High Frequency - English Speech Identification Test
(HF – ESIT)

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The LORD is my shepherd: I shall not want.
He maketh me to lie down in green pastures: he leadeth me be
side the still waters.
He restoreth my soul: he leadeth me in the paths of
righteousness for his name's sake.
Yea, though I walk through the valley of the shadow of
death, I will fear no evil: for thou art with me; thy rod and
thy staff they comfort me.
Thou preparest a table before me in the presence of mine
enemies: thou anointest my head with oil; my cup runneth
over.
Surely goodness and mercy shall follow me all the days of my
life: and I will dwell in the house of the Lord for ever.

Psalm 23: 1-6.

Dedicated To,

My Dearest Ma'a, Papa & Neena, my cute sister

Without whom I am no where

And

To my Guide Prof. Asha Yathiraj,

For her matchless Guidance.

CERTIFICATE

This is to certify that this dissertation entitled **"High Frequency - English Speech Identification Test"** is a bonafide work in part fulfillment for the degree of Master of science (Audiology) of the student Registration no: A0490011.This has been carried under the guidance of a faculty of this institute and has not been submitted earlier to any other university for the award of any diploma or degree.

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CERTIFICATE

This is to certify that this dissertation entitled **"High Frequency - English Speech Identification Test"** has been prepared under my supervision & guidance. It is also certified that this dissertation has not been submitted earlier to any other university for the award of any diploma or degree.

Asha Yathiraj

Prof. Asha Yathiraj

Guide

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April 2006

DECLERATION

This is to certify that this master's dissertation entitled "**High Frequency – English Speech identification Test**" is the result of my own study and has not been submitted earlier to any other university for that award of any degree or diploma.

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April 2006

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INTRODUCTION

Speech perception is defined as the process of decoding a message from a stream of sounds coming from a speaker (Borden & Harris, 1980). The study of speech perception is concerned with the listener's ability to perceive the acoustic waveforms produced by a speaker as a string of meaningful words and ideas (Godinger, Pisoni & Logan, 1991).

It is a known fact that individuals with a hearing loss have a communication problem. Pure tone audiometry does not provide a complete understanding of a person's communication deficit. Hence, it is necessary to use a speech test (Hood & Poole, 1971; Jerger, Speaks, & Trammell, 1968).

Speech audiometry, for the assessment of speech intelligibility or speech perception has become an indispensable tool in clinical evaluation for various reasons. Some of them include the following:

- They provide validating data for pure tone thresholds (Carhart, 1952; Chaiklin & Ventry, 1964).
- They also determine the extent to which a person has disruption in the perception of complex signals like speech (Wilson & Margolis, 1983)
- At supra-threshold levels, speech recognition scores contribute to decisions regarding site of lesion (Hannley, 1986)
- Speech materials is also used in selection and prescription of amplification devices (Niemeyer, 1976)
- It also reflects the degree of communication handicap created by a hearing loss (Mendel & Danhauer, 1997).

- It helps to provide information regarding planning and managing auditory (re)habilitation (Mandel & Danhauer, 1997).
- It can be used to monitor a listener's performance throughout a therapeutic process (Mendel & Danhauer, 1997).
- It can be used to assess the success of different types of medical and surgical treatments (Mendel & Danhauer, 1997).
- In addition it can be utilized to monitor the performance of subjects' in a research paradigm (Mandel & Danhauer, 1997).

Overall speech tests provide a measure of how well listeners understand speech. Thus, the assessment of auditory recognitions or identification of words, nonsense syllables or phonemes is a necessary part of clinical evaluation of hearing impairment and the associated communication difficulties.

A person with a hearing loss is bound to have difficulty in perception of speech. The kind and degree of perceptual difficulty depends on several factors. These include the degree of hearing loss, the type of hearing loss and the configurations of the audiogram (Jerger & Jerger, 1971; Gardner, 1971; Pascoe, 1975; Owens & Schubert, 1977; Lacroix & Harris, 1979). Depending on the audiograms configuration the speech perception ability would vary. A person with a high frequency hearing loss would have difficulty mainly in hearing speech sounds having energy concentration in the high frequency regions (Risberg & Margolis, 1972, cited in Stark, 1979; McDermott & Dean, 2000). Martin (1987*)* concluded in his study that speech perception varied depending on whether the person had gradually sloping, sharply sloping or precipitously sloping audiograms.

Mascarenhas (2002) also found similar result as Martin (1987*)*. In her study she found that individuals with a sharply sloping high frequency hearing loss performed poorly compared to those which gradual sloping and precipitous sloping high frequency hearing loss, on the High Frequency-Kannada Speech Identification Test (HF-KSIT), developed by her.

Speech is a stimulus of high redundancy because the information in it is conveyed in several ways simultaneously (Martin, 1994). A hearing loss involving only part of the auditory frequency range may go undetected in a speech test which is not carefully controlled. A standard speech test can give reasonably accurate prediction of the best hearing threshold levels in the mid frequency region of the auditory range. However, the use of a regular speech identification test would be insensitive towards identification of the problem of a person with a sloping high frequency hearing loss (SHFHL). The low frequency information may contribute redundant cues to the perceptual ability, thus decreasing the sensitivity of the test in detecting their communication handicap (Sher & Owens, 1974; Schwartz & Surr, 1979; Kiukaanniemi & Maatta, 1980)

It was also noted by Turner and Cummings (1999) that the redundancy of natural speech can compensate for supra threshold deficits when the hearing is mild-to-moderate in the low frequencies and sloping towards the high frequencies. This occurs when the listening condition are favorable.

Owens & Schubert (1977) found in his study that individuals with a high frequency hearing loss were not sensitive to a regular speech test, i.e. CID W – 22. He concluded that this test did not assess the real communication problem of individuals with a high frequency loss and expressed the need to use high frequency speech test material. Similar results were also obtained by Chung and Mack (1979). They found that in a quite condition, both normal hearing subjects and individuals with a high frequency hearing loss performed equally on a regular speech test (CID W-22). This indicated that the test was not sensitive to the communication problems of individuals with a high frequency sensori neural hearing loss.

Surr, Seidman, Schwartz and Mueller (1982) in their study demonstrated that a good agreement between the pure tone and speech band thresholds was obtained at low frequencies but there was no correlation between pure tone and speech band thresholds at high frequencies. This was seen because the subjects in this study had a mild hearing loss in the low frequencies and more loss at the higher frequencies. They concluded that one had to be careful while assessing and interpreting the problems of individuals with a high frequency hearing loss.

Aniansson (1974) studied subjects with a high frequency hearing loss, with normal hearing for the frequencies below 3000 Hz. A speech identification score of 88% was obtained on monosyllabic words, measured in quiet. Similar results were obtained by McDermott and Dean (2000) in their study on six adults with very steeply sloping high frequency hearing loss. However, when this individual were assessed using different signal-to-noise ratios, the scores differed from that of the normal hearing individuals, reflecting the communication problems of individuals with a high frequency hearing loss.

Thus, several studies have noted that, regular speech identification tests are not sensitive to assess the perceptual problems of individuals with a sloping high frequency hearing loss. Hence, special test need to be developed and used while testing them.

According to Mandel and Danhauer (1997) speech recognition tests can be scored using two procedures. In one procedure a synthetic (all or none) / word scoring method is used, in which the subjects must perceive the entire stimulus correctly to receive credit. The other scoring procedure uses a phoneme scoring method, where the subject is awarded credit for any part of the stimulus perceived correctly. When an all or none scoring procedure is used, the experimenter may choose not to transcribe the subject's responses but rather may simply check off right or wrong on a printed list of response items. This method of recording errors does not provide the experimenter with any information about what caused the entire word to be incorrect. Phonemic, phonetic or orthographic transcriptions are more informative methods of recording the subject's responses because they tell the experimenter what phonemes are incorrect (Boothroyd, 1968; Edgerton & Danhauer, 1979). Accuracy in recording a subject's responses and the use of analytic scoring methods may increase the sensitivity of tests by providing a more informative profile of listener's speech perception abilities than is available through all or none procedures. Even Feeney (1990) reported that phoneme scoring was more sensitive in assessing the perceptual problem of individuals with a sloping high frequency hearing loss.

However, Mascarenhas (2002) found that the word scoring was sensitive to the problem of the individuals with a sloping high frequency hearing loss (SHFHL). As the slope increased, the word score decreased but it was not so for the phoneme scores. There was no significance difference even at 0.05 levels for the phoneme scores. Hence, she noted that phoneme scoring was not sensitive to detect the perceptual difficulty of persons with a SHFHL.

In order to determine the perceptual problems of individuals with a sloping high frequency hearing loss (SHFHL) special speech test need to be developed. These standardized tests should have phonemes with a high frequency emphasis. These tests might be more sensitive to the problems of these individuals (Mandel and Danhauer, 1997). However, the existing speech tests in India do not satisfy the requirement for the Indian English speaker with a sloping high frequency hearing loss.

NEED FOR THE STUDY

From the studies that have been reviewed it is evident that there is a need to develop special speech identification tests for individuals with a sloping HFHL for the following reasons.

- Most speech identification tests have been developed to determine the communication problems of individuals having a flat frequency hearing loss. The speech tests normally used would provide redundant information and hence not indicate the true nature of the communication problem of a person with a sloping HFHL. Hence, special tests need to be designed for them.
- In order to select appropriate hearing aids for clients with a sloping hearing loss, it is essential that a test that is sensitive to their problems be utilized. It is highly possible that a person with a sloping HFHL may get maximum scores unaided, if a regular speech identification test is used. Hence, it will not be possible to check for a problem in communication if such a test is used. It is unlikely that a person with a SHFHL may get maximum scores unaided, if tested with material that is specifically designed to detect his / her problem.

- It has been reported by Mendel and Danhauer (1997) and Mascarenhas (2002) that the procedures used for scoring the responses would alter the validity of the test results. Hence, comparison of a phoneme scoring procedure with a word scoring procedure requires to be done.

AIMS OF THE STUDY

- To develop a speech identification test for testing adults with a sloping high frequency hearing loss. The test would have a word subtest and a sentence subtests. Each subtest would have several lists.
- To obtain normative data for the newly developed material
- To check the equality of the different lists that is developed.
- To administer the test on a sample of adults with a sloping high frequency hearing loss to check its utility.
- To check whether the scoring technique alters the validity of the test.

REVIEW OF LITERATURE

Many listeners with cochlear hearing losses often do not manifest reduced word identification scores when performance is assessed with many of the more commonly used monosyllabic word lists, despite reports of a hearing handicap. This is particularly evident when word recognition ability is assessed in persons with high frequency sensorineural hearing loss (HFSNHL) (Sher & Owens, 1974).

Most of the sensory or cochlear hearing impairment are of high frequency hearing loss. Millions of people around the world with acquired sensory hearing loss have a high frequency hearing loss. Though this type of problem is not life threatening, it can become a major burden in social and professional life (Kemperman & Cremers, 2002).

There are a variety of causes that results in an acquired sloping high frequency hearing loss. Some of the causes are ototoxic medication (Crifo, 1975; Matz, 1990), noise induced hearing loss (Hoople, 1961; Helfer, Jorclan & Lee, 2005), presbyacusis or age related hearing loss (Rosenhall, Pederson & Dotenall, 1986; Rooij & Plomp, 1990; Felder & Schrott, 1995; Tyberglein, 1996), acoustic neuromas (Selesnick & Juckler, 1993), and HIV-positive (Christensen, Morehouse, Powell, Alchediak, & Silio, 1998).

In high frequency hearing loss, hearing is preserved below 1 kHz. Patients with this type of hearing loss are mostly able to perceive speech in quiet but have difficulty in noisy environment and with the speech sound whose energy concentration is in the high frequency region i.e. above 1 kHz (Lundborg, Risberg, Holmqvist, Lindstrom & Svard, 1982).

Kiang and Moxon (1974) conducted a study on cats, which showed that neurons with high characteristics frequencies (CF) also carry information of sounds in the speech frequencies. This kind of information is not available to people with a high-frequency hearing loss, in whom information from speech signals is obtained only through low-frequency neurons.

Data from acoustical studies provides further evidence for the importance of frequencies above 2 kHz in speech detection. Hughes and Halle (1956) reported the resonance region for /s/ to be between 2000 and 4000 Hz; for /ʃ/, 3500 Hz and above; and for /f/, between 6800 and 8400 Hz. Pascoe (1975) suggested that the critical range of frequencies which have a significant effect on word recognition, particularly in noise, are those between 2500 and 6300 Hz. Hence, the individuals with a SHFHL have difficulty in the perception of speech sounds having a high frequency energy. This indicates that high frequency information is an important aspect in speech recognition. In case of children also high frequency audibility is necessary for the speech and language development as reported by Stelmachowicz, Pittman, Hoover, Lewis and Moeller (2004).

Johnson, Stein, Broadway and Markwalter (1997) did a study on children with normal hearing and children with minimal high frequency hearing loss (age range from 6 to 14 years). They found that in a quite condition there was a significant difference in the consonant identification score between both the groups. The children with minimal high frequency hearing loss scores poorer. Thus, the author concluded that, there is an important role played by the high frequency information in consonant identification score.

The above studies indicate that there is a need to identify speech problems in individuals with a high frequency hearing loss. This problem goes undetected by the regular audiological test battery.

Communication problems and high frequency hearing loss:

In individuals with a presbycusis, pure-tone thresholds tend to increase as their age: longitudinal and cross-sectional studies put the rate of decay at about 5.5 to 9 dB/decade for the better ear depending on the frequency (Davis, Ostri & Parving, 1990; Gates, Cooper, Kannel & Miller, 1990; Ostri & Parving, 1991) the worse ear often deteriorates almost 50% faster. Divenyi, Stark and Haupt (2005) compared elderly subjects with normal hearing. The findings revealed that decline of speech understanding measures accelerated significantly relative to the decline in audiometric measures in the seventh to ninth decades of life. On the assumption that speech understanding depends linearly on age and audiometric variables, there is evidence that this linear relationship changes with age, suggesting that not only the accuracy but also the nature of speech understanding evolves with age.

Speaks, Jerger and Trammell (1970) compare the sentence identification and conventional speech discrimination scores in flat sensorineural hearing loss (SNHL) cases and in sloping high frequency hearing loss cases. They found that individuals with flat a SNHL performed equally in both. However, in individuals with a sloping high frequency hearing loss the scores of the sentence identification was better than the word (PB word) discrimination scores. The author concluded that the individuals with a high frequency hearing loss have more problems in the perception of words in isolation but perceive the same word when it occurs in the sentence because of the redundancy effect.

Niemeyer (1967) used German sentences in random noise corresponding roughly to traffic noise. He found that loss of intelligibility can occur with a sensorineural loss above 3000 Hz to 4000 Hz and is invariably with a loss above 2000 Hz to 3000 Hz.

Kaplan and Pickett (1982) investigate the differences in speech discrimination in the elderly as a function of type of competing noise: speech-babble or cafeteria. The elderly subjects had a high frequency hearing loss (HFHL). The results of the study reveal that the elderly individuals with a HFHL had poor speech discrimination in both the noise condition. When the performance was compared within the two noise condition, it was found that the subjects with a high frequency hearing loss performed poorly in cafeteria noise than speech babble. They explained this difference based on the differing frequency spectra of the two noises. The frequency spectrum of cafeteria noise was essentially flat through 3500 Hz, but contained considerable energy above that frequency. Thus, there may have been less high-frequency speech information available to suffer stress of masking from the low frequencies. In contrast, the major spectral component of speech-babble was below 1 kHz, which might allow for more release of masking by attenuation. Hence, one should consider this type of communication difficulty, which may not be present or manifest in quiet condition.

Cohen and Keith (1976) did a similar type of study, which attempted to determine whether word recognition scores obtained in noise were more sensitive to the presence of a hearing loss than recognition scores obtained in quiet. Subjects with normal hearing, high frequency cochlear loss and flat cochlear hearing loss were tested in quiet and in the presence of a 500 Hz low-pass noise in two signals-to-noise (SNR) condition of - 4dB and -12 dB. The results indicated that, while the word recognition scores of groups were similar in quiet, but the more negative the SN ratio, poorer the recognition scores of the hearing impaired subjects as compared with that of the normal hearing subjects. When both pathology groups were compared, there was a significant difference between the two groups. Individuals with a high frequency hearing loss had poorer scores than the flat cochlear hearing loss group. Thus, it indicates that individuals with a high frequency hearing loss have more difficulty in a noisy environment than in a quiet environment.

Hurwitz, Dubno and Ahlstrom (2002) studied the recognition of low-pass-filtered consonants in noise with normal hearing and impaired high-frequency hearing. This study was designed to determine if high-frequency hearing loss resulted 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 (0 dB, 6 dB, 12 dB) that was spectrally shaped to match the long-term spectrum of the speech. The findings of this study were:

(a) Listeners with impaired high-frequency hearing showed deficits in recognition of unfiltered speech in noise compared to normal-hearing listeners. The authors felt that this deficit was related to the reduction in high-frequency speech audibility.

(b) Listeners with impaired high-frequency hearing showed deficits in recognition of low-frequency speech in noise compared to normal-hearing listeners. These results were not predicted on the basis of speech audibility because speech and noise were low-pass filtered and presented only at frequencies for which both groups had normal hearing and nearly equivalent masked threshold. This result is consistent with the hypothesis that damage to the base of the cochlea results in reduction in the encoding of lower frequency speech information.

(c) The use of a high-pass noise of sufficient intensity to assure that the fibers in the base of the cochlea are disrupted, may result in elevated mid to low-frequency thresholds. Therefore, studies using high-pass noise to model loss of contribution from high frequency fibers should be undertaken with caution.

The authors concluded that, these findings may have clinical implications involving the nature of deficits accompanying high-frequency hearing loss and the provision of high frequency amplification.

The studies on individuals with a HFHL indicate that they do have perceptual problems that are related to their lack of audibility in the high frequency. In the presence of noise they had more difficulty in hearing than in a quiet situation. Also, the difficulty varied depending on the frequency spectrum of the noise. The perception problem was more for isolated words than for sentences which carried redundant information.

Studies have been carried out to determine the specific problems in the perception of consonants and vowels, in individuals with a HFHL. The following section reviews these studies.

Perception of Consonant in Individuals with a Sloping High Frequency Hearing Loss:

Dubno, Dirks and Ellison (1989) evaluated the utilization of certain frequency regions for consonant place perception for normal hearing listeners and listeners with a HFHL and to characterize the differences in stop consonant place perception among these listeners. Stop-consonant recognition and error patterns were examined at various speech-perception levels and under condition of low and high pass filtering. Differential filtering effects on consonant place perception were consistent with the spectral composition of acoustic cues. Performance for each consonant under filtered conditions was consistent with the presence of broadband spectrally based cues and additional vowel-dependant cues under low pass filtering. Stop consonant recognition and error patterns for normal hearing and individuals with a hearing impairment were equivalent for stimulus band widths that corresponded to regions of normal hearing for both subject groups. There were differences between the normal hearing and individuals with a HFHL in recognition. Error patterns were observed when the spectrum included regions of threshold elevation for the listeners with a HFHL.

Owens, Benedict and Schubert (1972) studied phonemic errors related to pure tone configuration and certain kind of hearing impairment. They observed that /s, ʃ, tʃ , dz/ and the initial /tʃ/, /θ/ were easily identified by patients with flat pure tone configurations, but were difficult for patients with sharply falling slopes from 500 Hz to 4000 Hz. Identification of /s/ and initial /tʃ/ and /θ/ was highly dependent upon the energy in the frequency range above 2000 Hz, whereas identification of the /tʃ, ʃ, dz/ was highly depend on the range between 1000 and 2000 Hz. Error for individual phonemes seemed to be more closely related to pure-tone configurations than to the type of hearing impairment. Slightly higher error probabilities occurred for /s, tʃ, dz/ and initial /tʃ / and initial /θ/ for the noise-induced loss group, presumably because their pure tones slopes generally fell more sharply compared to the presbycusis group. It was also observed that although the error response phonemes were usually the same as the stimulus phoneme in manner of production, it was not the same in place as the stimulus phoneme. Similar findings were reported by Chung and Mack (1979).

Another study was conducted by Ochs, Humes, Ohde and Grantham (1989) on frequency discrimination ability and stop-consonant identification in normally hearing and individuals with a hearing loss. They examined place of articulation in the synthesized syllables /bi/, /di/, and /gi/ in a group of subjects with a HFHL and two groups of normal subjects, one listening with and another without masking noise. Stimuli with a moving F2 format transition (moving F2 stimuli) were compound with stimuli in which F2 was consonant (straight F2 stimuli) to assess the F2 transition in perceiving stop consonant for both moving and non-moving F2 stimuli, the performance of three groups was similar in identifying /di/ and /gi/. However, performance of hearing impaired and noise masked hearing listeners was below that of the unmasked hearing group for /bi/ for the moving F2, and especially for the straight F2. Error with /bi/ most commonly involved confusion with /di/. A possible explanation, for this result may be due to the pronounced spectral peak in the onset spectra for /g/ stimuli which may be more resistant to changes introduced by sloping audiometric configurations than the rising / falling onset spectra for /b/ or /d/.

Lawrence and Byers (1969) studied identification of voiceless fricatives by individuals with a HFHL. Five male adults (aged 25-55 years) with HFHL were taken. The ear with the best sensitivity for pure tones was selected as the test ear. The stimuli used were 16 CV syllables forward by combining each of the fricative /ʃ /, /s/, /f/, /θ/ with each of the four vowels, /i/, /e/, /o/, /u/. The percentage of the fricatives that were identified correctly were as follows /ʃ/ - 87%, /3/-83%, and /s/ = 77%, /θ/ - 72%. The subjects showed idiosyncratic confusion patterns. There were no vowel confusions;

however the fricatives were more often confused in association with the front vowels /i/ and /e/, than with the back vowels /u/ and /o/. Even /ʃ/ was confused for /s/ and /f/ for /θ/. Examination of the fricatives suggested that low frequency energy, intensity and duration of the fricative sounds, as well as formant transitions of vowels were available to the subjects to serve as possible cues for voiceless fricative identification.

A study was carried out by Hogan and Turner (1998) to investigate the effect of increasing audibility in high frequency regions for normal hearing and individuals with a high frequency hearing loss on speech recognition scores. Five normal hearing and individuals with high frequency hearing loss were asked to identify nonsense syllables that were low passed filtered at a number of cut-off frequency. They found that normal hearing individuals demonstrated an increase in recognition scores as audibility increased. Listeners with mild HFHL performed similarly to the normal hearing listeners, while those listeners with a moderate HFHL performed poorer than the normal hearing or mildly hearing loss listeners. The listeners with a severe HFHL performed worse than the three other groups. In particular it was observed that as hearing loss increased above approximately 55 dB HL, listeners were not as efficient as normal hearing listeners in using high frequency information to improve speech recognition performance. They concluded that eliminating amplification with-in frequency regions that cause a decrease in performance score might help those listeners to improve their ability to recognize speech. Their results suggest that clinicians should use some discretion in providing amplification above 4000 Hz when hearing loss in those regions is greater than 55 dB HL.

Sher and Owens (1974) studied consonant confusion associated with hearing loss above 2000 Hz. They included two groups, one group with normal hearing up to 2000 Hz and a high tone loss beyond 2000 Hz, the degree of slope averaging 30 dB between 2000 Hz to 3000 Hz, and 15 dB between 3000 Hz to 4000 Hz. These groups include presbyacusis, sudden hearing loss and other SN loss. Another group included normal hearing individuals, who heard the speech stimuli presented through a low-pass filter with a cut-off at 2040 Hz. The results of the study indicated that, overall there was difficulty in phonemic identification. The phonemes contributing to this difficulty were primarily /p, b, t, k, s, θ/ in both initial and final positions, /tʃ,ʃ, f, dz, z, v/ in final position only. Hence, individuals with normal hearing up to 2000 Hz accompanied by a high frequency loss do have difficulty identifying a substantial number of phonemes.

From the above discussed studies, it is clear that individuals with a high frequency hearing loss have difficulty in the perception of speech. However, there is variation in the severity of the problem across individuals. Individuals with lesser slope are known to have lesser problems in perceiving high frequency speech sounds.

As it is established that individuals with a HFHL have specific problem in the perception of consonants, it is appropriate that tests that tap these problems be used while evaluating them. The following section reviews the need for such tests and the tests that have been developed to specifically identify their problems.

Speech tests for the assessment of individual with a high frequency hearing loss:

A. Need for the tests to assess high frequency hearing loss:-

Sher and Owens (1974) reported in their study that the mean score on the CID-22 word lists for 35 subjects with a high frequency sensorineural hearing loss, beginning at 2000 Hz was 94.6% (standard deviation, 4.8%). They noted that the clients were often confused when told of their high scores, as the information did not confirm with their actually experiencing difficulty understanding conversation in certain situations.

Other investigators have also reported that CID W-22, a regular speech test was often incapable of differentiating between normal and impairment listeners (Carhart, 1965, Keith & Talis, 1972; Geffner & Denovan, 1974). Hence, there was a need to have a test which differentiates the normal hearing individuals from the individuals with a high frequency hearing loss. As many of the individuals with a hearing loss scored high on this test, it was felt that the relative ease of these materials did not permit differentiation among minor deficits in phonemic discrimination.

Due to the inherent problem associated with the CID W-22 recordings, researchers have developed several new speech testing materials in an effort to increase the sensitivity of monosyllabic word recognition measurement. Among these is the North Western University Auditory test number 6 developed by Tillman and Carhart (1966, cited in Schwartz & Surr, 1979). This test has gain wide clinical popularity in Western countries.

Walden, Prosck, and Worthington (1975, cited in Schwartz and Surr, 1979) conducted an extensive investigation on 3000 active duty army personnel. Pure tone audiometry and speech identification test was carried out on them. The result of pure tone audiometry did not correlate with the NU-6 scores. The pure tone audiogram finding revealed they had that normal hearing till 1 kHz with perceptions sensorineural drop in the high frequencies. The result of NU-6 ranged from 96.1% to 98.9% in their individuals. Hence, the performance on the NU-6 list did not reflect, the communication difficulties experienced by individuals with a high frequency hearing loss. These studies substantiated the need for special speech identification tests for individuals with a HFHL.

B. Existing test for individuals with a sloping high frequency hearing loss.

Due to the inability of the regular speech identification tests to detect the perceptual problems of individuals with a high frequency hearing loss, researchers developed special tests for these clients. This was done in order to prevent misdiagnosis in individuals with a sloping high frequency hearing loss.

These test included:

- The Gardner High Frequency Word Lists (Gardner, 1971)
- The Pascoe High Frequency Test (Pascoe, 1975)
- The California Consonant Test (Owens & Schubert, 1977)
- The Speech Identification Test for Hindi and Urdu Speakers (Ramachandra, 2001)
- High Frequency – Kannada Speech Identification Test (Mascarenhas, 2002)

The Gardner High Frequency Word List (Gardner, 1971)

Gardner (1971) compiled a list of words to meet the need for testing individuals having a high frequency hearing loss. According to him accurate measurement of the effects of modification in tubing diameter, ear mold design or acoustic filter placement, which results in the critical enhancement of high frequency information, are essential. With improvement in technology and availability of instrument whose specification suggests their suitability for cases, there are few clinical methods for demonstrating the benefits of amplification. In order to test the subtle perceptual changes that the acoustical or electro acoustical modification brought about, he designed the high frequency word list.

His list consists of seven voiceless consonants /p, t, k, s, f, θ, h/ in conjunction with the vowel /i/. These consonants have been known to be confusing in individuals with a high frequency hearing loss. The fifty words were arranged in random order and assigned alternatively to two lists of twenty-five words in each. The Gardner high frequency word lists were recommended to be used with a live voice presentation or with a tape recording of a female (or high pitched) talker. It was also recommended that the lists of stimuli to be randomized while presenting to the subjects, especially when performing hearing aid evaluation. Though the test was specially designed for application in hearing aid selections, it may be used for auditory training as well.

The drawback of the Gardner test was that no standardization information was reported for the different talker's presentation modes or randomized lists. Therefore the sensitivity of this test is doubted. Also the stimuli require to be tested under specified conditions to determine if they are sensitive enough to provide the kind of information desired from the test.

The Pascoe High Frequency Test (Pascoe, 1975)

Pascoe developed this test to assess the speech perception abilities of individuals who are hearing impaired, using words with difficult phonemes. The list included fifty monosyllable words that emphasize phonemes that are difficult for hard-of-hearing subjects. Only three vocalic nuclei were used (/I/, /ai/ and /ou/) in order to increase the weightage 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 words were recorded by a male and female talker. The words were divided into two lists.

Using the material developed by him, Pascoe conducted an experiment which consisted of two parts, one in which eight hearing impaired subjects were tested with binaural master hearing aids with five different frequency response. In the second part, the Pascoe high frequency test was compared with the PB-word list in quiet and in noise. The results indicated a high correlation between the subjects' adjusted hearing levels, using a high frequency band and the identification scores in a non PB-list (i.e. the high frequency list). The Pascoe high frequency test was advantageous in that, it provided standardized information on a male and female talker's version of the test. The test was found to be useful for hearing aid evaluation as well as checking difficulty in perception in the presence of noise.

The California Consonant Test (Owens and Schubert, 1977)

The California consonant test (CCT) developed by Owens and Schubert (1977) consists of 100 monosyllables, equally divided into two sub list with 50 items in each. This test has been developed expressly for use with hearing-impaired patients. This test is a multiple-choice test for consonant identification. The authors believed that a clinical test should be developed which permitted phoneme variation in only one position in any given item, which employed an easily manageable number of foils. A computer-assisted analysis was obtained for the test responses of 550 patients with sensorineural hearing loss. The test was found to be highly sensitive to high frequency losses. This was especially true for groups of subjects with high tone losses beginning at successively higher frequency as measured audiometrically. Poor scores revealed that a fairly low correlation (-0.40) was found between the CCT and the degree of loss for 59 subjects with a relatively flat configuration between 250 Hz to 4 kHz.

The authors also compared the W-22 test with CCT, in subjects with varying audiometric configuration. They found that the CCT became more difficult, relative to the W-22 lists, as the pure-tone threshold slope became sharper. An analysis of the test words revealed that the W-22 word list contained 22% of high frequency component sounds, but the CCT consist of 38% of high frequency speech sounds in the test lists. According to the authors the reliability of the CCT was high and its range of difficulty was appropriate for separating patients with different degrees of difficulty. They noted that the utility of the test in rehabilitation procedures and in hearing aid comparisons would be substantial if it is used to identify consonant errors predominate in the speech reception of a given patient. A correlation of 0.35 with the W-22 list indicated that the two tests were measuring different aspects of speech perception, with the W-22 measuring the over all perceptual problem, and CCT specifically measuring the perceptual problems of high frequency hearing loss.

A drawback of the test is that despite of the test being designed specifically for detection of high frequency hearing loss, it contains only 38% of high frequency speech sounds. This indicates that major part of the test does not include high frequency speech sounds.

The Speech Identification Test for Hindi and Urdu Speakers (Ramachandra, 2001)

Ramachandra (2001) developed a high frequency speech identification test in India for Hindi and Urdu speakers. She developed two lists of randomized words rated for familiarity. The first list consisted of high frequencies phonemes in the initial position and the second category consisted of high frequency phonemes in the final position. She administered the test on 15 patients with a sloping high frequency hearing loss and found that the test was more sensitive to their perceptual problems compared to the common speech discrimination test for Indians (Mayadevi, 1974).

The results revealed no significant difference between the groups of Hindi and Urdu speakers for the sensation levels from 0-40 dB at the 0.05 level of significance. Hence, she recommended that the test could be used for subjects speaking either language.

High Frequency – Kannada Speech Identification Test (Mascarenhas, 2002)

Mascarenhas (2002) developed a speech identification test in Kannada, exclusively for adults with a sloping high frequency hearing loss (SHFHL). The test items consisted of different phonemes classes like vowels /a/, /i/, /e/, /o/, /u/, semi vowels /i, r, l/, stops /k, t, o/, fricatives /s, ʃ , f/, and affricates /tʃ/. Using these phonemes, word subtests and sentence subtests were complied. Each subtest has three lists.

She administered the three lists randomly on 30 normal hearing and 30 individuals with a high frequency hearing loss. She also checked the utility of the test by administering the test on five individuals with a high frequency hearing loss (i.e. gradually sloping, precipitously sloping and sharply sloping) with and without hearing aids. The results were compared with those obtained with the "Common speech discrimination test for Indians" (CSDTI) developed by Mayadevi (1974).

It was found that there was no significant difference between the word subtests and sentence subtests in the normal hearing group. Also there was no significant difference between HF-KSIT and CSDTI in normal hearing population.

The high frequency hearing loss group obtained poorer scores on the word subtest compared to the sentence subtest, indicating that the former was more sensitive to detect their problem. The sentence subtest was unable to differentiate subjects with a HFHL from normal subjects. To make the sentence subtest more sensitive, she suggested administering it in the presence of background speech noise.

The group with a HFHL got poorer scores when the word scores were used compared to when the phoneme scores were used. Thus, the word scoring procedure was recommended for individuals with a high frequency hearing loss.

A significant negative correlation was obtained between the slope of the audiogram and the word identification scores for HF-KSIT. This was observed when the word scoring procedure was used. This correlation was not observed with the CSDTI. The individuals with a high frequency hearing impairment were tested both in aided and unaided condition. The result showed that there was a significant difference in the performance of the subjects for the word and sentence subtest in both the condition. Hence, the test was considered useful for the selection of hearing aids.

She concluded that the HF-KSIT was a sensitive test for assessing sharply sloping HFHL, when compared within the sloping HFHL group. Over all it saw found to be a sensitive test to assess individuals with a HFHL as well as a useful test for selection of hearing aids.

Researchers have thus developed different tests to assess the perceptual difficulties of individuals with a sloping high frequency hearing loss. It is generally observed that as regular speech tests are not sensitive to assess accurately the communication problem of individuals with SHFHL. Hence, the use of these specially designed tests is advocated.

Comparative Studies of Special Tests, which are Available for the Assessment of Individuals with HFHL

Carhart, Tillman, & Wilber (1963) point out that the rational for speech discrimination testing should dictate the selection of the specific test to be administered. If the purpose of the test is to determine whether the hearing of the client falls within normal limits, the NU-6 test appears to be satisfactory. However, if testing is to be done for purpose of evaluating a hearing aid or of determining the fine auditory discrimination ability of an individual with a HFHL, then a more sensitive test is needed. Following are studies, which compare regular speech tests with tests designed specifically for individuals with a HFHL.

Schwartz and Surr (1979) conducted three experiments using the CCT. They compared performance scores on the CCT with those on the NU-6 lists and examined internal consistency and split half reliability of forms one and two of the CCT.

The findings of Schwartz and Surr (1979) supported the results of Owens & Schubert (1977). Schwartz and Surr (1979) suggested that the CCT was sensitive to phoneme recognition difficulties experienced by listeners with a high frequency hearing loss. The performance intensity formation for both normal hearing individuals and those with a cochlear hearing loss indicated that the test should be administered at a sensation level of 50 dB for maximum speech discrimination at a fixed intensity level. The result of the second experiment revealed that in the comparative distribution of scores for the NU-6 list and the CCT, the hearing impaired individuals often attain relatively high scores on the NU-6 materials despite a significant HFHL. Conversely the results from the CCT demonstrated a markedly reduced word identification scores. Such findings seem consistent with the communication difficulties reported by these individuals. In their concluding remarks the authors reported that the CCT had considerable implication and determining progress in auditory rehabilitation for persons with a HFHL.

In another study, Maroonroge and Diefendorf (1984) compared the performance of normal hearing and individuals with a HFHL on the NU-6, CCT and Pascoe high frequency word test. The tests were presented to two groups of listeners. One group consisted of 12 subjects with normal hearing up to 2 kHz accompanied by a HFHL and the second group includes 12 persons with normal hearing. The authors found that persons who sustain HFHL encounter varying degree of difficulty in perceiving and distinguishing between similar sounds. They undertook the study to investigate the importance of frequencies above 2 kHz for understanding speech.

In their study, they found that the CCT and Pascoe's test did not differ significantly on the overall speech identification scores. However, for the NU-6, scores were significantly higher than the other two tests. The findings suggest that the NU-6 identification test is the least sensitive and may not be appropriate for identification difficulties in individuals with a HFHL. The high NU-6 test scores among individuals with sharp slopes may be attributed to the perceptual cues provided by low frequency elements.

These cues may have facilitated word discrimination in quiet as noted earlier by Goezinger (1972) and Hopkinson (1972).

Gordon-Salant (1986) compared responses of young and elderly normal and hearing impaired listeners using NU-6 and CCT. The subjects had a mild-to-moderate sloping HFHL. The presentation level of the test material was 80 dB and 95 dB SPL respectively. The subjects were compared on their ability to judge the accuracy of their responses on the speech recognition task. Judgments of accuracy were higher for all groups using NU-6 than for CCT. Subjects were also found to be more confident in their responses to the Nu-6 than the CCT materials.

The above mention studies once again substantiate the need for special tests to assess difficulties in perception in individuals with a high frequency hearing loss. Such test would enable better rehabilitation of these individuals.

Application of High Frequency Speech Tests for the Selection of Hearing Aid Fitting in Individuals with HFHL

In the 1960's individuals with normal threshold at 500 Hz, normal or mild-loss thresholds at 1 kHz and a mild, moderate or severe loss at 2000 Hz were not consider for successful hearing-aid fitting. Thus, all individuals with a HFHL were not consider as good / appropriate candidates for hearing aid fitting. This was due to the limited technology used in hearing aid in those days (Gardner, 1971).

However, with time there is great development in technology of hearing aids, such as wide dynamic range compression (WDRC), digitally programmable circuits, totally digital circuits and deep or completely in the canal devices, which allow the audiologist to provide amplification in the high frequency region. Since, hearing aids are able to provide useful amplification even in the high frequency region, it becomes a necessity to test hearing in the high frequencies (Mendel and Dunhaner, 1997). Hence, while fitting or selecting hearing aids, for the individuals with a HFHL, it is necessary to use high frequency word test.

Dennison and Kelly (1978) did a study to check high-frequency consonant word discrimination with hearing aids. Their results showed that in 5 of the 9 subjects, the same hearing aid was selected using either the high frequency consonant test or the NU-6 test. However, in the remaining four subjects, while the NU-6 test indicated that the amplification was appropriate, the high frequency consonant score indicated that the amplification was not appropriate. They concluded that the high-frequency consonant scores should serve as a supplemental to the NU-6 test scores and not as a replacement for NU-6. The high frequency consonant scores obtained by two of the subjects lead to the selection of different aids than the ones selected using the NU-6 test and the patient preference. Perhaps the reason the patient chose an aid other than the one that would most benefit him was that he was most comfortable with an aid that allowed him to hear in the manner to which he was accustomed, even if he did not do as well with it. If a person had become accustomed to not hearing the high-frequency sounds, an aid that suddenly allowed him to hear those sounds might disturb him. The addition of high frequency amplification might have made speech sound foreign to him. It would have been much easier for him to choose the aid that he was most comfortable with. However, if the individual, after getting the appropriate hearing aid, had gone for auditory training for the better perception of high frequency speech sounds, which would have reduced his communication problems, he would have found it better.

Skinner (1980), and Skinner, Karstaedt, and Miller (1982) used the Pascoe high frequency word test for the selection of hearing aids in individuals with a sensori neural hearing loss. It was found that it was much better to select the appropriate hearing aid based on the requirement of the client by using Pascoe's high frequency word test than the regular speech identification test.

Mascarenhas (2002) found that there was a significant difference between the aided and unaided scores on the word sub-test of the High Frequency-Kannada Speech Identification Test (HF-KSIT) developed by her and the Common Speech Identification Test (CSDTI) developed by Mayadevi (1974). The latter was a regular speech identification test. She concluded that her test was sensitive to the perceptual problem of individuals with a sloping HFHL. Hence, she recommended that the high frequency word test should be use in the fitting of hearing aids in the individuals with a sloping HFHL.

Krishnan (2003) developed a hearing aid test protocol for sloping HFHL. In his study, he used the HF-KSIT developed by Mascarenhas (2002) as the test stimulus. 30 subjects including 11 gradually sloping, 13 steeply sloping and 6 precipitously sloping hearing loss individuals were tested. An analogue behind-the-ear (BTE) was selected using the POGO II formula (Schwartz, Lyregaard & Lundh, 1988). Each of these subjects were tested both in the unaided and aided condition using the selected hearing aid at two signal-to-noise ratios (SNR) of +5 dB and 10 dB SNR. The result revealed that a significant difference existed between the aided and the unaided condition for both the word and sentence subtests across the audiometric slopes. This was present at both the SNRs that were evaluated. Also a significant difference was observed between the +5 dB and +10 dB SNR, for the word subtest. This was seen in both the aided and the unaided condition, for all the three types of slope. However, he did not find any significant difference between the two SNRs for the sentence subtests for all the three-audiogram slopes. The findings of his study implies that either the word or the sentence subtest, in the presence of noise (+5 dB or +10 dB) could be used equally effectively in selecting hearing aids for steep and the precipitous sloping hearing loss. In the gradual slope also both word and sentence subtest could be used, but only at the +10 dB SNR.

These studies indicate the need to utilize tests that are able to detect the perceptual problems of the hearing impaired with a HFHL. A test not specifically designed for them would not be sensitive to their perceptual problem. In this way the high frequency speech identification test will meet the needs of the individuals with a sloping high frequency hearing loss in the selection of hearing aids.

From the review it is evident that there have been tests developed for the assessment of individual with a sloping HFHL but the tests are few in number and are available in limited language. Research has shown that general speech tests are not designed to identify the specific perceptual problems in these individuals. Hence, it is essential that a speech identification tests be designed for this population.

METHOD

The aim of the present study was to develop a High Frequency-English Speech Identification Test (HF – ESIT) for adults. In addition, the study also aimed at checking the utility of the test. The study was carried out in three stages.

Stage – I: Construction of the test material.

Stage – II: Obtaining normative data for the test in adults.

Stage- III: Determining the utility of the test material.

Subjects:

- 20 normal adults from different walk of life were selected to check for the familiarity of the test material (Stage – I).
- 30 normal adults were used to obtain the normative data (Stage – II).
- 10 adults with a bilateral sloping high frequency sensorineural hearing loss were taken to confirm the utility of the material (Stage – III).

Subject inclusion criteria for Stages I & II.

To be included in the study, each subject had to meet the following criteria:

- The age of the subject was more than 15 years.
- Had English as a medium of instructions for a minimum of 5 years and were able to speak it fluently.
- Had normal hearing i.e., air conduction and bone conduction thresholds were less than 15 dB.
- Had an air-bone gap of less than or equal to 10 dB.

- Had normal speech and language.
- Able to perceive and produce all the phonemes of English.
- Able to write English.
- No history of a hearing loss.
- Not have any illness on the day of testing.
- Not have any report of a neurological problem.

Subject inclusion criteria for Stage III.

The subject inclusion criteria for stage III was the same as that of the earlier two stages, except that they had a bilateral high frequency sloping hearing loss. These subjects either had a hearing loss, gradually sloping, sharply sloping or a precipitously sloping hearing loss. The classification was done based on the Lloyd and Kaplan (1978, cited in Silman & Silverman, 1991).

Instrumentation*:*

- A calibrated diagnostic audiometer (dual channel Orbiter 922) and immittance audiometer (GSI-TS) was used.
- A computer with the Creative Wave Studio software (version 4.21.07) was used to record the material.
- Normalization of the speech material was done by using the Audio-lab software.
- A CD burner (Nero Express) was used to transfer the material onto a CD.
- A CD player (Philips CD player) was utilized to play the recorded material.

Test Environment:

The testing for stages II and III was done in a sound-treated double room, with the ambient noise level within permissible limits as recommended by ANSI (1989).

Procedure:

Stage – I:

The phonemes, which had the primary cue for perception in the high frequency region i.e., above 1 kHz were used (Table –1). As far as possible voiced consonants were avoided. Using these phonemes, 300 words were constructed. These words were checked for familiarity on 20 fluent English

Table –1: List of high frequency phonemes

Phoneme Class	***Phoneme***
Vowels	|i| , |e|
Semi Vowels	|j| , |r| , |l|
Stops	|t| , |θ| , |k|
Fricatives	|s| , | ʃ | , |f|
Affricatives	|tʃ |

.**Evaluation of Familiarity of Test Items:**

The subjects were instructed to classify the words according to familiarity or frequency of occurrence in daily conversation. The words were classified on a three-point scale as follows:

- Most Familiar Words: Words which occur more than 75% in daily communication (> 75%).
- Familiar Words: Words which occur between 50% - 70% in daily communication.
- Not familiar words: Words which occur less than 50% in daily communication (< 50%).

The words, which were considered high familiar or familiar by 90% of the subjects was utilized for the final construction of the test. Four lists of words were constructed, with each list having 25 words. In addition four lists having ten meaningful sentences were constructed. The content words of these sentences had high frequency phonemes. The developed test was named “High Frequency-English Speech Identification Test” (HF-ESIT).

Recording of Material:

A female who spoke English fluently, served as the speaker. Her fundamental frequency was within normal limits (212 Hz) which was measured by using the *Vaghmi soft* ware. The words and sentences were recorded in a Pentium 4 computer by using the “Creative Wave Studio” software. Scaling of the singles was done by using the “Audio Lab” software to ensure that the intensity of all words was brought to the same level. Prior to each list, a 1 kHz calibrations tone was recorded. The recorded material was burnt on a CD using, a CD burner Nero Express.

Stage – II:

Administration of the HF-ESIT on normal hearing individuals was done in stage-II. Prior to the administration of the test, their pure tone thresholds were obtained. Their SRT was established using the English pair-word list developed by Chandrashekar, (1972). The recorded version of the HF-ESIT was played using the CD player. The output of the player was routed to an audiometer Madsen OB922. The 1 kHz calibration tone was used to adjust the VU meter deflection of the audiometer to zero. The output from the audiometer was played at 40 dBSL with reference to the subjects SRT, and delivered through headphones (TDH 39 with Mx 41/AR ear cushion). The subjects were asked to write down their responses.

Stage III:

Administration of HF-ESIT on individuals with a sloping high frequency hearing loss.

The ten subjects with a sloping high frequency hearing loss were tested using the HF-ESIT without and with a hearing aid. The hearing aid selection was done based on the insertion gain (IG) which was measured by using NAL-N1 formula in Fonix-EP-40 analyzer. The same digital hearing aid was used with all the subjects. The programming was done for each subject to ensure that the gain of hearing aid was in their fitting range. As in stage II, the speech material was played through a CD player, which was routed to an audiometer. From the audiometer speech material was delivered through loud speakers (MAICO speaker). The speakers were placed at 45^0 azimuths at a distance of one meter from the head of the subject. The signal was presented from the side where the subject wore on his or her hearing aid.

The subjects were also tested using a list of the English Monosyllable Word Test (Rout, 1996), which is a phonemically balanced test. Each subject was tested in the unaided and in the aided condition, using different lists of the test. The scoring was compared with that of the scores obtained from HF-ESIT in the both the condition.

Scoring:

The responses of the subjects in stages II and III were scored in a similar manner. For the word subtest of HF-ESIT, a word as well as a phoneme score was calculated. Every word / phoneme that was correctly identified was assigned a score of one. Thus, the maximum score was 25 for the word score and 85 for the phoneme score.

For the sentence subtest of the test, the key words that were correctly identified were given a score of one. The maximum score that was obtainable in this subtest was 27. Phoneme analysis of the key words was also done and a phoneme score was assigned. The maximum phoneme score for the key words was 107 for three lists and 108 for one list. In addition to scoring the HF-ESIT, for the subjects tested in stage III, word scores were calculated also for the English Monosyllabic Word Test.

The raw scores of the subjects were statistically analyzed using the computer software SPSS 10.0.

RESULTS AND DISCUSSION

The data obtained from both normal and individuals with a sloping high frequency hearing loss was analyzed using the statistical software package SPSS (version 10.0). Analysis was done to check the significance between different aspects of the newly developed test and a regular existing test. Also the utility of the test in selecting hearing aids was evaluated. The analysis was carried out as follows:

I. Analysis of normative data for the High Frequency- English Speech Identification Test (HF-ESIT)

A. Test of significance was done to obtain:

(i) Between list variation

(ii) Word sub-test versus sentence sub-test differences

(iii) Word scoring versus phoneme scoring differences

II. Analysis of data obtained from the individuals with a sloping HFHL

A. Test of significance for HF-ESIT between the following was done

(i) Word subtest versus sentence subtest

(ii) Word score versus phoneme score

B. HF-ESIT versus English Monosyllabic Word Test (EMWT) on individuals with a sloping high frequency hearing loss.

III. Comparison between the normal and individuals with a sloping HFHL group on the HF- ESIT

IV. Comparison between the aided versus unaided scores using the HF-ESIT.

I. ANALYSIS OF NORMATIVE DATA

(i) Between list variatiation

To check for the variation between the four lists of the HF-ESIT, repeated measures ANOVA was performed. It was found that there was no significant difference between the word sub-tests, across the four lists [F (3, 87) = 0.974, P > 0.05]. Similarly there was no significant difference between the four sentence sub-tests [F (3, 87) = 0.834, P>0.05]. This indicates that all four lists are of equal difficulty and any one of them could be used while evaluating the speech identification ability of clients with a sloping HFHL.

(ii) Word subtest versus sentence subtest

As there was no difference between the four lists, the scores were combined while evaluating the difference between the scores of the word and the sentence subtests. Since the maximum scores were not equal for the two subtests, the raw scores were converted to percentage scores. This was done to enable a comparison between the scores. The significance between means was calculated using the t-test. No significance difference was found between the two subtests. This was found immaterial whether a word score or a phoneme score was calculated (Table 2).

Table-2: Mean, SD, and t value for the word and sentence subtest using phoneme and word scores.

Score procedure	Subtests of HF-ESIT	Mean (%)	SD	t-value
Word	Word	97.46	2.55	.500 (NS)
	Sentence	97.18	2.42	
Phoneme	Word	98.04	2.07	.434 (NS)
	Sentence	97.83	1.88	

NS=Not significant at 0.05 level

Similar results were reported by Mascarenhas (2002) in her study. She also did not find any different between the word sub-test and the sentence sub-test in her normal hearing subjects.

(iii) Word scoring versus phoneme scoring

Both the word score and phoneme score was analyzed for the word and sentence subtests to check the significance of difference between the scoring procedures.

Table-3: Mean, SD and t value for the word scoring versus phoneme scoring of word and sentence subtest.

Subtest	Scoring for HF-ESIT	Mean (%)	SD	't' value
Word	Word	97.47	2.56	1.037 (NS)
	Phoneme	96.19	6.40	
Sentence	Word	97.18	2.43	1.198 (NS)
	Phoneme	95.26	8.03	

NS=Not significant difference at 0.05 level

There was no significant difference in the scoring procedure at the 0.05 levels (Table-3) for both word and for phoneme scores. This is because most of the normal individuals obtained near perfect scores. However, the variability in the scores was more for the phoneme scores, as indicated by the standard deviation (Table-3). Mascarenhas (2002) also reported similar results. This may be because majority of the individuals with normal hearing obtained 100% scores.

II. ANALYSIS OF DATA OBTAINED FROM THE INDIVIDUALS WITH A SLOPING HIGH FREQUENCY HEARING LOSS.

A. Test of significance for the HF-ESIT between the following was done.

(i) Word sub-test versus sentence sub-test

The utility of the HF-ESIT was checked on individuals with a sloping high frequency hearing loss. The t-test was use to check the significance of difference between the word and the sentence sub-tests for these individuals. This was done for both the word scoring and phoneme scoring procedure (Table-4).

Table-4: Mean, SD, and t-values for the word versus sentence sub-test of the HF-ESIT using phoneme scores and word scores.

Scoring Procedure	Subtest	Mean (%)	SD	t-value
Word	Word	20.50	4.40	19.15**
	Sentence	62.03	9.14	
Phoneme	Word	49.94	6.40	-2.851*
	Sentence	57.97	11.88	

*Significant at 0.05 level, **Significant at 0.01 level.

From table-4, it is evident that there was a significant difference at the 0.01 level for the word scoring procedure for both the words and sentence sub-tests. The phoneme scores for both word and sentence sub-tests were significantly different at the 0.05 level. The scores of both word and phonemes were high for the sentence sub-test compared to the score of the word sub-test. This is probably because of the redundancy of information in sentences. Individuals with a high frequency hearing loss find it difficult to identify words in isolation, but when the words occurs in sentences they are easier to identify.

Similar result was found by Speaks and Jerger (1965). In their study they reported that as the slope of the hearing loss increased the score of a PB test decreased but it was not so for the sentence identification scores. These findings also were supported by Miller, Heise and Litchten (1951), Speaks, Jerger and Jerger (1966), Giolas & Duffy (1970).

Mascarenhas (2002) reported similar findings in her studies, where her subjects with a sloping HFHL scored more in the sentence sub-test than in word sub-test, for both word and phoneme scoring. She recommended the use of the words sub-test scores rather than sentence sub-test scores for the assessment of individuals with a sloping HFHL. She recommended this since the former score gave a better indication of the perceptual problems of those with a sloping HFHL, than the latter. Similar findings were obtained in the present study also. The word scores were lower than the sentence scores, depicting the perceptual problems of clients with a sloping HFHL to a greater extent. Hence, it is recommended that the word sub-test be used rather than the sentence sub-test, when testing individuals with a sloping HFHL.

To reduce the redundant cues in the sentence subtest, Mascarenhas (2002) recommended that this subtest be used in the presence of speech noise. Earlier Kalikow, Stevens & Elliott (1977) also recommended that sentence tests be mixed with speech babble at various signal-to-noise ratios to improve the sensitivity of the test. Hence, it is recommended that if required, the sentence subtest can be used in the presence of speech noise or speech babble at various signal-to-noise ratios, to increase or improve the sensitivity of the sentence sub-test.

(ii) Word score versus phoneme scores

To check the significance of difference between the phoneme and the word scoring procedure of the word and sentence sub-tests of the HF-ESIT in the individuals with a sloping HFHL group, the t-test was used.

Table-5: Mean, SD and t-value for the word and phoneme scores

Subtest	Scoring procedure	Mean (%)	SD	t- value
Word	Word	20.50	4.40	24.904**
	Phoneme	49.94	6.40	
Sentence	Word	67.00	9.87	2.608*
	Phoneme	62.60	12.83	

*Significant difference at 0.05 level, ** Significant different at 0.01 level

The results revealed that there was a significant difference between the word and phoneme scores for both sub-tests. This difference was larger for the word sub-test then for the sentence sub-test. While the difference was statistically different at the 0.01 level for the former sub-test, it was significant only at the 0.05 level for the later sub-test. It was found that the word sub-test gave a better indication of the perceptual problems of the individuals with a HFHL. It is recommended that words scores be calculated rather than phoneme scores, since this scoring procedure depicts the perceptual problems better. However, if the client is to be referred for auditory listening training, the phoneme scoring procedure may be used. This result is in agreement with the findings of Mascarenhas (2002), Dillon and Ching (1995). Boothroyd (1968) also reported that phoneme scores are 20-30% higher that the whole word score.

B. HF-ESIT versus English Monosyllabic Word Test (EMWT) on individuals with a high frequency hearing loss group

One sample t- test was done to check the significant difference between the HF-ESIT and EMWT. Mean, SD and t values were obtained for both tests in individuals with a sloping high frequency hearing loss. Only word scoring was done, since it was found to be more sensitive to their perceptual problems.

Table-6: Mean, SD and t- value (for the word score) for HF-ESIT and EWT in individuals with a sloping HFHL group.

Subtest	Scoring	Mean	SD	t-value
Word	HF-ESIT (Word score)	20.50	4.40	43.9**
sentence	HF-ESIT (Word score)	62.04	9.15	6.77**
EWT	(Word score)	81.63	3.01	

** Significant at 0.01 level

As shown in the table 6, the mean word scores in both the word and sentence sub-tests were less than the score of English Monosyllabic Word Test. The scores on the latter test are not very deviant from that seen in individuals with a normal hearing (Rout, 1996). This confirms that a regular phonemically balanced test is not sensitive to the perceptual problems of individuals with a sloping HFHL. Similar results were obtained by Schwartz and Surr (1979), Maroonroge and Diefendorf (1984), Gordon-Salant (1986), Ramachandra (2001), and Mascarenhas (2002) when they compared the regular speech identification tests with special speech identification tests which were developed to assess the perceptual problem of individuals with a sloping HFHL.

The HF-ESIT was able to identify the perceptual problems of these individuals. Hence, both word and sentence sub-tests are sensitive in the assessment of individuals with a sloping HFHL when compared to the English Monosyllabic Word Test.

III. Comparison between normal and subjects with a sloping HFHL on HF-ESIT.

Mean, SD and t-values were calculated to check the significance of difference between the normal hearing subjects and individuals with a sloping HFHL for the HF-ESIT (Table 7).

Table-7: Mean, SD and t-value for score of HF-ESIT in normal and in individuals with a sloping HFHL.

Sub-test	Group	Scoring	Mean	SD	t-value
Word	Normal	Word	97.46	2.55	68.10**
	HI		20.50	4.40	
	Normal	Phoneme	333.36	7.04	36.53**
	HI		169	21.78	
Sentence	Normal	Word	104.95	2.62	19.52**
	HI		67.00	9.87	
	Normal	Phoneme	418	8.08	18.15**
	HI		248	50.84	

** Significant at 0.01 level

Note: Maximum word score for word sub-test = 25
Maximum phoneme score for word sub-test = 85
Maximum word score for sentence sub-test = 27
Maximum phoneme score for sentence sub-test = 107

The results obtained indicated that there was a significant difference at the 0.01 level between the two groups. The subject with a sloping HFHL performed significantly poorer than the normal hearing individuals in both word and in sentence sub-tests. This revealed that the newly developed HF-ESIT could be used effectively to assess individuals with a sloping HFHL.

The findings of the present study are similar to that of the findings of the Gardener (1971), Pascoe (1975), Owens and Schubert (1977), Ramachandra (2001) and Mascarenhas (2002) who reported that word tests having frequency specific sounds do differentiate the normal hearing individuals from the individuals with a high frequency hearing loss, who gets undetected by the regular speech identification tests.

IV. Comparison between unaided and aided scores using HF-ESIT

Comparison of the unaided and aided scores of the subjects with a sloping HFHL on HF-ESIT by calculating mean, SD and t- value.

Table-8: Mean, SD and t-value for comparison of unaided and aided scores of individuals with a sloping HFHL on HF-ESTI

Subtest	Group	Mean	SD	t-value
Word	Unaided	20.50	4.40	11.48**
	Aided	94.10	1.91	
Sentence	Unaided	67.00	9.87	10.11**
	Aided	104.73	1.92	

** Significant at 0.01 level

From the results shown in table-8, it is clear that there was a significant difference at 0.01 level for both unaided and aided condition. This difference occurred for both the word and sentence sub-test. Thus, it is recommended that either or both sub-test be used in the prescription or in the selection of amplification devices for individuals with a sloping HFHL.

The special tests developed by Gardner (1971), Pascoe (1975), Owens and Schubert (1977), Mascarenhas (2002) have been reported to be useful in the selection of hearing aid for the individuals with a sloping high frequency hearing loss. Skinner (1980) and Skinner, Karstaedt, and Miller (1982) used Pascoe's High-Frequency Word List for the selection of hearing aid for individuals with a sloping HFHL and found to be useful. Like these tests, the test developed in the present study is useful in selecting hearing aids for individuals with a sloping HFHL.

From the above mention results, it can be concluded that:

- The HF-ESIT may be used while assessing individuals with a sloping high frequency hearing loss.
- The word sub-test was more sensitive to their problems than the sentence sub-test.
- The word scoring procedure was found to be more useful for diagnostic purpose. However, for therapeutic purposes, the phoneme scoring procedure may be used.
- To make the sentence sub-test more sensitive it can be used in the presence of speech noise or speech babble.
- The HF-ESIT word and sentence sub-tests were found to be useful for the selection of amplification devices for the individuals with a sloping high frequency hearing loss.

SUMMARY AND CONCLUSION

The ability to discriminate speech sounds occurs effortlessly for normal hearing individuals. However, persons who sustain high frequency hearing loss encounter varying degrees of difficulty in perceiving and distinguishing between similar sounds (Sher & Owen, 1974; Maroonroge & Diefendorf, 1984; Beattie, Barr & Roup, 1996; Mendel & Danhauer, 1997). When the individuals with a sloping hearing loss are assessed with a regular speech test, their problem goes undetected due to the redundancy characteristics of the speech material. Thus, special tests need to be used to assess such individuals (Gardner, 1971; Pascoe, 1975; Owens & Schubert, 1977; Mascarenhas, 2002).

The present study was done to develop a speech identification test for Indian English speakers to assess the perceptual problem of individuals with a high frequency hearing loss. The present study was carried out in three stages. In the first stage, the material for the word and sentence sub-test was developed by using the phonemes that had the primary cues for perception in the high frequency region. Familiarization of the test was done on people from different walk of life and familiar words were selected to make the test. The test includes four word and four sentence sub-tests.

The four lists were randomized and administered on 30 normal and ten individuals with a sloping high frequency hearing loss. The responses were scored in terms of word as well as phoneme scores. The scores of the present speech identification test were compared with the scores obtained from the English Monosyllabic Word test developed by Rout (1996), which was a phonemically balanced test.

The statistical analysis of the data revealed the following conclusion:

(i) There was no significant difference between the word and sentence sub-tests.

(ii) All the four lists of both the word and sentences sub-tests were similar in the subjects with normal hearing.

(iii) There was no significant difference in the phoneme scores and the word scores for the normal hearing individuals.

(iv) However, there was a significant difference between two scoring procedure in individuals with a sloping HFHL. Word scores were more sensitive in assessing the perceptual problems of individuals with a sloping high frequency hearing loss.

(v) There was a significant difference in the word and sentence sub-tests in hearing impaired group. Individuals with high frequency hearing loss got poorer scores in word sub-test than the sentence sub-test. Hence, the word sub-test was considered more sensitive to assess the perceptual problems of individuals with a sloping HFHL.

(vi) There was a significant difference between the scores of HF-ESIT and the English Monosyllabic Word Test in individuals with a sloping high frequency hearing loss.

(vii) There was a significant difference in the aided and unaided scores for individuals with a high frequency hearing loss. This indicates that the test could be used usefully in hearing aid selection.

Thus, from the above findings it may be conclude that the HF-ESIT is a sensitive test for the detection of perceptual problems of the individuals with a sloping high frequency hearing loss. This test may be use as a part of a diagnostic test battery as well as in the selection of appropriate amplification devices for individuals with a high frequency hearing loss. This test also can be used to check the utility of a therapy procedure on individuals with a high frequency hearing loss.

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