HEARING AID TEST PROTOCOL FOR SLOPING HIGH FREQUENCY HEARING LOSS

Reg. No. 02SH0009

AN INDEPENDENT PROJECT SUBMITTED IN PART FULFILLMENT
FOR THE FIRST YEAR M. Sc, (SPEECH & HEARING)
UNIVERSITY OF MYSORE, MYSORE.

ALL INDIA INSTITUTE OF SPEECH & HEARING
MANASAGANGOTHRI, MYSORE.

JUNE 2003

DEDICATED TO..

MY PARENTS

for their love,....

CERTIFICATE

This is to certify that this Independent Project entitled **"HEARING AID TEST PROTOCOL FOR SLOPING HIGH FREQUENCY HEARING LOSS"** is a bonafide work in part of fulfillment for the degree of Master of Science (Speech & Hearing) of the student **(Register No.02SH0009)**

Dr. M. Jayaram
Director
All India Institute of
SpeechandHearing,
Mysore.

Mysore
June 2003

CERTIFICATE

This is to certify that this Independent Project entitled **"HEARING AID TEST PROTOCOL FOR SLOPING HIGH FREQUENCY HEARING LOSS"** has been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier in any other University for the award of any diploma or degree.

GUIDE

Dr. Asha Yathiraj
Reader & H. O. D.,
Department of audiology,
A11India Institute of
Speech and Hearing,
Mysore-570006

Mysore

June 2003

DECLARATION

This Independent Project entitled **"HEARING AID TEST PROTOCOL FOR SLOPING HIGH FREQUENCY HEARING LOSS"** is the result of my own study under the guidance of **Dr. Asha Yathiraj,** Reader & H.O.D., Dept. of Audiology, All India Institute of Speech and Hearing, Mysore, and not been submitted in any other University for the award of any degree or diploma.

Mysore,
June, 2003 **Reg. No. 02SH0009**

ACKNOWLEDGEMENTS

- I *would like to express my sincere gratitude to my guide* **Dr. Asha Yathhiraj,** *Reader* & H *O. D., Department of Audiology, All India Institute of Speech & Hearing, for her constant help, valuable suggestions & support throughout the project. Ma'm, a '***thank you** *is just not enough to express myself.*

I would like to than Dr, **M. Jayaram,** *(Director, All India Institute of Speech and Hearing, for permitting me to carry out the study.*

I extend my sincere thanks to Katz for her valuable suggestions in a situation where I was **"nowhere"..**

Thanks to **Dr. Rajalakshmi, Mrs. Manjula, Mr. Jo6y, Mr. Sameer, Mrs. Poornima, Ms. Sreevidhya** *for their help and suggestions.*

Seetha, *you've been turned out to be a good friend (I shall say like that, now!!) of mine. Thanf you for your affection and inspiration..*

A special thanks to you,G. K., for your constant help offers and the good time you'd with me in AIISH .

I am thankful to **Dr. Balakrishna Acharya** *for helping me out in steering the "U" turns in the Statistical analysis.*

I would also like to express my sincere thanks to all the **subjects,** *who patiently sat through the whole data collection and made this project possible.*

I *thanks my friends* ***Varghese, Shivaprakash, Bikku, Vijay,*** *who were encouraging me in all circumstances.*

A *special thanks to* ***J.K.Rajkmar & Sandeep,*** *for being good friends and supporting me at every stage.*

I thank all ***my*** *classmates for their timely help, moral support and their* ***timely nonsense!!!***

My sincere thanks to all the ***library staff*** *for their help in reaching the books and journals.*

My sincere thanks to ***Mr. Shivappa*** *and* ***graphics,*** *who shaped this project to be as it is in your hand.*

Finally, I thank ***God,*** *for being my friend & giving me the strength and the inspiration for what I'm being now...*

TABLE OF CONTENTS

LIST OF TABLES

INTRODUCTION

Sensory neural hearing loss has received a considerable amount of attention over the decades. This is the most explored entity in the field of Audiology in terms diagnostic and rehabilitative aspects. Sensory neural hearing loss, due to causes such as noise exposure, presbycusis, ototoxic drugs usually results in a descending type of hearing loss with fairly well preserved hearing below 1000 k Hz (Hayes & Jerger, 1979). Patients with this type of hearing loss are mostly able to perceive speech in quiet surroundings without any appreciable difficulty, but experience considerable difficulty in noisy surroundings or when several individuals are speaking simultaneously (Lundborg, Riseberg, Lindson, & Svard, 1982).

Sensory neural hearing loss exhibits a large variability in its clinical manifestations. This may vary according to the severity of the hearing loss, configuration of the audiogram, and the speech identification scores. Among this type of hearing loss, sloping high frequency hearing loss is one that receives tremendous consideration (Gimsing, 1990).

The effect of a high frequency hearing loss is that it creates an abnormal relationship between the lower and higher frequencies of speech. With this configuration of hearing loss, the presence of normal hearing in the lower frequencies is of little benefit for the purpose of amplification (Kiukaanniemi & Maatta, 1980). The person with a high frequency hearing loss is very much aware of environmental and speech sounds that contain low frequency information. However, they experience limited ability to locate the sound source and to block out background sounds or understanding speech from another room (Hull, 1982).

The presence of normal hearing in the higher frequencies appears to be critical while listening in noisy environments. Many people with high frequency hearing loss do not complain of hearing difficulty in a quiet environment. They however, experience difficulty in environments with significant ambient noise. The effect of high frequency hearing loss may also be reflected in the patient's own speech production of high frequency consonant sound production (Hull, 1982).

Conventional speech audiometry in general, is performed monaurally by means of headphones with single words in a sound-insulated and non-reverberatory room. Speech communication in daily life does not use single words and one ear, but occurs at the semantic level of the sentence involving both ears, and usually in ambient noise. The listener constantly receives a mixture of interference and signal, the latter in the form of sentences. All these imply a considerable difference between the listening situation in life and in the test environment (Niemeyer, 1976).

Though a large number of hearing aid selection procedures have been described in literature, few have been developed exclusively for the purpose of selecting hearing aids for individuals with sloping high frequency hearing loss. There are also no set protocols for the selection of hearing aids for this particular population. The conventional hearing aid selection procedure does not result in correct selection of the amplification since this is always carried out in a quiet situation and the performance in the quiet situation cannot be equated to that of in the presence of background noise (Beattie, 1989). It is reported in literature that, individuals with a sensory neural hearing loss are more subjected to the detrimental effects of noise than individuals with normal hearing or conductive hearing loss. Hence, it is recommended that speech testing be carried out in the presence of competing background noise by various authors (Kalikow, Stevens, & Elliot 1977; Barrenas & Wikstrom 2000; and Mascarenhas, 2002). Hagerman (1984) and Jayaram, Baguley, and Moffat (1992) recommended determining the speech recognition testing in the presence of noise for the purpose of selection of hearing aids.

Need for the study

- Speech is a stimulus of high redundancy because the information in it is conveyed in several ways simultaneously (Martin, 1994). The use of conventional speech materials would be insensitive towards identifying the problems of persons with sloping high frequency hearing loss. The low frequency information may contribute redundant cues to the perceptual ability, thus decreasing the sensitivity of the test in detecting their subtle communication handicap.

- In conventional hearing aid testing, the device is selected based on the performance of the client in a quiet situation. Further, they could be tested using test materials that contain both low and high frequency speech sounds. In such a situation, the clients with a sloping hearing loss do not exhibit any difficulty in perceiving speech. Hence, they are advised not to use the hearing aid. However injeal life situation, they have considerable difficulties in understanding speech. This is possible since in real life, the hearing aid user has to invariably listen to speech in the presence of noise. This throws light on the need to cany out hearing aid testing at different signal-to-noise ratios.

- In regular conversation, sentences are used, not words. Hence, it would be ideal to use a sentence test while selecting the hearing aids. However, Mascarenhas (2002) reported that the sentence subtest of the test developed by her was not sensitive in differentiating sloping hearing loss individuals from normal hearing individuals. There is a need to see if the sentence subtest of the High Frequency-Kannada Speech Identification Test (HF-KSIT) can be made sensitive to the perceptual problems individuals with sloping high frequency hearing loss by presenting the presence of noise.

- There is a need to see if the test is equally sensitive while selecting hearing aids for individuals with high frequency hearing loss that vary in steepness.

Aim** of **the study

The aim of the study is to develop a comprehensive hearing aid test protocol for the purpose of the hearing aid selection for individuals with sloping high frequency hearing loss using, the word and sentence subtests of the High Frequency-Kannada Speech Identification Test developed by Mascarenhas (2002). The aided and the unaided performance would be evaluated for the following:

> Two different signal-to-noise ratios (SNRs) (i.e., +10 & +5 dB)

> Three different audiometric sloping configurations (i.e., gradual slope, steep slope, and precipitous slope).

REVIEW OF LITERATURE

The recommendation of hearing aids for a given hearing loss is not yet a science, but there is a consensus that some kind of hearing aid evaluation procedure is desirable. There has been a myriad and divergent procedures employed since the late 1930s to select, verify, and monitor wearable amplification system, though none have been emerged as "the" accepted standard. Literally, every approach to hearing aid selection has its satisfied users and can be considered to be successful to some degree (Staab, 1996).

In literature, a large number of hearing aid selection procedures have been listed out. However, few have been designed for any specific audiogram configuration. There is a paucity of selection procedures, exclusively designed for persons with high frequency hearing loss. A few of them, with or without certain modifications, can be used for hearing aid selection for individuals with high frequency hearing loss. These procedures include:

A. "TRADTIONAL HEAREVG AID EVALUATION" (Carhart, 1946)

This approach emphasizes the ranking of hearing aids based on word recognition performance when comparing a variety of pre-selected hearing aids. The hearing aids were compared in sound field, and the instrument(s) that provided the greatest improvement in SRT, the best word-recognition scores in quiet and noise, and the widest dynamic range were judged as being the most appropriate for the patient. To use this approach for hearing aid selection for individuals with sloping high frequency hearing loss, different speech identification tests have been designed.

The Gardner High Frequency Word List (Gardner, 1971)

This is a word list containing high-frequency consonants exclusively developed for use in discrimination testing in cases of high-frequency hearing loss. The items consist of two lists of 25 words each. Seven voiceless consonants (p, t, k, s, f, 9, h) known to result in confusion when attempted to be identified by persons with high frequency hearing loss, were used in conjunction with a single vowel, *l\l*. This test also recommends the presentation of the material by a woman with a fairly high-pitched voice in cases of mild-to-moderate high frequency hearing loss.

The Pascoe High Frequency Test (Pascoe, 1975)

Pascoe (1975) assembled a "High Frequency" word list containing 50 monosyllabic words that emphasize phonemes that are difficult for hard-of-hearing subjects. Only three vocalic nuclei were used *(III, lai/, Ion/)* in order to increase the weight of the consonants in the correct identification of the words.

He tested eight hard of hearing subjects in the age range of 55 to 75 years with a binaural master hearing aid. This aid had "on-the-head" miniature transducers and an adjustable frequency response. The average hearing of the subjects at 0.5 KHz, 1 KHz, and 2 KHz were between 30 and 60 dB and the average slope of their audiometric curves ranged from 0.25 KHz to 6.0 kHz and did not exceed +10 dB per octave. He compared the high frequency words with the PB list and found that the high frequency word list could reveal the perceptual problems in quiet as well as in noise whereas, the PB list was insensitive to the handicap in quiet and showed only a minimal difficulty in noise. Thus, the Pascoe high frequency test is useful in selecting hearing aids in quiet as well as noisy conditions.

California Consonant Test (CCT) (Owens & Schubert, 1977)

This is a closed set response discrimination test using 100 CVC items. The items selected for inclusion were based on the phoneme recognition errors of hearing impaired subjects. Each item consisted of four words that differ only in either initial or final consonant position. These 100 items are divided in to two 50-item sub-forms based on the equivalency. This test was found to be highly sensitive to high frequency hearing loss and it showed a fairly low correlation (-0.40) with the degree of pure tone loss for 59 subjects with relatively flat audiometric configuration between 250 and 4000 Hz. Its reliability is high and its range of difficulty appeared to be sufficient enough for separating patients with differing degrees of difficulty. This test is found to have utility in rehabilitation procedures and hearing aid comparisons.

Error analysis of the CCT has resulted in the criticism that the CCT has an imbalanced distribution of consonants for everyday speech with respect to manner of articulation. Hence, it is believed that this might result in errors estimation of word recognition ability for some listeners (Townsend & Schwartz, cited in Ross, 1994).

Schwartz and Sun-, (1979) evaluated the efficacy of California Consonant Test (CCT) by calculating the performance-intensity function and found that CCT is sensitive to the phoneme recognition difficulties experienced by listeners with high frequency hearing loss.

Tecca and Binnie (1982) used the California Consonant Test (CCT) in hearing aid evaluation. The CCT was processed through two hearing aids and presented to 14 normal hearing adults. Two procedures were used which included an adaptive procedure to determine the signal-to-noise ratio (SNR) that would permit 50% intelligibility and a full list of the CCT was presented at this SNR for validation purpose. The results of this study suggested that hearing aids could be effectively differentiated with considerable time-saving when an adaptive procedure is applied to the CCT. Results of the full list presentation demonstrated the adaptive procedure to be sufficiently accurate. The limitations of this study were that this procedure was not applied in hearing impaired population. Further, the use of 50% intelligibility point on the performance-intensity function for CCT materials may not be appropriate for persons with high frequency sensory neural hearing loss, and those with reduced speech recognition performance.

The above research on CCT indicates that there is no total consensus on the utility of the test with individuals having a high frequency hearing loss. While some researchers have found it to be a good test to determine the perceptual problems of individuals with a high frequency hearing loss, others report otherwise.

Comparative studies on CCT, Pascoe High Frequency Word Test and NU 6

Maroonroge and Diefendorf (1984) compared the Northwestern Auditory Test Number 6 (NU 6), California Consonant Test (CCT), and Pascoe's High-Frequency Word Test in terms of their ability to detect consonant confusions. The subjects were divided into 2 groups; one group consisting of 12 patients with normal hearing up to 2 kHz accompanied by a high frequency loss, and the second group consisting of normal hearing subjects.

The results obtained from the hearing impaired subjects showed that the CCT and Pascoe's tests do not differ significantly on the overall speech discrimination scores, and the NU 6 tests scores were significantly higher than the other two tests. All three of these tests were compared for their sensitivity in detecting minor deficits in phonemic discrimination. For the NU 6, 58% of the subjects obtained scores of 90 to 100%, 25% of the group achieved 80 to 90%, and only 17% of the subjects scored below 80%; for the Pascoe's test, 25% of the patients achieved 90 to 100%, 67% scored 80 to 90%, and 8% of the subjects scored 70 to 80%. However, the range of scores on the CCT was more evenly distributed: 47% scored 90 to 100%, 25% of the subjects scored 80 to 90%, and 33% of the subjects scored between 70 and 80%. The results of this study suggested that NU 6 test was not sufficiently sensitive to detect consonant confusions in individuals with high frequency hearing loss, whereas CCT was highly sensitive.

Gordon-Salant in 1986 (cited in **Ross,** 1994) compared response criteria of young and elderly normal and hearing impaired listeners using NU-6 and CCT. The hearing impaired subjects had mild to moderate high frequency sloping sensory neural hearing loss. The presentation level of the materials was 80 and 95dB SPL. 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.

These studies indicate the need to utilize tests that are able to detect the perceptual problems of the hearing impaired with a high frequency hearing loss. A test not specially designed for them would not be sensitive to their perceptual problem.

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

Ramchandra (2001) developed a high frequency speech identification test for Hindi and Urdu speakers. This test consisted of two lists of randomized words, rated for familiarity. The first list consisted of high frequency phoneme in the initial position and the second list consisted of high frequency phoneme in the final position. She administered the test on 15 patients with 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 limitation of this test was that the test-retest reliability for hearing impaired population was not performed. Also, this test was not used for the purpose of hearing aid selection in persons with sloping high frequency hearing loss.

High frequency - Kannada Speech Identification Test (Mascarenhas, 2002)

Mascarenhas (2002) developed a speech identification test material in Kannada, exclusively for sloping high frequency hearing loss. The test items consisted of different phoneme classes like vowels (\a\, \i\, \e\, \o\, \u\), semivowels (\j\, \r\, \1\), stops (\t\, \ \, \k\), fricatives (\s\, \f\, \ \), and affricate (\t \). The test material consisted of three word and sentence subtests including high frequency consonants, equalized for familiarity, recorded in a compact disc.

This test was administered on 30 hearing impaired subjects with bilateral sloping configuration and 30 normal subjects. The results revealed that there was a significant difference in the word subtest, between normal and high frequency hearing impaired individuals. However, the sentence subtest was unable to differentiate high frequency hearing-impaired subjects from normal subjects. To make the sentence subtest more sensitive, she suggested administering it in the presence of background speech noise. The hearing impaired individuals were tested both in aided and unaided conditions. The result showed that there was a significant difference in the performance of the subjects for the word and sentence subtest in the aided and unaided condition. Hence, the test was considered useful for the selection of hearing aids.

From the above review, it is observed that while selecting hearing aids for individuals with slopping High Frequency Hearing Loss, it is suggested to use test material specially designed for them.

B. PRESCRIPTIVE PROCEDURES IN HEARING AID SELECTION

There have been a large number of prescriptive procedures reported in the literature for the selection of hearing aids. But few of them have been exclusively designed for sloping high frequency hearing loss. The well-known procedures that account for the selection of analogue hearing aids are:

1) Inverted Audiogram or Direct Mirror Fitting (Watson & Knudsen, cited in Staab, 1996) where, gain is recommended at each frequency that is identical to the dB loss at that frequency.

2) Half-Gain Rule (Lybarger, cited in Staab, 1996) which was based on the concept that average intensity o conversational speech was 65 dB SPL at one meter distance. Here the functional gain was the one half the hearing threshold levels.

3) Berger (1976) described a formula based on the assumptions that the amount of gain required should amplify sounds to average speech spectrum levels, low-frequency amplification should be reduced to keep the signal from degrading, and that speech sounds above 4000 Hz are relatively unimportant to intelligibility. Berger's procedure also accounts for conductive and mixed hearing loss by adding an additional gain equal to the size of the air-bone gap divided by five, up to a maximum gain of 8 dB.

4) National Acoustic Laboratories (NAL) (Byrne & Tonnison, 1976) was based on the half-gain rule except that the low frequency correction was included to

minimize the effects of background noise. National Acoustic Laboratories-Revised (NAL-R) (Byrne & Dillon, 1986) recommends multiplication of the thresholds at each frequency by a factor of 0.31 and a greater reduction of gain at low frequencies to account for steeply sloping hearing loss.

5) Prescription Of Gain and Output (POGO) (Mc Candless & Lyregaard, 1983) was based on the assumption that the hearing aid should amplify the speech to Most Comfortable Level (MCL). The gain at 250 Hz and 500 Hz were reduced by 10 and 5 dB respectively, to reduce the upward spread of masking. Schwartz, Lyregaard, and Lundh (1988) modified the **POGO** formula, and called it **POGO II,** for patients with a hearing loss greater than 65 dB HL. An additional gain (½ hearing loss minus 65) was provided to them in order to compensate for the greater degree of hearing loss.

6) One-Third Gain Rule (Libby, 1986) assumes that the gain in mild-to-moderate hearing losses more closely approximates a one-third-gain rule. For hearing losses greater than moderate degree, he suggested a two-third-gain rule. Corrections were provided for lower frequencies to prevent possible upward spread of masking.

Supra threshold based prescriptive procedures

Supra threshold procedures attempt to place the spectrum of normal conversational speech at the most comfortable level of preferred listening range of the patient. Here, the belief is that amplification must be comfortable to listen to or the patient. Here, the belief is that amplification must be comfortable to listen to or the patient will not accept it. A few of the commonly used supra-threshold prescriptive procedures are Shapiro method (Shapiro, 1975), CID method (Staab, 1996), Bragg Bisection Approach (Bragg, 1977) MSUv3 (Cox, 1988), Levitt Procedure (Nueman, Levitt, Mills, & Shwander,1987). All these procedures attempt to provide the amplified speech at the most comfortable level of the subject. All these procedures have been developed for hearing loss in general.

Though none of the formulae have been designed exclusively for individuals with sloping high frequency hearing loss, they could be used effectively in prescribing hearing aids for such individuals. As long as the formula enables amplification from low intensities to high intensities, as well as accounts for preventing upward spread of masking of the low frequencies, the formula could be used. The majority of the •formulae, developed after the 1970's do account for these aspects and hence can be used in prescribing hearing aids for sloping high frequency hearing loss.

C. ARTICULATION INDEX IN HEARING AID SELECTION.

Articulation Index has been steadily gaining importance as a procedure for hearing aid selection. The Articulation Index (AI) is a calculated value that expresses the proportion of the average range of speech cues that are audible to the patient (Palcovic, 1991).

Rankovic (1991) reported an application of the articulation index (AI) model to the fitting of the linear amplification. He evaluated 12 subjects with sensory neural hearing loss. Comparisons were made of amplification characteristics specified by NAL prescription (Byrne & Dillon, 1986) and POGO prescription (McCandless & Lyregaard, 1983) as well as a procedure that attempted to maximize the AI (AI max). For all the subjects, the relationship between percent-correct scores on a nonsense syllable test and AIs was monotonic for the two prescriptions. However, subjects having sloping high frequency hearing losses demonstrated non-monotonicity due to AI max condition. For these subjects, the AI max required much more gain at high than at low frequencies and this condition was considered to be exceptional.

D. AUDITORY BRAIN STEM RESPONSES IN HEARING AD) SELECTION

Beauchaine, Gorga, Reiland, and Larson (1986) proposed a hearing aid selection process based on click evoked Auditory Brain Stem responses. Estimates of gain were calculated using shifts in wave V threshold shifts; shifts in wave V latency-level function, acoustic-reflex measurements, coupler gain measurements and measurement of functional gain. Results suggested that click evoked ABR does not distinguish between differing amounts of low frequency gain, although reasonable estimates of high frequency gain appears possible.

Earlier, Kileny in 1982 reported that brainstem responses, elicited by clicks, reflect hearing sensitivity in the range of 2000-4000 Hz. Hence, this procedure would provide information in that frequency range for the purpose of hearing aid selection.

Beanchaine, Gorga, Reiland, and Larson (1983) reported that reasonable estimates of gain for middle and high frequencies are possible from wave V threshold shifts. However, these measurements reflect gain only for the higher frequencies. No information would be present regarding the lower frequencies.

Hecox (1983) also pointed out the limitations of ABR in the hearing aid selection process due to its inability to assess the auditory integrity below lOOOHz. This is a critical limitation, particularly in light of recent concerns regarding the possibility of low frequency activity masking high frequency information. Another shortcoming of this procedure is that it rarely distinguishes among losses of greater than 75 dB.

Despite the limitations of this procedure, it probably could be used in individuals who mainly require amplification in the higher frequencies and not in the lower frequencies. Studies to check the usefulness of this procedure in selecting hearing aids for individuals with high frequency hearing loss, needs to be carried out.

E. HEARING AID FITTING AND 'DEAD REGIONS IN COCHLEA'.

A dead region is defined as a region where there are no functioning inner hair cells (IHCs) and/or neurons and it can be characterized in terms of the IHCs bordering that region. Evaluation for the presence of dead regions is a pre-requisite for prescribing hearing aids in individuals with a high frequency hearing loss. Psychophysical tuning curves and Threshold-Equalizing Noise (TEN) test (Moore, Huss, Vickers, Glasberg, & Alcantara, 2000) could be used to evaluate this. These tests would provide information as to whether a client has useful hearing in the high frequency region or not, i.e., the absence or presence of dead regions.

Vickers, Moore, and Baer (2001) reported the significance of "dead regions" in cochlea in hearing aid fitting procedure for persons with high frequency hearing loss with and without dead regions. In their study, the speech stimuli used were vowel-consonant-vowel (VCV) nonsense syllables including three vowels (\i\, \a\, and \u\) and 21 consonants. In a baseline condition, the subjects were tested using broadband stimuli with a nominal input level of 65 dB SPL. The stimuli were subjected to the frequency-gain characteristic prescribed by the "Cambridge" formula. The stimuli for all other conditions were initially subjected to this same frequency-gain characteristic. The results showed that for subjects without dead regions, performance generally improved progressively with increasing the cutoff frequency. This indicated that they benefited from high-frequency information. For subjects with dead regions, two patterns of performance were observed. For most subjects, the performance improved with increasing the cutoff frequency until the cutoff frequency was somewhat above the estimated edge of the dead region using psychophysical tuning curves and the TEN test (Moore, Huss, Vickers, & Baer, 2001). For a few subjects, performance initially improved with increasing the cutoff frequency and then worsened with further increases. This study cautions the presence of dead regions in cochlea while fitting the hearing aids for individuals with high frequency hearing loss.

From the above review, it is evident that several procedures are available in hearing aid selection. However, techniques specifically designed for individuals with sloping high frequency hearing loss are limited. The use of word tests having phonemes mainly in the frequency region, is the most popular method in selecting hearing aids for individuals with sloping high frequency hearing loss. Prescriptive procedures that enable amplification across a wide range of intensities and give due consideration to spread of masking, could also be used in selecting hearing aids for this population.

METHOD

The aim of the present study was to develop a hearing aid test protocol for individuals with a sloping high frequency, sensory neural hearing loss.

Subjects:

Thirty subjects were selected based on the following criteria:

> Had less than 40 dB hearing threshold level at low frequencies (below 1 k Hz)

> Had sloping high frequency sensory neural hearing loss. The subjects were further divided in to three different groups based on the slope of the audiogram: (i.e. gradual slope, steep slope and precipitous slope). The criterion given by Lloyd and Kaplan (1978, cited in Silman and Silverman, 1991) was employed to determine the groups.

> Had acquired hearing loss with normal speech.

> Had speech identification score of 60% or more on the "Common Speech Discrimination Test for Indians" (CSDTI) (Mayadevi, 1974).

> Were fluent Kannada speakers.

> Did not a have history of any neurological involvement.

Instrumentation:

1) GSI 61 Diagnostic Clinical Audiometer, calibrated according to ANSI S3.6 1996 standards (cited in Wilber, 2002) was used for pure tone and speech audiometry.
2) GSI Tympstar Immittance meter, calibrated according to ANSI 1987 (S3.39-1987-R, 1996) (cited in Wilber, 2002), was used to screen for the existence of any middle ear problems.

3) A Philips DVD player (729K) was used to present the recorded test material.
4) Fonix 6500 C Hearing Aid Test system was used to select the hearing based on POGO-II formula.

Test material:

The High Frequency-Kannada Speech Identification Test (HF-KSIT) developed by Mascarenhas (2002) was used for the present study. This test has been exclusively developed for patients with high frequency sloping sensory neural hearing loss. The original version of the test consisted of three word and three sentence subtests recorded in a compact disc (CD). All the three lists were balanced for item familiarity. In the present study, items of list one were randomized to make a fourth list. This was done since four lists were required for the evaluation procedure.

Test Environment:

The testing was done in a sound treated room with ambient noise levels within the permissible limits, as recommended by ANSI 1991 (S3.1-1991) (cited in Wilber, 2002).

Procedure:

Routine pure tone and immittance audiometry were carried out for each client before the test procedure. Based on the audiometric pure tone test results, a suitable analogue Behind-The-Ear (BTE) hearing aid was selected using POGO-II formula (Schwartz, Lyregaard, & Lundh, 1988), using Fonix 6500 C Hearing Aid Test System. POGO-II formula was selected since it could be used for prescribing hearing aids for individuals having hearing loss ranging from mild to severe degrees, immaterial of the configuration.

Speech identification testing using HF-KSIT:

The speech material that was recorded on a CD was played using a Philips DVD player (729K). The output of the CD player was routed to the GSI 61 clinical audiometer. The speech out put from the audiometer was routed to the left sound field speaker. Speech noise was also routed to the same speaker from the audiometer. Prior to the presentation of the stimuli, the 1000 Hz calibration tone, that was recorded on the CD, was used to adjust the VU meter of the audiometer to zero.

The testing was done using two different signal-to-noise ratios i.e. +10 dB and +5 dB. The presentation level of the speech was 40 dB HL and the noise was presented at 30 and 35 dB HL. The signal-to-noise ratios were kept constant in both the aided and unaided conditions. The unaided testing was done initially and the scores were obtained. Later, the selected hearing aid was fitted and the same procedure was repeated. It was ensured that no subjects heard the same list more than once.

The ear in which the subjects had a sloping hearing loss and better speech identification abilities was selected for testing. Twenty-eight subjects were tested in one ear while two subjects were tested in both ears. The second ear of these subjects was tested after an interval of over a week to eliminate the role of memory on the test performance.

The subjects were seated one meter away, at 45° azimuth from the loud speaker. They were instructed to repeat the test items and to ignore the noise that was presented along with the test items. They were also instructed to close their non-test ear to avoid its participation, by pressing the tragus against the external auditory canal.

Scoring:

The scoring was done for both the word and sentence subtests separately. It was based on the number of correctly identified words as recommended by Mascarenhas (2002). In the word subtest, each correctly identified word was given a score of one and the wrong response was given a score of zero. For the sentence subtest, similar scoring was done for the key words iri the sentence. The obtained scores were statistically analyzed using paired sample t-test.

RESULTS AND DISCUSSION

The data obtained from the individuals with high frequency sloping hearing loss was subjected to analysis using the SPSS statistical software.

Using the t-test, the following were determined:

I. Comparison between aided and unaided conditions.

II. Comparison between the two signal-to-noise ratios (SNRs), i.e., +10 and +5 dB.

III. Comparison between the word subtest and the sentence subtest.

Each of the above were evaluated for the three different audiogram slopes (i.e., gradual slope, steep slope and precipitous slope).

I. Comparison between aided and unaided conditions

The comparison was made between aided and unaided conditions for both signal-to-noise levels for all three groups of slopes.

Table 1: Mean, Standard Deviation, and 't'-values for the aided Vs unaided scores (word subtest)

Audiogram Slopes	Aided/Unaided condition & SNR	Mean (Raw score)	SD	t-value
Gradual Slope (N=ll)	Aided at +5 SNR	15.73	1.79	14.87**
	Unaided at +5 SNR	9.27	2.97	
	Aided at +10 SNR	19.45	1.63	12.03**
	Unaided at+10 SNR	12.18	3.06	
Steep Slope (N=13)	Aided at +5 SNR	13.31	3.41	12.07**
	Unaided at+5 SNR	4.46	3.57	
	Aided at+10 SNR	16.31	3.47	21.07**
	Unaided at+10 SNR	8.23	4.25	
Precipitous Slope (N=6)	Aided at+5 SNR	12.00	3.8	6.89**
	Unaided at+5 SNR	4.17	3.97	
	Aided at +10 SNR	15.00	3.69	6.47**
	Unaided at+10 SNR	6.00	5.14	

** P < 0.01 N = number of subjects SNR = signal-to-noise ratio

Table 2: Mean, Standard Deviation, and 't'-values for the aided Vs unaided scores (sentence subtest)

Audiogram Slopes	Aided/Unaided condition & SNR	Mean (Raw score)	**SD**	t-value
Gradual Slope (N=ll)	Aided at +5 SNR	8.09	0.94	6.64**
	Unaided at +5 SNR	6.00	1.10	
	Aided at +10 SNR	8.91	0.3	7.02** .
	Unaided at +10 SNR	7.45	0.93	
Steep Slope (N=13)	Aided at +5 SNR	7.23	2.00	7.42**
	Unaided at +5 SNR	3.46	2.36	
	Aided at +10 SNR	8.31	1.44	6.31**
	Unaided at +10 SNR	5.77	2.59	
Precipitous Slope (N=6)	Aided at +5 SNR	6.17	2.04	10.30**
	Unaided at +5 SNR	3.40	2.00	
	Aided at +10 SNR	7.83	0.98	6.22**
	Unaided at +10 SNR	4.33	2.33	

**P<0.01 N = Number of subjects SNR = signal-to-noise ratio

The results reveal that there was difference between aided and unaided conditions at 0.01 level of significance for both +5 dB and +10 dB SNRs (tables 1 & 2). This was observed for both the word and the sentence subtests. Since the aided and unaided scores were significant at the 0.01 level for both the SNR values, it is recommended that the testing can be done at either +5 dB (40 dB speech & 35 dB noise) or at +10 dB (40 dB speech & 30 dB noise) SNRs. Thus, immaterial whether the individual has a gradual, steep or precipitous slope, a +5 dB or a +10 dB SNR can be used while selecting hearing aids.

II. Comparison between the two signal-to-noise ratios (SNRs)

In the second analysis, the two signal-to-noise ratios were compared for both aided and unaided conditions for the word and the sentence subtests. This was done for all three different groups of slopes. Table 3 & 4 show the mean, standard deviation and the t-value for the word and sentence subtest scores, respectively.

Table 3: Mean, Standard Deviation, and 't'-values for the different SNRs (Word Subtest)

Audiogram Slopes	Aided/Unaided Condition & SNR	Mean (Raw score)	SD	t-value
Gradual Slope (N=11)	Unaided at +5 SNR	9.27	2.97	8.49**
	Unaided at +10 SNR	12.18	3.06	
	Aided at +5 SNR	15.73	1.79	10.38**
	Aided at +10 SNR	19.45	1.63	
Steep Slope (N=13)	Unaided at +5 SNR	4.46	3.57	6.64**
	Unaided at +10 SNR	8.23	4.25	
	Aided at +5 SNR	13.31	3.61	11.85**
	Aided at +10 SNR	16.31	3.47	
Precipitous Slope (N=6)	Unaided at +5 SNR	6.00	5.14	2.80*
	Unaided at +10 SNR	4.12	3.97	
	Aided at +5 SNR	12.00	3.68	11.62**
	Aided at +10 SNR	15.00	3.58	

** P < 0.01   * P < 0.05   N = Number of subjects   SNR = signal-to-noise ratio

Table 4: Mean, Standard Deviation, and 't'-values for the different SNRs (Sentence sub test)

Audiogram Slopes	Aided/Unaided Condition & SNR	Mean (Raw score)	SD	t-value
Gradual Slope (N=ll)	Unaided at +5 SNR	6.00	1.10	7.02**
	Unaided at +10 SNR	7.45	0.93	
	Aided at +5 SNR	8.09	0.94	3.61**
	Aided at +10 SNR	8.91	0.30	
Steep Slope (N=13)	Unaided at +5 SNR	3.46	2.37	4.41**
	Unaided at +10 SNR	5.77	2.59	
	Aided at +5 SNR	7.23	2.00	4.50**
	Aided at +10 SNR	8.31	1.44	
Precipitous Slope (N=6)	Unaided at +5 SNR	3.00	2.00	2.99*
	Unaided at +10 SNR	4.33	2.33	
	Aided at +5 SNR	6.17	2.04	2.39 NS
	Aided at +10 SNR	7.83	0.98	

**P<0.01, *P<0.05, NS = Not significant N = Number of subjects,
SNR = signal-to-noise ratio

Table 3 reveals that for the word subtest, there was a significant difference between the +5 dB and +10 dB SNR, both in the aided and unaided conditions, for all three groups. The significance was present at the 0.01 level for all conditions except for the unaided condition in the precipitous sloping hearing loss. Here it was significant at the 0.05 level.

Table 4 shows the performance of the different slopes on the sentence subtest. The findings are similar to that of the word subtest scores for the gradual and steep slopes. In the precipitous slope, though there was a significant difference at the 0.05 level in the unaided condition, the difference was not significant in the aided condition. These findings indicate that increasing the SNR did improve the speech perception in individuals with gradual and steeply sloping hearing loss. This improvement was much lesser in the individuals with a precipitous hearing loss. This result is in accordance with the findings of Beattie, Barr, and Roup (1997) who found in a normal and hearing-impaired group that as the SNR was increased, the word recognition scores improved. Finitzo-Heiber and Tillman (1978) and Perkkarinen, Sulmivalli, and Suonpaa (1990) also reported of similar findings.

Further, the influence of SNR on the improvement with the use of a hearing aid was obtained (i.e., aided minus unaided scores). The difference in the aided and unaided conditions was calculated for the +5 dB and +10 dB SNRs separately for all three groups of slopes. These scores were subjected to the paired sample t-test. The results are given in table 5.

Table 5: Mean, Standard Deviation and t-values for the aided improvement scores across the two SNRs.

Audiogram Slopes	Test Condition &SNR	Aided minus Unaided Mean (Raw score)	SD	t-value
Gradual Slope (N=11)	Word at +10 dB	7.27	2.00	3.105**
	Word at +5 dB	6.45	1.44	
	Sentence at +10 dB	1.45	0.68	-1.75 NS
	Sentence at +5 dB	2.09	1.04	
Steep Slope (N=13)	Word at +10 dB	8.08	1.38	-1.18 NS
	Word at +5 dB	8.84	2.64	
	Sentence at +10 dB	2.54	1.45	-2.086 NS
	Sentence at +5 dB	3.77	1.83	
Precipitous Slope (N=6)	Word at +10 dB	9.00	3.41	1.472 NS
	Word at +5 dB	7.83	2.78	
	Sentence at +10 dB	3.50	1.38	0.466 NS
	Sentence at +5 dB	3.17	0.75	

**P<0.01 N = Number of subjects NS = Not significant SNR = signal-to-noise ratio

This result shows that, there is no significant difference in the hearing aid performance in the two SNR conditions, except for the word subtest in the gradual slope. The lack of significant difference between the two SNRs for the remaining conditions (i.e., word scores for the steep slope and the precipitous slopes) indicates that either of the SNR could be used for these conditions. Since the +10 dB SNR is an easier condition, it would probably be better to test using this SNR rather than the +5 dB SNR.

The two SNRs for the word subtest in the gradual slope was significant at the 0.01 level. Thus, while testing patients with gradual slope on the word subtest of HF-KSIT, care should be taken while selecting the SNR. From table 5, it is apparent that the +10 dB results in a better performance than the +5 dB. Hence, for hearing aid selection purpose, a +10 dB SNR may be used while using the word subtest for individuals with gradually sloping hearing loss.

From the above findings, it is seen that while the SNR did have an influence on the scores in the aided and the unaided performance individually (tables 3 & 4), it generally did not have an influence in the difference between the two, i.e., aided minus unaided scores (table 5). This is in account of there being a proportional change in the scores in the aided and the unaided condition individually when the SNR is changed. Thus, irrespective of the SNR, the improvement in the scores (aided minus unaided) is constant.

III. Comparison of performance between word subtest and sentence subtest

Table 6: Mean, Standard Deviation and 't'-values for the improvement scores (word and sentence subtest)

Audiogram Slopes	Test condition &SNR	Mean Aided minus Unaided (% score)	SD	't'-value
Gradual Slope (N=ll)	Sentence at +5 dB	24.00	11.87	-0.734 NS
	Word at +5 dB	25.82	5.76	
	Sentence at+10 dB	16.00	7.56	-6.437**
	Word at+10 dB	29.09	8.02	
Steep Slope (N=13)	Sentence at +5 dB	42.08	20.48	2.089 NS
	Word at +5 dB	35.38	10.56	
	Sentence at+10 dB	27.23	16.13	-1.492 NS
	Word at+10 dB	32.62	6.08	
Precipitous Slope (N=6)	Sentence at +5 dB	33.83	9.85	0.349 NS
	Word at +5 dB	31.33	11.15	
	Sentence at+10 dB	39.00	15.67	0.501 NS
	Word at+10 dB	36.00	13.62	

**P<0.01 N = Number of subjects NS = Not significant SNR = signal-to-noise ratio

The significance of difference between the word and the sentence subtests was calculated using the paired sample t-test. This was done for the improvement obtained for each of the subtests (i.e., unaided scores were subtracted from the aided scores). The analysis shows that there was no significant difference between the word subtest and the sentence subtest at both the SNRs. This was true for all three slopes of audiogram except for the gradual slope where there was a significant difference between the word and the sentence subtests at the 0.01 level for the +10 dB SNR (table 6). Thus, either the word or the sentence subtest in the presence of noise could be used equally effectively in selecting hearing aids for the steep and the precipitous sloping hearing loss. This result is in contrary to the findings of Speaks, Jerger, and Trammel (1965) who found that as the slope increases, the performance on PB word tests and synthetic sentences apparently differed. This difference in finding could be attributed to the stimuli used. While, they carried out the study in quiet, the present study was carried out using different SNRs. Hence, from the present study, it is evident that the sentence subtest could be made sufficiently sensitive by presenting it with background noise as recommended by Kalikow, Stevens, and Elliot (1977); Barrenas and Wikstrom (2000); and Mascarenhas (2002).

Mascarenhas (2002) had reported that the sentence subtest of the High Frequency-Kannada Speech Identification Test (HF-KSIT), developed by her is less sensitive to the perceptual problems of persons with sloping high frequency hearing loss when compared to the word subtest. Such a finding was probably obtained since she carried out the test in a quiet situation. The present finding shows that even the sentence subtest of the HF-KSIT could be made sensitive by administering it in the presence of speech noise.

The result also shows that, for persons with gradually sloping configuration, there was no significant difference in word and sentence subtest at +5 dB SNR, whereas at the + 10 dB SNR, there was significant difference between the two subtests. This indicates that for this particular configuration, the sentence and word subtests of the HF-KSIT are equally sensitive only at +5 dB SNR, but a high SNR, i.e. at +10 dB, the sentence subtest loses its sensitivity on patients with gradually sloping configuration. This is evident from the improvement in scores for the sentence and the word subtest at the +10 dB SNR (table-6). The improvement was larger for the word subtest (29.09) compared to sentence subtest (16.00). This finding may be attributed to the influence of syntactic and semantic redundancy of sentences. This enabled the subjects to get fairly high scores in the unaided condition itself for the +10 dB SNR. At the lower SNR (+5 dB), they obtained lesser redundant cues due to the masking effects of the noise. This could have accounted for the difference being present between the two subtests at the higher SNR and not being present at the lower SNR.

From the obtained results, the following conclusions may be drawn:

> A significant difference existed between the aided and the unaided conditions for both the word and sentence subtests across the audiometric slopes. This was present at both the SNRs that were evaluated.

> A significance difference was seen between +5 dB and +10 dB SNR for the word subtest. This was see in both the aided and the unaided conditions, for all the three groups.

> On the sentence subtest, the results revealed a significant difference between both the +5 dB and the +10 dB SNRs in individuals with gradually and steeply sloping audiogram configurations. However, in individuals with precipitous slope, though there was a significant difference at the 0.05 level in the unaided condition, the difference was not significant in the aided condition.

> There was no significant difference in the aided minus unaided scores across the two SNR conditions. This is due to there being a proportional change in the scores in the aided and the unaided condition individually, when the SNR is changed. Thus, irrespective of the SNR, the improvement in the scores (aided minus unaided) is constant. In the gradual slope, there was a significant difference at the 0.01 level across the two SNRs for the word subtest.

> There was no significant difference between the two SNRs for the sentence subtests for all the three audiogram slopes.

> 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 the steep and the precipitous sloping hearing loss. In the gradual slope also both word and sentence subtest can be used, but only atthe +10 dB SNR.

Thus, while selecting hearing aids for individuals with sloping hearing loss, the HF-KSIT should be used along with speech noise. In individuals with steeply sloping or precipitously sloping audiogram configurations, any of the two SNRs (i.e., +5 dB or +10 dB) and any of the subtests (i.e., word or sentence) could be used. In individuals with gradually sloping audiometric configuration, the word subtest could be used at both the SNRs, whereas, the sentence subtest should be used only at the +10 dB SNR.

SUMMARY AND CONCLUSIONS

Individuals with sloping high frequency hearing loss exhibit considerable difficulty in speech perception in the presence of back ground noise than in quiet (Niemeyer, (1976) and Riseberg, Lundborg, Lindson, and Svard, (1982). There have been a large number of hearing aid selection procedures reported in literature, but a few of them account for persons with sloping high frequency hearing loss.

The present study aimed at developing a hearing aid test protocol for individuals with sloping high frequency hearing loss. The High Frequency Kannada Speech Identification Test (HF-KSIT) developed by Mascarenhas (2002) was used as the test stimulus. Thirty subjects, including eleven gradually sloping, thirteen steeply sloping, and six precipitously sloping hearing loss individuals were tested. An analogue Behind-The-Ear (BTE) was selected using POGO II formula (Schwartz, Lyregaard, & Lundh, 1988). Each of these subjects were tested both in the unaided and the aided condition, using the selected hearing aid, at two SNRs of+5 dB and +10 dB. The results revealed the following findings:

- A significant difference existed between the aided and the unaided conditions for both in the word and sentence subtests across the audiometric slopes. This was present at both the SNRs that were evaluated.

- A significant difference was seen between the +5 dB and +10 dB SNR, for the word subtest. This was see in both the aided and the unaided conditions, for all the three groups.

- On the sentence subtest, the results revealed a significant difference between both the +5 dB and the +10 dB SNRs in individuals with gradually and steeply sloping audiogram configurations. However, in individuals with precipitous slope, though there was a significant difference at the 0.05 level in the unaided condition, the difference was not significant in the aided condition.

- There was no significant difference in the aided minus unaided scores across the two SNR conditions. This is due to there being a proportional change in the scores in the aided and the unaided condition individually when the SNR is changed. Thus, irrespective of the SNR, the improvement in the scores (aided minus unaided) is constant. In the gradual slope, there was a significant difference at the 0.01 level across the two SNRs for the word subtest.

- There was no significant difference between the two SNRs for the sentence subtests for all the three audiogram slopes.

The findings of the 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 the steep and the precipitous sloping hearing loss. In the gradual slope also both word and sentence subtest can be used, but only at the +10 dB SNR.

REFERENCES

. . Barrenas, M. L. & Wikstrom, I. (2000). The influence of Hearing and Age on Speech Recognition Scores in Noise in Audiological Patients and in the General Population. *Ear and Hearing, 21 (6),* 569-577.

Beattie, R. C. (1989). Word recognition functions for the CID W-22 test in multitalker noise for normally hearing and hearing-impaired subjects. *Journal of Speech Hearing Disorders, 54,* 20-32.

Beattie, R. C, Barr, T., & Roup, C. (1997). Normal and hearing-impaired word recognition scores for monosyllabic words in quiet and noise. *British Journal of Audiology, 31,* 153-164.

Beauchaine, L.L., Gorga, M.P., Rieland, J.K., & Larson, L.L. (1986). Application of Auditory Brainstem Responses to the Hearing Aid Selection Process: Preliminary Data. *Journal of Speech and Hearing Research, 29,* 120-128.

Berger, K. W. (1976). Prescription of hearing aids: A rationale. *Hearing instrument, 27 (4),* 18-22.

Bragg, V. C. (1977). Toward a more objective hearing aid fitting procedure. *Hearing Instruments, 28 (9),* 6-9.

Byrne, D. & Dillon, H. (1986). The National Acoustic Laboratories' (NAL) new procedure for selecting the gain and frequency response of a hearing aid. *Ear and Hearing,* 7, 257-265.

Byrne, D., & Tonnison, W. (1976). Selecting the gain of hearing aids for persons with sensory neural hearing impairments. *Scandinavian Audiology, 5,* 51-59.

Carhart, R. (1946). Speech Reception in relation to pattern of pure tone loss. *Journal of Speech and Hearing Disorders,* 11, 97-108.

Cox, R.M. (1988). The MSU hearing instrument prescription procedure. *Hearing Instrument, 39,* 6,8,10.

Finitzo-Hieber, T. & Tillman, T. W. (1978). Room acoustic effects on monosyllabic word discrimination ability for normal and haring-impaired children. *Journal of Speech and Hearing Research, 21,* 440-458.

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

Gimsing, T. (1990). Word recognition in presbycusis. *Scandinavian Audiology, 19,* 207-211.

Hagerman, B. (1984). Clinical measurement of speech reception threshold in noise. *Scandinavian Audiology, 13,* 57-63.

Hayes, D. & Jerger, J. (1979). Aging and use of hearing aids. *Scandinavian Audiology, 8,* 33-40.

Hecox, K.E. (1983). Role of Auditory Brain Stem Responses in the selection of Hearing Aids. *Ear and Hearing, 4 (1),* 51-55.

Humes, L.E., Dirks, D.D., Bell, T.S., Ahlstorm, C, & Kincaid, G.E. (1986). Application of the Articulation Index & the Speech Transmission Index to the Recognition of Speech by Normal and Hearing Impaired Listeners. *Journal of Speech and Hearing Research, 29,* 447-462.

Hull, R. H., (1982). Evaluation of communication function and success in Aural Rehabilitation of Elderly clients. In R.H. Hull (Ed.) (pp.407-423), New York: Grunne & Stratton, Inc.

Jayaram, M., Baguley, D. M., & Moffat, D. A. (1992). Speech in noise: a practical test procedure. *The Journal of Laryngology and Otology, 106,* 105-110.

Kalikow, D. N., Stevens, K. N., & Elliot, L.L. (1977). Development of a test of speech intelligibility in noise using sentence materials with controlled word predictability. *Journal of the Acoustical Society of America, 61,* 1337-1351.

Kilney, P. (1982). Auditory Brainstem Responses as Indicators of Hearing Aid performance. *Annals of Otology, Rhinology, and Laryngology, 91,* 61-64.

Kiukaanniemi, H. & Maatta, T. (1980). Speech Discrimination and Hearing Loss Sloping to High Frequencies. *Scandinavian Audiology, 9,* 235-242.

Libby, E. R. (1986). The 1/3 -1/2 insertion gain hearing aid selection guide. *Hearing Instruments, 3,* 27-28.

Lundborg, T., Riseberg, A., Holmqvist, C, Lindstrom, B., & Svard, L. (1982). Rehabilitative Procedures in Sensory Neural Hearing Loss. *Scandinavian Audiology, 11,* 161-170.

Maroonroge, S. & Diefendorf, A.O. (1984). Comparing normal and hearing impaired subjects performance on the North Western University Auditory Test Number 6, California Consonant Test, and Pascoe's High Frequency Word Test. *Ear and Hearing, 5(6),* 356-360.

Martin, F.N. (1994). Hearing aid selection, in *Introduction to Audiology.* (pp. 256-279). Prentice Hall, Englewood Cliffs.

Mascarenhas, K.E. (2002). A High Frequency-Kannada Speech Identification Test (HF-KSIT). *Unpublished Master's Dissertation,* Mysore: University of Mysore.

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

McCandless, G. A., & Lyregaard, P.E. (1983). Prescription of gain/output (POGO) for hearing aids. *Hearing Instruments, 34,* 16-21.

Moore, B. C. J., Huss, M., Vickers, D.A., & Bear, T. (2001). Effects of low-pass filtering on the intelligibility of speech in noise for people with and without dead regions at high frequencies. *Journal of the Acoustical Society of America, 110(3),* 1865-1871.

Moore, B. C. J., Huss, M., Vickers, D. A., Glasberg, B. R., & Alcantara, J. I. (2000). A test for the diagnosis of dead regions in the cochlea. *British Journal of Audiology, 34,* 205-224.

Neuman, A. C, Levitt, H., Mills, R., & Schwander, T. (1987). An evaluation of three hearing aid selection strategies. *Journal of the Acoustical Society of America, 82 (6),* 1967-76).

Niemeyer, W. (1976). Speech Audiometry and Fitting of Hearing Aids in Noise. *Audiology,* 75,421-427.

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

Palcovic, C. (1991). Speech recognition and five articulation indices. *Hearing Instruments, 42,* 20-24.

Pascoe, D.P. (1975) Frequency responses of hearing aids and their effects on speech perception of hearing impaired subjects. *Annals of Otology, Rhinology, and Laryngology, supplement, 23,* 1-40.

Pekkarinen, E., Salmivalli, A., & Suonpaa, J. (1990). Effect of noise on word discrimination by subjects with impaired hearing, compared with those with normal hearing. *Scandinavian Audiology, 19,* 31-36.

Ramchandra, P. (2001). High Frequency Speech Identification Test for Hindi and Urdu speakers. *Unpublished Master's Dissertation,* Banglore: University of Banglore.

Rankovic, CM. (1991). An application of the Articulation Index to Hearing Aid Fitting. *Journal of Speech and Hearing Research, 34,* 391-402.

Riseberg, A. Lundborg, T. Lindson, P., & Svard, L. (1982). Effect of noise on speech recognition in individuals with hearing loss. *Scandinavian Audiology, 11,* 126-131.

Ross, M. (1994). Overview of Aural Rehabilitation. In J. Katz (Ed.). *Hand Book of Clinical Audiology,* (pp: 587-615). Baltimore: Lippincott Williams & Wilkins.

Schwartz, D.M., & SUIT, R.K. (1979). Three experiments on the California Consonant Test. *Journal of Speech and Hearing Disorders, 24,* 55-60.

Schwartz, D.M., Lyregaard, P.E., & Lundh, P. (1988). Hearing Aid Selection For Severe-To-Profound Hearing Loss. *The Hearing Journal, 13,* 13-16.

Shapiro, I. (1975). Prediction of most comfortable loudness levels in hearing aid evaluation. *Journal of Speech and Hearing Disorders, 40,* 434-438.

Silman, S. & Silverman, C.A. (1991). *Auditory Diagnosis-Principles and Applications*^ San Deigo: Academic Press Inc.

Speaks, C, Jerger, J., & Trammel, G. (1965). Performance intensity characteristics of synthetic sentences. *Journal of Speech and Hearing Research, 9,* 305-312.

Staab, W. J. (1996). Hearing Aid Selection: An Overview in J. Sandlin (Ed.). *Textbook of Hearing Aid Amplification,* (pp. 55-135), New York: Thieme.

Tecca, J. E. & Binnie, C. A. (1982). The application of an adaptive procedure to the California Consonant Test for hearing aid evaluation. *Ear and Hearing, 3 (2),* 72-76.

Vickers, D. A., Moore, B. C, & Bear, T. (2001). Effects of low-pass filtering on the intelligibility of speech in quiet for people with and without dead regions at high frequencies. *Journal of the Acoustical Society of America, 110(2),* 1164-1175.

Wilber, L. A. (2002). Calibration of Pure tone, Speech, and Noise Signals. In J. Katz, (Ed). *Handbook of Clinical Audiology*, Baltimore: Lippincott Williams and Wilkins.