearing subjects. Only three vocalic nuclei were used, /□/, /ai/ and /ou/ in order to increase the weight of the consonants in the correct identification of words. Voiceless fricatives and plosives formed 63% of the number of consonants. The rest were nasals, laterals and voiced plosives. The scores obtained in Pascoe high frequency list was compared with that of the phonetically balanced list in quiet and in noise. The results indicated that the identification scores in the high frequency list was more sensitive in detecting the deficits in communication.

California Consonant Test (CCT), developed by Owens and Schubert (1977) consisted of 100 items and was a multiple choice test for consonant identification. They believed that the clinical test should be developed which permitted phoneme variation in only one position. The results revealed that the test seemed sensitive to high frequency loss. This was true for losses beginning at higher frequency. Poor scores revealed that a fairly low correlation (-0.40) was found between the CCT and the degree of loss for 59 subjects with relatively flat configuration between 250 to 4 kHz.

2.4.2 High Frequency Speech Identification Tests in Indian languages

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 dearth of high frequency word lists in Indian languages. High frequency speech identification tests are developed only in Kannada (Kavitha, 2002), Hindi (Ramachandra, 2001) and English (Sudipta, 2006).

The first high frequency speech identification test in India was developed by Ramachandra (2001) in Hindi. The objective was to develop a list of meaningful, familiar, high frequency monosyllabic CVC words common to Hindi and Urdu speakers for the establishment of speech identification scores. The test material is a list of 50 high frequency words which were rated as most familiar by a group of native speakers. The first list consisted of high frequency phonemes in initial consonant position of the word and the second list consisted of high frequency phoneme in the final consonant position of the word. She administered the test on 15 patients with sloping hearing loss and found that is was more sensitive to their deficits compared to the common speech discrimination test for Indians developed by Mayadevi (1974).

Mascarenhas (2002) developed a speech identification material in Kannada for testing adults with a sloping hearing loss. The test consisted of three word list with sentence subtests with equal distribution of high frequency sounds. It included the bisyllabic and trisyllabic words. The test was administered on 30 normal and 30 individuals with sloping hearing loss. The utility of the test was determined by administering the test on five individuals with HFHL with and without hearing aids. The results were compared with common speech discrimination test for Indians (Mayadevi, 1974). There was a significant difference between the sentence subtest and the word subtest in high frequency hearing loss group. As the sentence sub test performance was more redundant, scores were better compared to the word subtest. The study concludes to administer the sentence subtest in the presence of noise.

The English spoken in India is different from that spoken in European countries and United States in terms of vocabulary as well as pronunciation. Hence, in spite of high frequency speech material available in English, a separate test had to be developed in India. Sudipta (2006) developed speech identification test for Indian English speakers to assess the perceptual problems of individuals with HFHL. The test includes four word lists and four sentence subtest. It was administered on 30 normal hearing subjects and 10 sloping hearing loss. The scores were compared with English monosyllabic word test developed by Rout (1996). Results showed a significant difference between normals and hearing impaired. Individuals with HFHL got poorer scores on words than sentence subtest. That is word subtests were more sensitive to sentence tests in identifying the perceptual deficits. Also, there was a significant improvement in the aided condition compared to unaided condition in individuals with HFHL. Thus, it was proposed to use this test also in the selection of hearing aids.

2.5 FACTORS AFFECTING SPEECH AUDIOMETRY

2.5.1 Familiarization

Recognition of the importance of familiarity with the speech stimulus is important. The purpose of familiarization is to ensure that the patient knows the test vocabulary and is able to recognize each word auditorily and, that the clinician can accurately interpret the patient’s responses (ASHA, 1988).

2.5.2 Recorded versus Monitored Live- voice Presentation

The physical attributes of speech vary considerably from person to person (Carhart, 1965; Brandy, 1966; Hood & Poole, 1980). Brandy (1966) pointed out that these attributes can vary for the same words spoken by the same person on different days. Recorded presentations can be used because they ensure greater consistency across presentations (Carhart, 1965; Brandy, 1966; Tillman and Olsen, 1973). However, in nonadjudication cases, most audiologists present the various suprathreshold word recognition test lists by Monitored live voice. The reasons are, greater flexibility and reduced test time. Kreul, Bell and Nixon (1969) found no significant difference in test scores between recorded and monitored live voice presentations.

2.5.3 Use of carrier phrase for testing

The use of carrier phrase before each test word had its origin with Fletcher and Steinberg (1929) who reported that CVC word recognition was greater with, than without, carrier phrase. Gladstone and Siegenthaler (1971) and, Gelfand (1975) reported poorer test scores for suprathreshold word recognition tests without carrier phrase than for those with one. Carrier phrases are desirable because it assists in monitoring the VU meter and hence in speaking at proper intensity.

2.5.4 Level of Presentation

The majority of audiologists continue to use SRT as a reference for determining the level at which to present the word recognition test. The most comfortable loudness is the next most frequently used level (Martin & Slides, 1985) to determine the word recognition scores. PB- Max for male voice presentations of W-22 and NU-6 test words occurs around 30 dB SL (ref to SRT) for normal hearing individuals. For other tests the PB- 50 and Maryland CNC tests, PB-Max for similar subjects is reported to occur at approximately 45 dB SL (ref to SRT).

Earlier studies (Speaks, Jerger & Trammell, 1970; Miner & Danhauer, 1976; Olsen &Matkin 1991), have shown that the minimum level for maximum score (PB-Max) varies across patient groups. When testing patients with substantial loss within a portion of the speech frequency range (hearing loss from 2000 & 4000 Hz or from 500 & 1500 Hz), the presentation level may be based on four frequency pure tone average (500, 1000, 2000 & 4000 Hz) instead of SRT. If the words are too loud for the patient the level is reduced to a more comfortable level.

2.5.5 Phonetic/ Phonemic balance

The concept of phonetic/ phonemic balance played a major role in the development of many speech recognition tests. However, phonetic/ phonemic balance has been found to have little practical impact on the outcome of speech recognition tests, and its clinical relevance is questionable (Tobias, 1964; Carhart, 1970; Bess, 1983).

2.5.6 Whole-word versus phonemic scoring

Speech recognition tests that use words are usually scored on a whole word basis. Whole word scoring reflects the patient's correct reception of the intended word, but also misrepresents how well the patient is able to make use of acoustical cues of speech. An alternative approach is to score word recognition on a phoneme-by- phoneme basis (Gelfand, 1993; Olsen, Van Tasell, & Speaks, 1997).

Compared to whole word scoring, the use of phonemic scoring -

- Provides a more precise and more valid measure of the correct reception of the acoustic cues of speech
- Improves reliability by maximizing the number of scorable items
- Makes it possible to obtain meaningful scores from patients whose whole word scores would have been zero
- Gives a better idea of which speech sounds are misperceived
- Minimizes the effects of non acoustic factors such as word familiarity, word level predictability, context and differences between word lists.

Comparing word scores and phoneme scores makes it possible to estimate the benefit to speech recognition provided by taking advantage of lexical information (Nittrouer & Boothroyd, 1990; Olsen, Van Tasell, & Speaks, 1997).

2.5.7 Full list versus Partial list

Although administering the full list is ideal, sometimes due to time constraints it may be necessary to have small list. Hence half lists will be prepared in which the frequency of occurrence of the phonemes should be same in the two half lists. Studies (Vandana, 1998) shown no significant difference in the percentage of identification between full list and half lists.

2.5.8 Foreign Language Influences and Implications

Speech audiometry involves material that is inherently linguistic in nature, so the results may be influenced by such factors as differences in phonology and morphologic rules between languages, and are exacerbated by word familiarity effects. 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. Hence, non native speakers of the language typically obtain lower scores on English speech recognition tests than do native speakers of the language (Gat & Keith, 1978). The perfect solution is for every patient to be tested in his native language by an audiologist who is also a native speaker or at least a fluent speaker of that language.

Chapter 3

METHOD

The following method was adopted to verify the objectives of the study. 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.

3.1 Phase 1: The Development of High Frequency Word List

The following steps were followed to arrive at the high frequency test list

3.1.1 Selection of the words

3.1.2 Assessment of familiarity of the selected words

3.1.3 Long-term average speech spectrum (LTASS) on the familiar words

3.1.4 Construction of word subtests

3.1.5 Recording of the test material

3.1.1 Selection of the Words

Only the bisyllabic and trisyllabic words were considered to develop the test list. This is because of the fact that 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. Approximately 355 words were collected for the purpose. Words with phonemes /k/, /t□/, /s/, /d□/, /r/, /d□/, & /l/ were preferred as these phonemes have spectral energy predominantly distributed in the frequencies above 1 kHz (Hughes & Halle, 1956). In terms of the vowels, words with vowels /i/ & /e/ were preferred as the F2 and F3 of these vowels are higher than that of the other vowels Copper, Liebermann, Delattre, Borst, & Gerstmann (1952).

3.1.2 Assessment of Familiarity of the Selected Words

Familiarity of selected words was verified to ensure that the words selected were well-known and is commonly used by the native speakers of Tamil. To establish the familiarity of the test items, participants were 30 adults, who were native speakers of Tamil. 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. Operational definitions of these terms were as follows:

- Most familiar words are those used commonly by all individuals,
- Familiar words are those words used occasionally and,
- Unfamiliar words are those words that are not used by the participants.

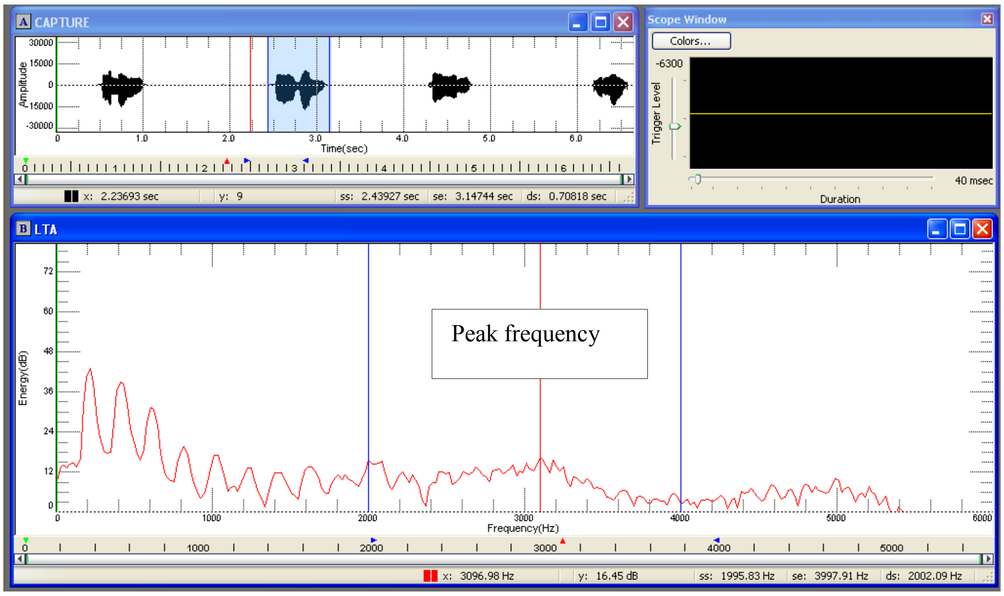
A printed version of the word list was given to the individuals and also the words were read out by the investigator (also a native speaker of Tamil). The participants were asked to tick the frequency of occurrence. Only the words that were most familiar to all of the subjects were selected for the construction of the test list. There were 111 such words out of the 355 selected words.

3.1.3 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/ & /l/ could differ depending on the context and hence the so called high frequency word may not be having high frequency spectral information. The 111 words that were rated as most familiar were assessed for the spectral information using LTASS. These words were spoken by an adult female who was a native speaker of Tamil and were recorded. The recording was done at 16 kHz sampling rate and 16 bit quantization using computerised speech lab (CSL) 4500 software. The samples were stored into a computer. LTASS was derived using CSL 4500 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.

Fig 3.1 Spectrum derived from LTASS for a representative word.



3.1.4 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.

3.1.5 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 microphone was placed at a distance of 5 inches away from the mouth. The speaker was instructed to say the words with flat tone and to keep the loudness constant across the words. The VU meter was monitored within optimum levels during the recording. 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. Amplitude normalization of the signals was done using the Adobe Audition software to maintain the amplitude constant across the words. The inter stimulus interval between the two words was set to 5 seconds. A calibration tone of 1 kHz was inserted before beginning the word list to adjust the VU meter at zero. The material was then copied onto an audio compact disc using a compact disc writer.

3.2 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.

3.2.1 Test Procedure

After estimation of pure tone thresholds, the speech recognition threshold (SRT) was estimated through bracketing method using standardized Tamil words. A calibrated two channel diagnostic audiometer (GSI- 61) was used to carry out pure tone and speech audiometry. Following this, using the same audiometer, 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. The order of the lists was randomized to avoid the order effect. An open set response in the form of an oral response was obtained.

3.2.2 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.

Chapter 4

RESULTS AND DISCUSSION

Results of the present study are reported under the following headings

4.1 Development of the high frequency word list/s
4.2 Development of the normative for the high frequency word list in Tamil

4.1 Development of the High Frequency Word List/s

4.1.1 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.

4.1.2 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 4.1. The cut off peak frequencies considered were 1, 1.5, 2, 2.5 and 3 kHz.

Table 4.1: *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 4.1, 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). The data obtained is as given in Table 4.2.

Table 4.2: *Mean and standard deviation (SD) of peak frequency for phonetically balanced word list*

Parameter	Number of words	Mean(Hz)	SD
Peak value	50	1278	880

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 4.3. 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 inturn supports the use of these words for the construction of a high frequency word list.

Table 4.3*: 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 above results show 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.

4.1.3 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 can not 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.

4.2 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 4.4

4.2.1Comparison between the ears

Scores obtained for the left and right ear are given separately. 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 4.5) 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 4.4: *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

Table 4.5: *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.

4.2.2Comparison 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 are [$F(2,398) = 5.402$, $p < 0.01$] 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 4.6. 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 4.6: *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. Although a statistical difference generally requires a logical explanation, in this case, it may not be necessary. 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.

Chapter 5

SUMMARY AND CONCLUSIONS

The speech identification tests developed are phonetically balanced and 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 aid in perception.

The present study aimed at developing and standardising a high frequency speech identification test in Tamil to evaluate adults with sloping hearing loss. The study was done in two phases. In the first phase, the material consisting of most familiar words with high frequency phonemes was developed. LTASS was done to determine if the most familiar words had spectral information predominantly in the higher frequencies. The peak frequency (as obtained on LTASS) of the most familiar were then statistically compared with the phonetically balanced words at different cut off frequencies and only those words having predominant spectral energy above 2 kHz were used for the construction of the word list. Three lists were constructed, 2 bisyllabic word half lists and 1 trisyllabic list. In the second phase, the test was administered on 100 normal hearing individuals and identification scores were obtained. The left and right ears were separately tested with all the 3 lists at 40 dB SL (ref. SRT).

The results showed that normal hearing subjects obtained mean score of more than 99% for all the three lists. There was no difference between the two ears in their identification scores. Comparison across the 3 lists showed that any of the 3 lists can be used to obtain high frequency speech identification scores. However, the test needs to be standardized on individuals with high frequency hearing loss.

Utility of the Test

The high frequency speech identification test 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.

REFERENCES

American National Standards Institute (1991). "American National Standard maximum permissible ambient noise levels for Audiometric Test rooms". ANSI S3.1. (1991). New York: *American National Standards Institute.*

American Speech – Language – Hearing Association (1988). Guidelines for determining the threshold level for speech. ASHA 3: 85-88.

Bess, F.H. (1983). *Principles of Speech Audiometry* , Konkle, D. F., & Rintlemann, W. F., WF (Eds). (127-201) Baltimore, M.D., University Park Press.

Brandy, W. T. (1966). Reliability of voice tests of speech discrimination. *Journal of Speech and Hearing Research, 9*, 461-465.

Bilger, R. C., & Wang, M .D. (1976). Consonant confusion in noise, A study of perceptual features, *Journal of Acoustical Society of America* , *54*, 1248-1266.

Carhart, R. (1952). Speech audiometry in clinical evaluation, *Acta Otolaryngologia, 41,* 18-42.

Carhart, R. (1965). Problems in measurement of speech discrimination, *Archives of Otolaryngology*, *82*, 253-260.

Carhart, R. (1970). Contemporary American Tests and Procedures. In C. Rosjshjer (Eds.) Speech Audiometry, Denmark: Second Danavox Symposium.

Chaiklin, J. B., & Ventry, I.M. (1964). Spondee threshold measurement, a comparison of 2 and 5 dB steps, *Journal of Speech Language and Hearing Disorders, 29,* 47- 59.

Cohen, R. L., & Keith, R. W. (1976).Use of low pass noise in word recognition, *Journal of Speech Language and Hearing Research*, *19*, 48- 54.

Cooper, F. S., Delattre, P. C., Libermann, A. M., Borst, J. M., & Gerstman, L. J. (1952). Some experiments on the perception of synthetic speech sounds, *Journal of Acoustical Society of America, 24,* 597-606.

De, N. S. (1973). Hindi PB list for speech audiometry and discrimination test. ,*Journal of Otolaryngology*, *25*, 64- 75.

Dorman, M.F., Studdert -Kennedy, M., & Rapheal, J.L. (1977).Stop-consonant recognition: Release bursts and formant transitions as functionally equivalent, context dependent cues, *Perception and Psychophysics,* 22(2) 109-122.

Dubno, J. R, Dirks , D. D, & Schaefer, A. B. (1987). Effects of hearing loss on utilization of short-duration spectral cues in stop consonant recognition , *Journal of Acoustical Society of America*, *81 (6)*, 1940–1947.

Dubno, J.R., Dirks, D.D., & Ellison, D.E. (1988). Stop-consonant recognition for normal-hearing listeners with .high frequency hearing loss. I. The contribution of selected frequency regions, *Journal of Acoustical Society of America, 85*(1), 349- 378.

Festen, J.M., & Plomp, R. (1983). Relations between auditory functions in impaired hearing , *Journal of the Acoustical Society of America,* 73*(2),* 652-62.

Fletcher, H., & Steinberg, J. C. (1929). Articulation methods, *Bell systems Journal*, *8*, 806- 854.

French, N. R., Carter, C. W., & Koenig, W. (1930). The words and sounds of telephone conversation, *Bell Systems Technology Journal*, *9*, 290- 324.

Gat, I.W., & Keith, R.W. (1978). An effect of linguistic experience, auditory word discrimination by native and non native speakers of English, *Audiology,17* ,339- 345.

Gardner, H. J. (1971). Application of high frequency consonant discrimination word list in hearing aid evaluation, *Journal of Speech and Hearing Disorder, 36*(3), 354-355.

Gelfand, S. A. (1975). Use of carrier phrase in live voice speech discrimination testing, *Journal of Audiology Research, 15*, 107-110.

Gelfand, S.A. (1993). Organic thresholds and functional components in experimentally simulated exaggerated hearing loss, *British Journal of Audiology*, *27*(1), 35-40.

Gladstone, V.A., & Siegenthaler, B.M. (1971). Carrier phrase and speech intelligibility test score, *Journal of Audiology Research, 11*, 101- 103.

Hannley, M. (1986). *Basic principles of Audiology Assessment*. A college Hill Publication, Little, Brown and Company: Boston.

Hirsh, I.J., Davis, H., Silverman, S.R., Reynolds, E.G., Eldert, E., & Benson, R.W. (1952). Development of materials for speech audiometry, *Journal of Speech and Hearing Disorders,17,* 321-337.

Hornsby, B.W.Y., & Ricketts, T.A. (2003). The effects of hearing loss on the contribution of high and low frequency information to speech understanding, *Journal of Acoustical Society of America, 113,*1706- 1717.

Horwitz, A. R., Dubno, J. R., & Ahlstrom, J. B. (2002). Recognition of low-pass-filtered consonants in noise with normal and impaired high-frequency hearing, *Journal of Acoustical Society of America, 111*, 409- 416.

Hood, J. D., & Poole, J. P. (1980). Speech Audiometry in conductive and sensorineural hearing loss, *Sound*, 5, 30- 38.

Hughes, G. W., & Halle, M. (1956). Spectral properties of fricative consonants, *Journal of Acoustical Society of America*, *28*, 303-310.

Katz, J. (2002). (Ed.), *Handbook of Clinical Audiology*, New York: Williams and Wilkins.

Kavita, E. M. (2002). *A high frequency kannada speech identification Test (HF-KSIT)* Unpublished Master's Dissertation. University of Mysore, India.

Kruel, E. J., Bell, D.W., & Nixon, J.C. (1969). Factors affecting speech discrimination test difficulty, *Journal of Speech and Hearing Research, 12*, 281-287.

Lawrence, D. L., & Byers, V.W. (1969). Identification of voiceless fricatives by high frequency hearing impaired listeners, *Journal of Speech and Hearing Research, 12* , 426- 434.

Libermann, M. C., & Dodds, L.W. (1984). Single neuron labelling and chronic cochlear pathology. III. Stereocilia damage and alterations of threshold tuning curves. *Hearing Research*, *16*, 55- 74.

Martin, F. N., & Slides, D.G. (1985). Survey of current audiometric practices, *American Speech and Hearing Association*, *27* (2), 29-36.

Maroonroge, S., & Diefendorf. (1984). Comparing normal hearing and hearing impaired individuals subjects performance on North-western Auditory test No.6, California Consonant Test & Pascoe's High Frequency word list. *Ear and Hearing, 5*(6), 356-360.

Miller, G. A., Heise, G. A., & Lichten, W. (1951). The intelligibility of speech as a function of the context of the test materials, *Journal of Experimental Psychology, 41,* 329-335.

Miner, R., Danhauer, J. L. (1976). Modified rhyme test and synthetic sentence idenfication test scores of normal and hearing impaired subjects listeners in a Multitalker noise, *Journal of Acoustical Society of America, 2,* 61-74.

Mayadevi (1974). Development and Standardisation of common speech discrimination test for Indians, *Unpublished Master's Dissertation*. University of Mysore, India.

Niemeyer, W. (1967). Speech audiometry with sentences. I. Principles and test material of the diagnosis of whole speech perception, *HNO*, *15* (11) 335- 343.

Nittrouer, S., & Boothroyd, A (1990). Context effects in phoneme and word recognition by young children and older adults, *Journal of the Acoustical Society of America* , *87*(6), 2705-2715.

Olsen, W.O., & Matkin, N.D. (1991). Speech Audiometry. In, , W.F., Rintelmann (Eds.), *Hearing Assessment.* University Park Press, Baltimore.

Olsen, W.O., Van Tassell, D.J., & Speaks, C.E. (1997). Phoneme and word recognition for words in isolation and in sentences, *Ear & Hearing*, *18*, 175-188.

Owens, E., Benedict, M., & Schubert, E. D. (1972). Consonant phonemic errors associated with pure tone configurations and certain kinds of hearing impairment, *Journal of Speech and Hearing Research, 15,* 308-322.

Owens, E., & Schubert, E. D. (1977). Development of California Consonant Test, *Journal of Speech and Hearing Research, 20,* 463- 474.

Pascoe, D. P. (1975). Frequency response of hearing aids and their effects on the speech perception of hearing impaired subjects, *Annuals of Otology, Rhinology, Laryngology, supp-23,* 84, 1-40.

Pavlovic, C.V. (1987). Derivation of primary parameters and procedures for use in speech intelligibility predictions. *Journal of the Acoustical Society of America* , *82*, 413-422.

Penrod, J. P., (1994). Speech threshold and word recognition/ discrimination testing . In Katz, J . Handbook of Clinical Audiology 4th ed. 147- 164. Williams & Wilkins. Baltimore.

Plomp, R. (2002). *The intelligent ear*, *the nature of sound perception*, Mahwah, N. J. Lawrence Earlbaum Associates.

Prakash, B. (1998). Picture identification test in Tamil for children*, Unpublished Master's Dissertation*. University of Mysore. India.

Prawin & Yathiraj. (2008). Presented in *International Symposium on Audiology Medicine*, Bhubaneshwar, India.

Ramachandra (2001). *High frequency speech identification test in Hindi*. Unpublished Master's Dissertation. University of Bangalore. India.

Rout, A. (1996). *Perception of monosyllabic words in Indian children*. Unpublished Master's Dissertation. University of Mysore. India.

Schwartz, D. M., & Surr, R. K. (1979). Three experiments on the California Consonant Test, *Journal of Speech and Hearing Disorders, 64,* 61-72.

Sher, A.E., & Owens, E. (1974). Consonant confusions associated with hearing loss above 2000 Hz, *Journal of Speech and Hearing Research*, *17*(4), 669-681.

Sherbecoe, R.L., & Studebaker, G.A., (2002). Audibility index functions for the connected speech test, *Ear and Hearing, 23,* 385-398.

Silman, S., & Silverman, C. A. (1991). *Auditory diagnosis principles and applications.* San Diego: Academic Press.

Singh, S. & Black, J.W. (1966). Study on 26 intervocalic consonants as spoken and recognised by four language groups, *Journal of Acoustical Society of America, 39,* 372- 387.

Speaks, C., Jerger, J., & Trammell, J. (1970). Comparison of sentence identification and conventional speech discrimination scores, *Journal of Speech and Hearing Research*, *13*, 755- 767.

Studebaker, G. A., Pavlovic, C. V. & Sherbecoe, R. L. (1987). A frequency importance for continuous discourse, *Journal of Acoustical Society of America*, *81* (4),1130- 1138 .

Sudipta, K. (2006). *A high frequency English speech identification Test (HF-ESIT)* Unpublished Master's Dissertation. University of Mysore, India.

Tillman, T. W., & Olsen, W.O. (1973). *Speech Audiometry*. In Jerger (Ed) Modern Developments in Audiology, (37-34), New York, Academic Press.

Tobias, V.J. (1964). On Phonemic Analysis of Speech Discrimination Tests, *Journal of Speech and Hearing Research, 7*, 98-100

Turner, C. W., & Henry, B. A. (2002). Benefits of amplification for speech recognition in background noise, *Journal of Acoustical Society of America 112*(4) 1675-1680.

Vandana S. (1998). *Speech identification test For Kannada speaking children.* Unpublished Independent project. University of Mysore. India.

Williott, J.F. (1991). *Aging and the auditory system*, Singular, San Diego. Academic Press.

Zeng, F.G., & Turner, C.W. (1990). Recognition of voiceless fricatives by normal and hearing-impaired subjects , *Journal of Speech and Hearing Research, 33*(3) 440- 449.

APPENDIX

S.No	Bisyllabic word Half List 1	Bisyllabic word Half List 2	Trisyllabic List
1	□□□□□	□□□□□	kagid□am
2	□□ù□□□	s□ra□	□□□□□□
3	□5□□¥□□	□5□□□□	□□ù□□□□
4	□□□□□□	□□□5:□	□□ù□□□□
5	□□□□5□	□□ù□□	□□□¥□□5□□
6	□5□ù□□□□	□5□□:□□	□□□□□□□
7	□□□□□	□□□□□	□5□□□ù□□
8	□□□□	□5□ù□□□	□□□□□□□□
9	□□□□□	□□□5:□	□□□¥□□□□
10	□5□□5□	□5□□□□	□□□5□□□
11	□□□□□□□	□□□□5□	□□□□□□

12	□□□□□□	□5□□□:□	□□□¥□□□□□
13	□□¥□□	□□□□	□□□□□□
14	□□□□5□	□□□□5□□	□□□□□
15	□□¥□□	□□ù□□□	□5□□□□□□
16	□□□¥□	□□□□¥□□	□□□□□
17	□□□□	□□□□	□□□□□□
18	□□ù□□□	□5□□:□	□5□□□ù□□
19	□□□□□	□□□□□	□□□□□□□
20	□□□□□	□□□¥□□	□□□□□□□
21	□□□:□□	□□□□¥□□	□□□□□□□
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23	□ù□□□	□□5□□	□□□□□□
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