# QUALITY JUDGEMENTS OF INDIAN HEARING AIDS USING HEARING AID TRANSDUCED SPEECH DISCRIMINATION

A dissertation submitted in part fulfillment
For the degree of
Master of science (Speech and Hearing)
of
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# CERTIFICATE

This is to certify that the dissertation Entitled “Quality Judgments of Indian Hearing Aids using Hearing Aid Transduces Speech Discrimination” is the bonafide work In part fulfillment for MSc in Speech and Hearing, carrying 100 marks, of the student With Register No. 26

(DR.PR.KULKARNI)
MBBS,DORL,MS(ENT)
Director
All India Institute
of Speech & Hearing
Mysore 6

# CERTIFICATE

This is to certify that this dissertation
Has been prepared under my supervision and
Guidance

Guide

# DICLARATION

This dissertation is the result of my own study undertaken under the guidance of MR. S.P.C. Pandalay, Lecturer in Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier at any University for any diploma or degree.

Mysore Reg No. 26

Dates

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This study is dedicated to my beloved

Parents and to my brother to whom I

Owe my education and life

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<u>CHAPTER I</u>

# INTRODUCTION

The aural rehabilitation programmes to meet the needs of aural casualties are usually being planned by both medical and non-medical specialists. The first responsibility of an Audiologist is such a programme is to determine whether a given casualty would benefit from medical or surgical care. In evaluating the type and degree of hearing loss that a patient presented, he uses a series of audiometric tests available to him. Patients who cannot be helped by medicine or whose hearing loss is of a permanent, irreversible nature, are placed in the rehabilitation programme. In such a program the first and the foremost step is the determination of the need for and selection of an individual hearing aid.

A Hearing Aid can be described as any device that brings sound to the ear more effectively. In the narrow and more frequently used sense the modern hearing aid is a miniaturized amplifier circuit which is designed specifically for improving human hearing. The function of the hearing aid is to amplify sound energy and to present the amplified sound into the ear with as little undesirable distortion as possible. Since the sound energy cannot be adequately amplified directly, it is necessary to change the acoustic energy to an electrical signal. The electrical signal is then amplified and converted into acoustic energy at the ear.

Hearing aids though they may look alike physically may differ too widely in their performance. The performance of the hearing aids depends upon certain characteristics like :

(a) frequency response

(b) gain

(c) amount of distortion

(d) size and weight (e) extraneous noise

(f) flexibility and adjustibillty to individual needs

(g) sensitivity and

(h) output limiting action

A hearing aid might hare a wide range of frequency response and high amplification, yet be inferior because of excessive distortion. It can occur in the opposite way also. Good frequency response, strong output, high amplification and low distortion are not themselves mutually contradictory. It is relatively easy to achieve high amplification over a limited frequency range, but to achieve high amplification over a wide frequency range and control it selectively without distortion is a harder engineering task. A fine hearing aid is thus an engineering marvel in miniature size which achieves the most possible desirable balance between many factors of size, weight, cost, fidelity etc.,

It is a well recognised fact that even when the hearing aid is perfect in its characteristics, the performance of the best hearing aid can be altered significantly when it is coupled to a system or to an individual's ear. It is therefore accepted by almost all audiologists that a prescription of a hearing aid is made only after an individual evaluation. As early as in 1940, it was suggested that alterations in the ear piece would cause a reduction in low frequency amplification. A vent in the earmould can reduce low frequency amplification. When the earmould does nto fit snugly and if there is an acoustic leakage, then again it attenuates extreme low frequencies and even alter the hearing aid response pattern. Further the volume of air between the tip of the canal aperature and the tympanic membrane can produce variations in hearing aid performance.

After having recognised the importance of psychoacoustic evaluation of hearing aids, several methods have been recommended by different investigators for hearing aid evaluation and prescription. In 1943 Hughson and Thompson made the first evaluation of selective fitting of hearing aids. In 1946 Weiner and Miller suggested a hearing aid evaluation procedure which included monaural tests of the patient without a hearing aid which included thresholds for puretones and for speech tolerance for puretones and for speech and articulation tests with suitable word lists. In 1946 Raymond Carhart used a twelve step procedure for hearing aid evaluation. In 1946 Davis et al reported on the results of a fitting procedure that attempted to complement the audiogram by means of selective amplification and found that it was not an accurate method. In 1952 Bangs and Bangs tried a new method of fitting hearing aids to children as young as eighteen months old to determine if they could use a hearing aid eighteen months old to determine if they could use a hearing aid efficiently. In 1952 Glorig concluded that a highly selective procedure was not necessary for the selection of the aid. He further stated that it was not the selection procedure that would produce a good result, but adequate training in its use. In 1960 Jeffers recommended hearing aid selection on the basis of qualitative judgments by the subjects. In 1963 Resnick and Becker described a procedure in which audiological assessment and counseling of the patient was undertaken by the audiologist, while the actual selection of the hearing aid being left to the selected hearing aid dealers. After the patient has been issued an aid he returns to the referring audiologists and receives clinical evaluation of his aid.

In the electroacoustic evaluation of a hearing aid, the major factors that are responsible for speech intelligibility are determined. They are the frequency response, harmonic distortion, intermodulation distortion, signal to noise ration etc., It is essential to select a hearing aid with low distortion, amplegain, maximum power output and wide frequency response characteristics tio maintain maximum clarity of speech. Harris (1961), Bode (1968), Jerger (1966), Kastein (1967) and Lotterman (1967) have supplied evidence of decrease in speech intelligibility when excessive distortion products are present in low fidelity circutary. Olsen (1967) reported on the importance of the width of frequency response relating to hearing aid intelligibility. The exact role played by nonlinear distortion in degrading the signal processed by wearable hearing aids has yet to be definitely specified. There is increasing evidence to emphasize the importance of distortion products as being detrimental to both objective and subjective aided performance, particularly when such performance is evaluated in the presence of background noise or competing message. Recently, Jerger, speaks and Malaquist (1966) found both subjective quality judgements and intelligibility to be related to the degree of harmonic distortion present in hearing aids. Using tape recorded speech material and competing contineous discourse which had seen transduced through three hearing aids with harmonic distortion (the average of 500, 700 and 900 CPs) ranging from 4% to 16% they found the performance of normal hearing and hearing impaired listeners to be inversely proportional to harmonic distortion. Thus there are many studies indicating the effect of distortion on speech intelligibility. There are four types of distortions to be considered in evaluating the quality of hearing instruments :

1. Amplitude distortion due to generation of frequencies by the amplifier which are not present in the input signal. It is also called harmonic distortion.
2. Frequency distortion which is due to unequal amplification of various frequencies of the input.
3. Extraneous distortion is due to the creation of random noise such as frictional noise, rubbing noise.
4. Intermodulatory distortion -- distortion introduced duo to two or more frequencies transmitted through a system which generate a set of new frequencies which have no harmonic relationship.

For the maximum utilization of the auditory potential of the hard of hearing child it is imperative that the hearing aid functions optimally. A hearing aid can mean the difference between adequate or poor reception of auditory signals. Educational delay often results from partially received or distorted auditory messages (Zink 1972). The development of a meaningful standard method for measurement and reporting distortion levels in hearing aid should be a primary goal of both audiologist and hearing aid manufacturer. Such a standard should reflect distortions under conditions approximating those in which the hearing aid may be expected to operate and should likewise permit interpretation of distortion data by those engaged in the evaluation of hearing instruments.

Jerger (1971) reports that speech will be affected if there is distortions. He suggests to use hearing aid transduced speech for discrimination so as to select the best hearing aid. In the study of S.P.C. Pandaley (1970) it is reported that Indian hearing aids, differ very much in terms of distortion characteristics. It is also reported that most of the Indian aids produce more than 5% distortion which can therefore affect speech. If a hearing aid evaluation can be done through this means, then the problem of stocking all the aids in a clinic can also be eliminated. This is because the dealers of the day objects keeping the aid idle in clinic catching dust.

The aim of the present study is therefore to evaluate the efficiency of Indian hearing aids to reproduce speech in quiet and in noise. Since only very few studies have been made on Indian hearing aids and practically nothing on their speech reproduction ability, the present study was undertaken.

## Purpose of the present study

The purpose of the present study was to evaluate the efficiency and fidelity of various Indian hearing aids using hearing aid transduced monosyllables for discrimination.

## Hypotheses

1. There is no significant performance difference between different Indian hearing aids in speech reproduction.
2. The presence of noise does not significantly affect the performance of these hearing aids.

## Brief Plan of the study

Hundred subs.were selected for the study. All the subject to confirm normal hearing and normal discrimination, were taste using puretones and phonetically balanced monosyllables. Later to study the effect of hearing aid distortion in speech, five popular Indian hearing aids were chosen. Using controlled system four equivalent list of monosyllables were recorded through these hearing aids on a high fidelity tape recorder. It was then administered to the above subjects through the audiometer to find discrimination score. The difference between the two discrimination scores was taken to rank the hearing aids in terms of their fidelity.

Definitions – Speech reception threshold

The lowest sound pressure level at which fifty percent or more of the spondaic test words (words of two syllables having Equal stress) are repeated correctly.

Speech discrimination test

A test of the ability to understand speech as determined by scoring the number of words in a phonetically balanced list.

Distortion

In exact reproduction of a sound wave pattern

Amplitude distortion

In exact reproduction of a sound wave pattern which results when the output of an electroacoustic system is not proportional to the input.

Frequency distortion

In exact reproduction of the frequencies in a sound wave pattern.

Harmonic distortion

The new frequencies introduced by amplitude distortion harmonically related to the original frequency.

## Intermodulatory distortion

Distortion introduced due to two or more frequencies transmitted through a system which generate a set of new frequencies which have no harmonic relationship.

## Transient distortion

In exact reproduction of a sound wave pattern resulting from sudden change of voltage or of load.

## Limits of the study

1. All the Indian Hearing Aids were not included few the study due to lack of availability to the clinic

2. Since clinical cases were not included, no comparison of behavior could be obtained

## Implications of the Study

1. This procedure can be used as an alternative to the Conventional Hearing Aid evaluation procedure

2. The wastage of Hearing Aid by stocking them in the clinic can be eliminated

3. A more realistic procedure to check the quality and fidelity of a Hearing Aid

# CHAPTER II

## REVIEW OF LITERATURE

Hearing aids are as old as ancient society itself. A hearing aid is an instrument that brings sound more effectively to the listeners ear. It may simply collect sound energy from the air, it may prevent the scattering of sound during transmission or it may provide additional energy usually from the battery of an electrical amplifier. The beat objective of a hearing aid is to make speech intelligible. The quality or 'naturalness' of the speech nay be sacrified if necessary. Little thought was given to quality by those who used the old ear trumpets. They were satisfied if only speech could be made loud enough. Even with early electrical instruments the chief difficulty was still to deliver enough energy and any necessary compromise were acceptable as long as speech could be understood.

The simplest hearing aid used since man became civilized enough to grow old and become hard of hearing is the hand cupped behind the ear. The hand intercepts more of the oncoming sound wave' than doss the ear alone and deflects more of its energy into the external canal. The larger the scoop more energy can be collected. The ear trumpet which formed as a result of modification in the shape of ear scoop favoured more delivery of energy into the ear canal. the ear trumpet took many forms in efforts to compromise between effectiveness and convenience. These trumpets were more than mere scoops to collect acoustic energy. They were also resonators tuned broadly to frequencies in the speech range. The gain for speech provided by ear trumpet is likely to be about 10 - 15 dB. "Louder please" the cupped hand at the ear politely tells the speaker that the listener is having difficulty in hearing him and the speaker to raise his voice. It adds an extra 10 dB. Among the early bone conduction devices acoustic fan formed the first one. a sheet of metal or hard rubber decorated like a fan was held with one corner against the teeth. The vibration of the metal were transmitted through the teeth to the bones of the skull and thus to the timer ear. The acoustic fan is unable to collect sound energy from the air to be a very effective aid to hearing. Another class of mechanical hearing aid had the aim to deliver more efficiently to the inner ear the sound energy that enters the external canal. Such a devise may help a person whose ear drum is perforated or is missing. So a piece of flexible membrane or tissue placed over the perforation is helpful. Some-times a whisp of cotton placed in contact with stapes or the round window to transmit sound waves effectively.

The first electrical hearing aid is associated with the invention of the telephone by Alexander Graham Bell. The telephone was infact reported to be an out growth of Bell's effort to invent a hearing aid. Dr Ferdinand Alt of politizer clinic in Vienna is credited for producing the first amplified electrical hearing aid in 1900. An electrical hearing aid is a miniature telephone. It differs fundamentally from mechanical aids in that its batteries, not the human voice, supply the energy of the sound that the listener finally hears. Electrical hearing aids are three types :

1. Wearable
2. Portable
3. Group Aid

Comfort, convenience, desire to conceal the instrument and individual acoustic needs have all contributed to the development of a variety of types of wearable hearing aids.

The early type of electrical hearing aid employed a simple ‘Carbon Granule’ type transmitter operated with a single battery and a magnetic telephone type receiver. The tiny balls or granules of carbon had the peculiar property of producing variations in resistance to an electrical current which were proportionate to the pressure exerted on them by the motion of a diaphragm. Voltage supplied by batteries produced a strong current which was varied by the changing resistance of carbon particles. The result was a strong electrical current which pulsated correspondingly in frequency and in intensity, to the sound waves striking the diaphragm of the transmitter. The pulsating electrical impulses provided by the transmitter and battery were conducted to a magnetic earphone. This converted electrical signals to corresponding sound waves. Although the fundamental pitch of a tone would be the same as the original sound striking the transmitter, the inherent distortion of both the carbon transmitter and the magnetic type receiver would produce substantial changes and modifications of the original sound received by the transmitter. Also harmonic distortion is produced. In many carbon type hearing aids the harmonic distortion varied from 50% to 75%. The amount of amplification of carbon type hearing aids were only 10-15 dB over a range of 1000 Cps to 1800 Cps. This was insufficient for severe cases. To overcome it larger transmitter diaphragms were used which had a greater sound collecting surface area. This increased the intensity by building up sound pressure from sound collected over a greater area. This principle was carried still further by connecting two or three to provide still greater sound collecting area and more intensity at the earphone.

In order to provide greater intensity without the bulk of large multiple transmitters, the carbon amplifiers or ‘boosters’ were developed. The carbon amplifier however had all the draw backs of carbon transmitters. In this the reproduction of sound was completely out of when they bent over or leaned back too far throwing the carbon transmitter out of a vertical and into a horizontal position. They had even serious draw backs of introducing further distortion in the system along with added intensity. The limited frequency range, the harsh distortion, uneven frequency emphasis, sudden fluctuations in power, internal frying and crackling noises of the carbon type hearing aid seem tragic in retrospect.

In 1902 Miller Reese Hutchinson produced the ‘Acouphone and in 1902 Harper offered an instrument called ‘Oriphone’. The vaccum tube hearing aids originated during 1920’s. These units were very large, cumbersome and expensive. Most of them could be operated only with 110 volt even though some used large sided radio batteries. Multiple vaccum tube hearing aids using vaccum tube amplifiers were also offered by many companies (1930-1935). The originators of the vaccum tube hearing aids belongs to English firms. The Thompson – Houston company had begun to manufacture very small battery operated vaccum tubes in 1934-35. One of the most important contributions to the development of wearable vaccum tube hearing aids at this stage was the design and the production of both small light weight piezo electric crystal earphone or receivers and small highly sensitive crystal microphone.

The vaccum tube hearing aids were first introduced in mid 1930 and they differ primarily from the earlier telephone or carbon type aid in that it uses the electron tube for amplifications instead of the carbon transmitter and booster amplifier with the battery circuit. It differs also in that the higher amplification of the vaccum tubes permit the use of microphones of greater fidelity but lower sensitivity such as the pizo electric or crystal microphone in contrast to carbon button microphone. The English always refer to a vaccum tube as a ‘valve’ because of the fact that grid of the tube acts as a gate, releasing the much greater energy of the filament and plate of the tube when only a very alight amount of energy is impressed upon the grid.

The earliest type of receivers used in hearing aids were flat, over the ear type, magnetic receivers. This is uncomfortable after hours of use. The advent of BC receiver in 1931 gave a tremendous impetus to the hearing aid industry. Electric type bone conduction (BC) receiver was developed in 1920’s by Lieber. A BC receiver is a magnetic type receiver in which a contact surface transmits the mechanical vibrations to the bone of the head. Bunch says from an electromechanical stand point a BC ad is less efficient than one of the air conduction type. If one uses a BC aid he must supply power to vibrate the entire head.

Now the arts of electronic amplification and electroacoustic engineering have made it possible to deliver as much sound as the ear can tolerate. We can therefore raise our sights and say that a hearing aid should deliver sounds loudly enough to be heard easily but without discomfort. The listeners hearing loss should be overcome and his auditory nerve stimulated in a pattern as nearly normal as possible, Distortion of the original pattern of sound should be introduced only to the extent that it assists in bringing to the listener speech that is intelligible, comfortable and pleasing quality.

Among the various characteristics the hearing aids possess the frequency range and distortion forms the major ones which influence the intelligibility of the hearing aid. The frequency range of the hearing aid should be expressed in terms of useful frequency range i.e., frequency area where the gain is sufficient to over ride the deafness of the subject. A high quality hearing aid should provide a frequency range of atleast 3500 CPs although there will be cases where selective fitting makes it advisible to limit the response to only a part of this range. Davis found that narrowing the frequency range of a hearing aid to the zone between 1000 to 2000 CPs seriously affected the intelligibility score and operating range. He includes that a frequency range performance by normal hearing listeners found that in monaural reproduction speech the normal ear preferred a restricted frequency range (5000 CPs) although the wider frequency range was generally preferred otherwise. It would seem that although the low frequency range from 250 – 500 CPs is not essential in a hearing aid for intelligibility some response in this range gives a more pleasing tonal quality.

Distortion forms one of the major characteristics of hearing aids. Distortion has been defined as inexact preproduction of a sound wave pattern. Distortion which is present in a hearing aid will effect the output speech intelligibility to a greater extent. Harris (1961), Jerger (1966), Kastein and Lotterman (1967) and Bode (1968) have supplied evidence of decrease in speech intelligibility when excessive distortion products are present in low fidelity circuitory. Bode and Kastein made a study on the effect of hearing aid and consonant identification. His experiment was conducted with 34 normal hearing listeners to determine the offsets of distortion on consonant identification in noise. Fire experimental conditions were employed in which measured harmonic distortion ranged from approximately 1% to 35%. Each listening condition involved play back of recorded test materials at a constant sensation level. Results showed that average consonant identification scores relative to the high fidelity condition decreased 15 - 29% as a function error scores on the CID sentences and some physical measures of hearing aid performance especially harmonic distortion.

Jerger, speaks and Malmquist (1966) found both subjective quality judgements and intelligibility to be related to the degree of harmonic distortion present in hearing aids. 36 hard of hearing listeners representing various types and degrees of hearing loss were tested. Using tape recorded speech materials and competing continuous discourse which had been transduced through three hearing aids with harmonic distortion (the average of 500, 700 and 900 CPs) ranging from 4% to 16% they found the performance of normal hearing and hearing impaired to be inversely proportional to harmonic distortion.

Lotterman and Farrer (1965) examined the levels of nonlinear distortion present in modern hearing aids and the variability in distortion among instruments of a given model. The magnitude of distortion appeared to be inversely related to the 500, 700 and 900 CPs test frequencies while the frequencies at which maximum distortion occurred was commonly found at higher frequencies for ear level type hearing aids than for body type instruments.

Kasten and Lotterman did a longitudinal examination of harmonic distortion in hearing aids. This study examined the harmonic distortion levels of 1170 hearing aids submitted to the veterans administration for contract evaluation during the last six years. Measurements were made in a 75 dB SPL input at 500, 700 and 900 CPs and at the frequency at which maximum distortion was found. The gain of each hearing aid was set with a 62.5 dB SPL input to that point at which distortion at all amplified frequencies was less than 10%. Based upon average gain and average saturation sound pressure level each aid was placed in one of the three power categories. The results showed that the levels of maximum distortion appeared to be inversely proportional to the rated power of the aids.

Having said the important characteristics such as frequency range and distortion and its effect on the intelligibility of speech, it has been found that the difference in the physical characteristics of hearing aids is more important to some type of hearing impaired listeners than to others and that such individuals will reflect substantial performance difference not readily apparent in large group.

Jerger, Carolyn, Malmquist and speaks (1966) did a study in which a sentence intelligibility test recorded through three hearing aids were presented to 36 subjects with diverse types of hearing loss. Although hearing aids were rank ordered meaningfully on the sentence intelligibility test in inverse proportion to the harmonic distortion, performance difference were not systematically reflected in the monosyllabic word test results. The rank ordering of the aids on PAL-8 is identified for every group and the difference among the aids are relatively large. Jerger at al has concluded although it seem possible to devise a behavioral measure that will infact differentiate among hearing aids one is justified in assuming that such performance difference will necessarily be reflected by monosyllabic word lists as they are currently used in conventional hearing aid selection procedure. However, Jerger has concluded studying of such rank ordering of aids in the presence of competing message which is worthy of further study.

Jerger (1967) examined the influence of intermodulation distortion in a 'nonspeech' procedure. He suggested that such •valuation might be beneficial in detecting differences between aids with widely differing characteristics. Jerger and Thelin (1968) found that influence of these distortion is not as great as was previously reported.

Olsen and Wilber (1967)reported the results of an extensive investigation of the influence of various electroacoustic characteristics. They concluded that the effective band width of the instrument was the only measured characteristic which ranked the aids in the same order as did speech intelligibility.

Tillman, Carhart, Wayne and Olsen (1970) did a study on hearing aid efficiency in a competing speech situation. Discrimination for monosyllabic words against competing sentences was measured at the same sensation levels during unaided and aided listening using four types of subjects; normals, conductive loss cases, non presbicusis sensorineurals, and presbicusics. There were twelve subjects per group. Listening against competing sentences was binaural, monaural direct and monaural indirect at nominal primary to secondary ratio of + 18 dB and + 6dB. Unaided measures included SRT and monosyllabic discrimination were obtained by sound field testing conditions Aided measures were obtained with the subject in a separate room wearing hearing aid receiver and earmould while the hearing aids were mounted on an artificial head placed in the sound field test chamber. The aided measures were obtained at two gain settings. The main findings were :

1. that the hearing impaired required more of an increase in SPL in the sound field to achieve spondee threshold via the hearing aid than can be accounted for by the difference in methodology alone.

2. that intelligibility of monosyllabic words in quiet was some what poorer during aided listening than during unaided listening even though sensation level was held constant

3. subjects with presbicusis and other sensorineural losses were less resistant to masking by competing sentences during aided listening than were subjects with normal hearing or with conductive loss, and

4. that all groups exhibited reduced intelligibility for a constant sensation level. This last effect was particularly severe for patients with presbicusis and other sensorineural hearing loss.

Raymond Carhart (1964) did a study on speech discrimination with a hearing aid in a competing message situation. He took four groups of 12 subjects each - normals, conductive loss, young adults with sensorineural lose and presbicusics. They were given unaided and aided tests of monaural discrimination at 30 dB SPL in two levels of competing speech. The NU auditory teat # 2 was employed and conflicting stimuli were emitted from loud speakers on opposite sides of the subject. In one test condition the primary message originated from the contralateral side. The experiment was repeated with four comparable groups the only difference being that the gain of the hearing aid and the sound field in which it operated were changed. Results were comparable to an interference function plotted at an earlier date by presenting the and test # 2 to unaided normal listeners and using several levels of competing message. Performance of unaided normals agreed closely with the criterion function but it changed in the aided condition about as much as it would have had the competing message been increased approximately 10 dB during the unaided condition. Unaided performance of the conductive loss was nearly equal to that of normals, but the change in the aided condition was approximately twice as great. Young sensorineural loss cases and presbicusis performed essentially equivalently. Both groups showed extra interference unaided which was similar to that exhibited by normals aided and the hearing aid added still more to the interference effect of the competing speech. Moreover in this instance the slope of the interference function was modified so that discrimination had not reached maximum even at very favourable primary to secondary ratio.

Miller and Niemoeller (1967) reported reduction is intelligibility as hearing aid microphone was moved away when tested in the presence of noise. They relate this to distortion caused by reflected waves and recommend detachable microphones that can be held close to the talkers lips in order to improve speech to noise ratios.

Witter and Goldstein (1971) made a study on quality judgements hearing aid transduced speech. Frequency range, harmonic distortion, inter modulation distortion and transient measurements were made on five aids which manifested varying amounts of each property. Effects of these properties were most predictive of quality judgement and whether or not voice interacts with electroacoustic properties. The speech of male and female talkers were recorded through these aids and paired comparison judgements were made by thirty normal hearing listeners. Transient response was the beat predictor of listeners judgements and voice may be a factor in the quality Judgement task.

Lents has reported a study on speech discrimination in the presence of background noise using a hearing aid with a directionally sensitive microphone. The primary purpose of the present investigation was to evaluate whether a hearing aid with a directionally sensitive microphone actually permits better speech discrimination ability in the presence of background noise than do instruments with other types of microphones. For many years hearing aid users have commented and research has shown that one's ability to understand is seriously limited in the presence of competing noise (Olsen & Tillman 1965, Hahn & Demichelis 1967). Traditionally hearing aids have been manufactured using microphones which are not directionally sensitive, there by providing equal amplification for sounds arriving from any azymuth. However, Maico hearing instruments recently introduced a hearing aid which utilizes a directional microphone providing as much as 20 dB utterance in the frequency range of 500 – 4000 CPs, when the sound source is located at a 180° azymuth (Hensler, 1970). In addition preliminary study conducted at Colorado State University indicated that many individuals have sensorineural impairments understood 10 – 30% more monosyllabic words while wearing this aid in the presence of background noise than when using a conventional instrument not having a directionally sensitive microphone.

Vargo, Taylor, Tannahill and Plummer did a study on the intelligibility of speech by hearing aids on inductance loop and microphone modes of signal reception. A comparative evaluation was done on the speech intelligibility of two hearing one with a inductance loop and the other with a conventional body unit. Bach aid received and reproduced fifty monosyllables (CID W22) on both inductance coil and microphone input modes. The resultant 200 words were tape recorded from the output of a 2 cc coupler and then evaluated by 196 students. Words correctly written served as the criterion measure. Data analysis revealed significantly more intelligible speech for the conventional hearing aid for both inductance coil and microphone inputs. Further, the loop hearing aid was significantly less intelligible on its inductance coil setting than on microphone reception.

When Harris, Haines, Kelsey and Clack reported that harmonic distortion appeared to be the major contributor to the degradation of speech intelligibility, Jeffers reported on the relation between quality Judgements and acoustic characteristics. Therefore it was decided to measure the influence of these electroacoustic characteristics of fire Indian hearing aids on their performance to check the quality of these hearing aids and there by use it as an alternative procedure for the selection of the bearing aid.

# CHAPTER III

## METHODOLOGY

The aim of the present study is to judge the quality of Indian hearing aids through speech discrimination test using hearing aid processed stimuli and rank them according to their performance. The present study in brief includes the following steps :

1. Puretone air conduction thresholds

2. Conventional speech reception threshold and speech discrimination

3. Recording the phonetically balanced list through various Indian hearing aids

4. Testing the discrimination using the hearing mid processed speech

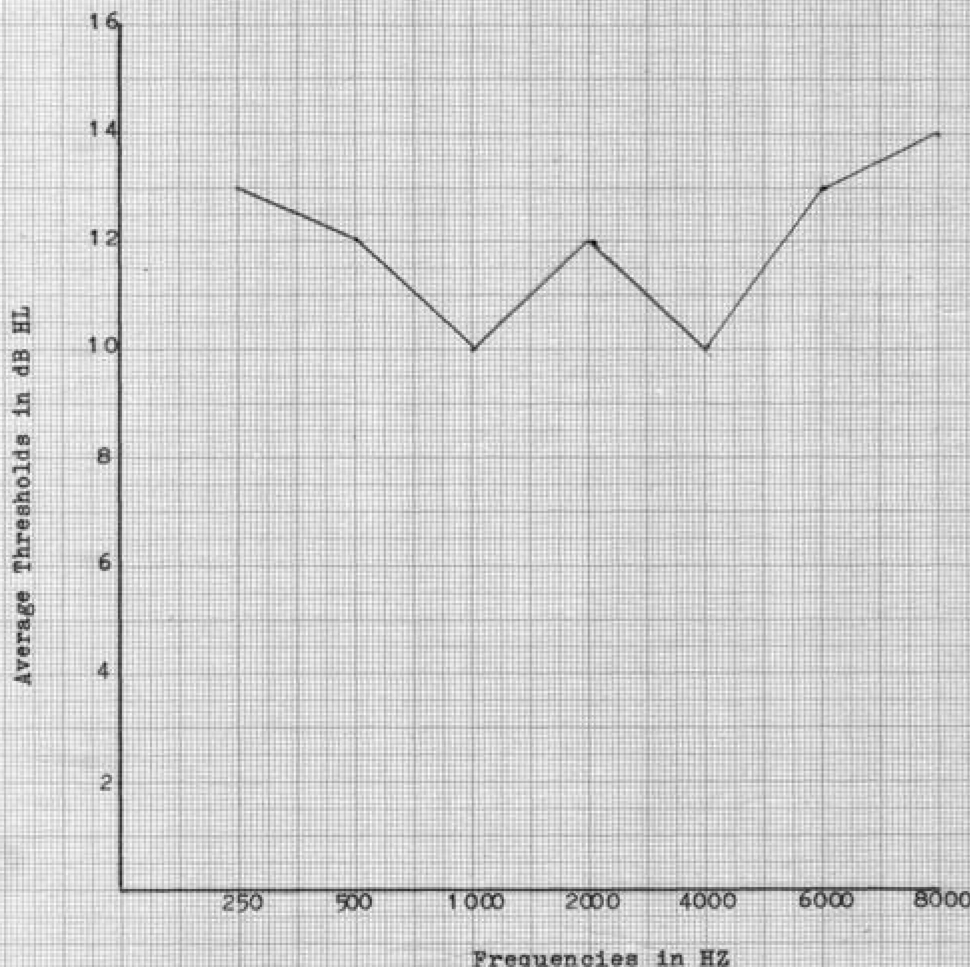
5. Testing the speech discrimination of hearing aid processed speech in presence of a competing noise

The total of 100 normal subjects selected for the study were divided into five groups to test the performance of each hearing aid. The subjects were selected randomnly from the student population of the Institute, The age of the subjects ranged from 17 years to 34 years. As the word list was in English only graduate students were included in the study to assure the familiarity of the words. All the subjects were otologically normal. The subjects were tested using Hughson-Westlake ascending procedure to establish thresholds for puretones of 250

CPs to 8000 CPs using a Beltone 15 CX two channel clinical audiometer caliberated to ISO (1964) standard. All the subjects had their thresholds below 20 dB all the test frequencies. The average hearing level of the subjects for each frequency is given in graph 1.

Using the spondee word list prepared by psychoacoustic laboratory which was standardized at this clinic (Swarnalatha, 1972) the speech reception thresholds of the subjects were established. To save time, the dysyllabic words were presented first at 15 dB above the subjects puretone average and then it was reduced in 5 dB steps till a 50% response level was obtained. This level was taken as the subjects speech reception threshold. The speech reception threshold was used as a measure to check the validity and reliability of puretone audiogram. All the subjects were required to give a speech reception threshold which was within ± 7 dB of their puretone average. The average of the puretone averages of the subjects was 11 dB and that of the speech reception threshold was 10 dB.

The discrimination word lists used in this study were prepared from the Pb word list of psychoacoustic laboratory which was standardized by Miss Swarnalatha (1972) at this clinic for Indian population. As a safety measure the list of words were further given to some hundred people to select 100 familiar words to prepare four equivalent list of twenty five words each. The lists were named as List 1, List 2, List 3, and List 4. These lists were used to measure the discrimination




Average Thresholds of 100 Normal Subjects

GRAPH - I

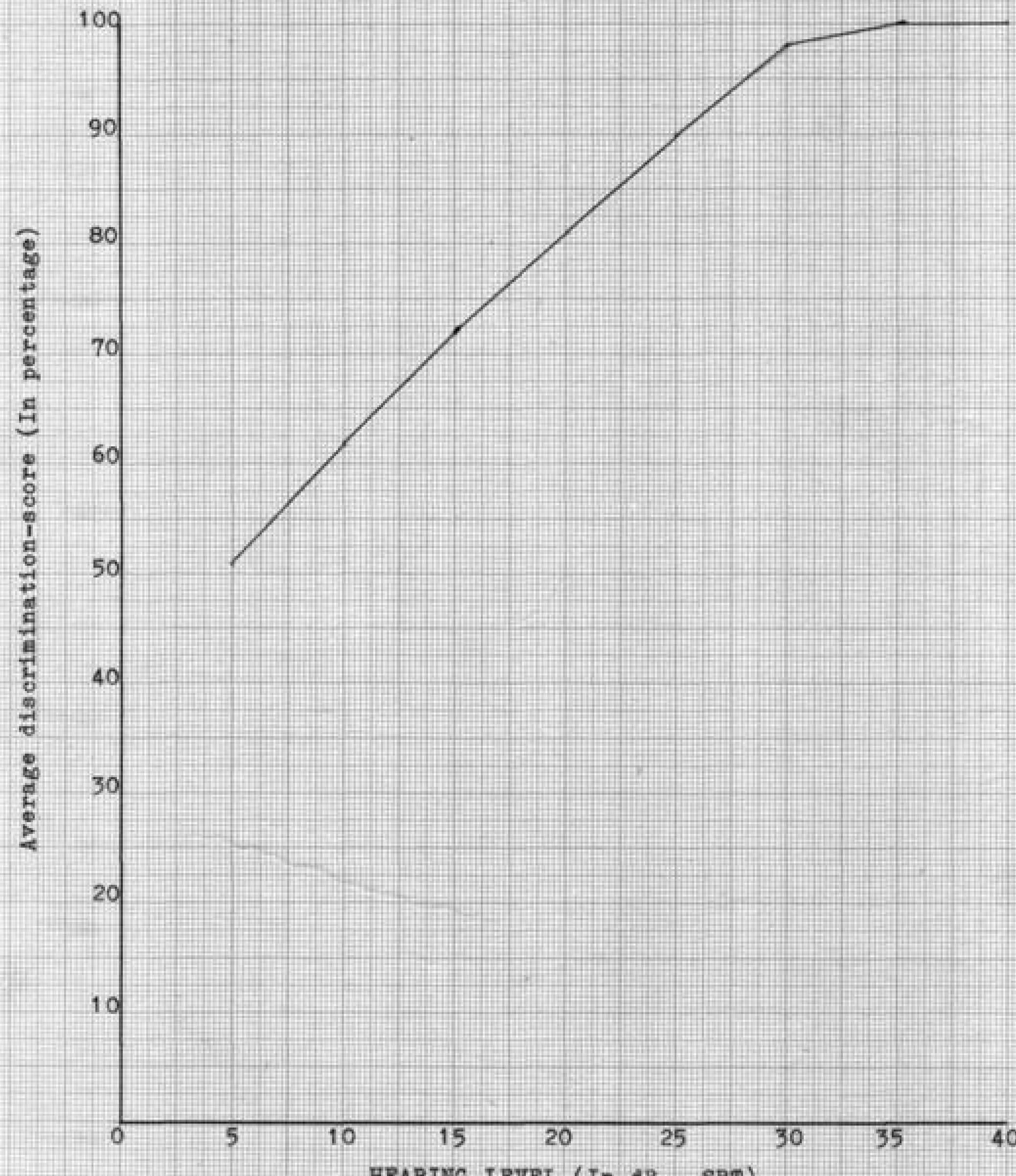
of the experimental subjects throughout the study. All the words were recorded on a sony tape recorded with the help of a male speaker. All the test words were proceeded by the carrier phrase “ say the word..............”. The recorded lists were first presented to 30 of the 100 normal subjects, selected randomly to study the function of intensity on performance. Starting from the speech reception threshold level of the subjects the words were presented in 5 dB steps till a 100% response level or plateau was obtained. The average performance of the subjects is given in graph II. The average intensity at which the subjects gave 100% discrimination was found to be 35 dB above speech reception threshold and hence it was taken as the level for the presentation of word lists throughout the study.

In the experiment the subjects were given the following instructions :

> “You will hear a list of words through the earphone. Each word will have a carrier phrase say the word ............. ”. Don’t repeat the carrier word, but repeat only the last word. If you are not sure guess” (Glorig 1965)

Each subject was given a minimum of 25 words to each ear. Using the talk back system the investigator recorded the response of the subjects.

The subjects were considered normal only when the discrimination score was above 92%. All the subjects selected




The average performance-intensity function of 30 normals

GRAPH 2

for the study exhibited a discrimination score of more than 92% and the average being 99.60%. The subjects responses were recorded on a sheet as shown below:

FREQUENCIES

| EAR | 250 | 500 1000 | 2000 | 4000 | 6000 | 8000 | PTA | SRT | DS% |
|---|---|---|---|---|---|---|---|---|---|
| Rt | | | | | | | | | |
| Lt | | | | | | | | | |

All the tests were administered in the sound treated room of the Institute. The noise levels of the room as recorded are given in the appendix.

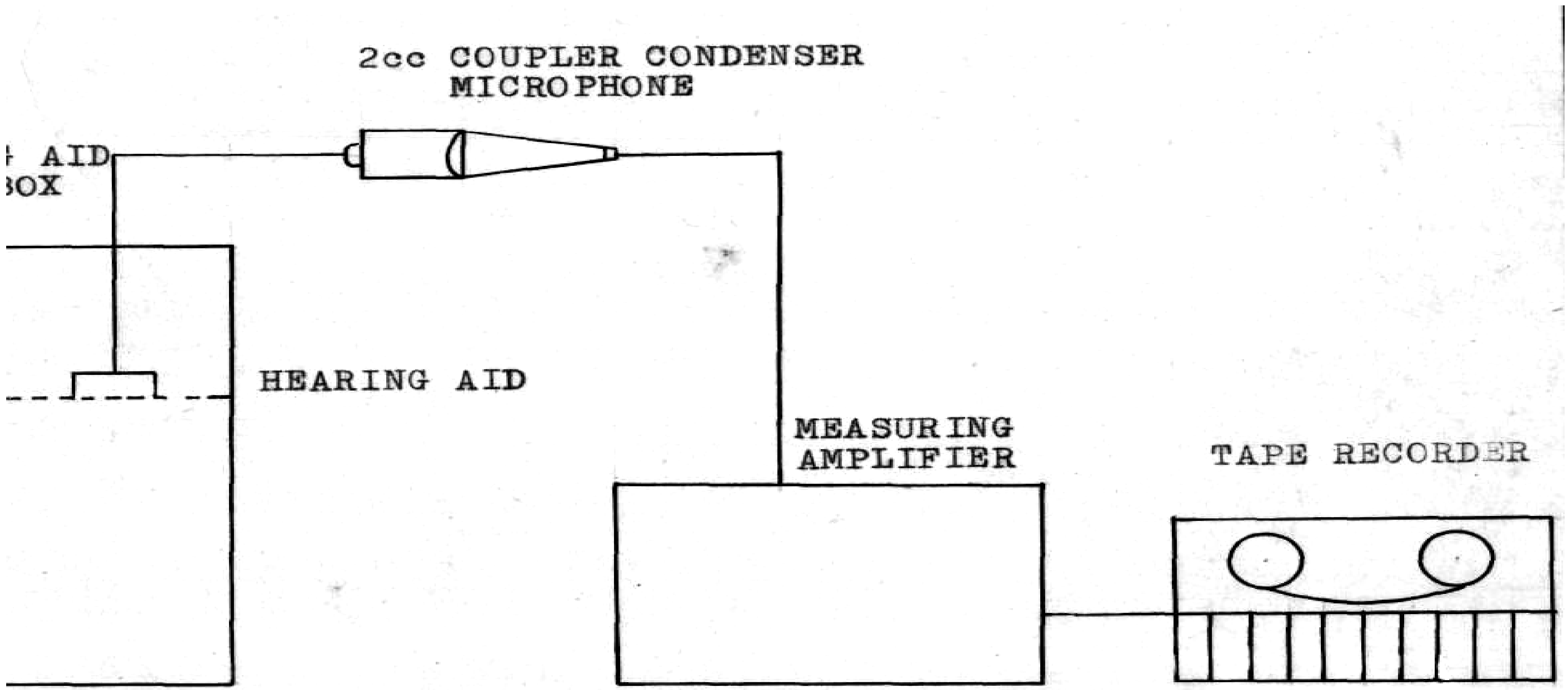
## Experiment

Five Indian hearing aids namely Oticon Extra Super, Oticon Super, Danavox 6471, Danavox AVC and Rionet were selected to conduct the study. The selection was mainly on the basis of their availability to the clinic. First these hearing aids were tested for their electroacoustic characteristics using a B & K hearing aid test box (type 4217) a 2 cc coupler, a condenser microphone (B & K type 4144) and a frequency analyzer (B & K 2107). Measurement of gain characteristic of the hearing aids helped to set the aids at half of their average gain at speech frequencies. This level was arbitrarily selected to avoid excessive distortion due to over loading. The recorded word lists from the tape recorder were then presented to the hearing aid test box and the input to the hearing aid was kept at 60 dB SPL. The receiver of the aid was connected to a condenser microphone using a 2cc coupler. Through a measuring amplifier (B & K 2607) the output was recorded on a sony tape recorder. All the four lists were transduced through each hearing aid. All the recordings were made in the sound treated room of the Institute to avoid the interference of the ambient noise. The block diagram of the set up for recordings is given in Fig 1.

The recorded hearing aid transduced speech was then present through Beltone 15 CX clinical audiometer using TDH 39 earphone with MX 41 cushion. 20 subjects were tested for each hearing aid. Only one list was presented to each subject so as to avoid the question of any familiarity. The presentation of the monosyllables were kept constant at 35 dB above speech reception thresholds.

Since the hearing aids are usually worn in noisy environment it was also decided to check the effects of white noise on the hearing aid transduced words. For this three signal to noise ratios namely 0 dB S/N, -5 dB S/N and –10 dB S/N were selected. A total of 25 subjects were selected for this study and were asked to repeat the words in presence of noise as much as they could. The results were recorded on a recording sheet as given below:

| Hearing Aid Model | Hearing Aid Make | List No | D S` | D S IN NOISE | | |
|---|---|---|---|---|---|---|
| | | | | 0 dB S/N | -5dB S/N | -10dB S/N |
| | | | | | | |


2cc COUPLER CONDENSER
MICROPHONE
AID
BOX
HEARING AID
MEASURING
AMPLIFIER
TAPE RECORDER

# CHAPTER IV

## ANALYSIS OF RESULTS AND DISCUSSION

The performance of hearing aids depends upon the amount of distortion, frequency response, gain etc., Among these factors the important character that affect speech reproduction is the distortion. Lotterman (1967) have supplied evidence of decrease in speech intelligibility when excessive distortion products are present in the hearing aid. When the distortion is higher the intelligibility of speech is affected to a greater extent. Recently Jerger, speaks and Malmquist (1966) found both subjective quality judgements and intelligibility to be related to the degree of harmonic distortion present in hearing aids.

The first aim of this study was to find out the difference between various hearing aids. Before analyzing this it was necessary to assure that there exist no difference among lists. To verify this "the two way classification with multiple but equal number of observation per cell" method was applied. The hypothesis framed was "there is no interaction among lists”. By the above method it was found that (F) table value was greater than (F) observed value.

| F(table value) | .05 | .01 |
|---|---|---|
| | 2.42 | 1.88 |
| F(observed value) | 1.00 | |

F(tab) F(Obs)

Results therefore forced to accept the hypothesis that there is no interaction among the lists that were used.

Secondly to test the null hypothesis i.e., “there is no difference among hearing aids” the “two way classification with multiple but equal number of observation per cell” method was used. It was found that F (observed) value is greater than F(table) value.

| | | |
|---|---|---|
| F(table value) | .05 | .01 |
| | 3.56 | 2.49 |
| F(observed value) | 94.08 | |

Hence the hypothesis that there is no difference among hearing aids has been rejected indicating that there is difference in performance among hearing aids.

To study whether this difference in performance is

Significant or not, the T test was used and obtained the following results:

| Srl. No. | Hearing Aids H1 | H2 | Mean Performance M1 | M2 | M 1-M2 | F(tab) | Results |
|---|---|---|---|---|---|---|---|
| 1 | OES | OS | 84.70 | 75.40 | 9.30 | 30.39 | .05R |
| 2 | OES | D AVC | 84.70 | 77.20 | 7.50 | 30.39 | .05R |
| 3 | OES | D6471 | 84.70 | 74.40 | 10.30 | 30.39 | .05R |
| 4 | OES | R 1 | 84.70 | 45.20 | 39.50 | 30.39 | .05A |
| 5 | D AVC | OS | 77.20 | 75.40 | 1.80 | 30.39 | .05R |
| 6 | D AVC | D6471 | 77.20 | 74.40 | 2.80 | 30.39 | .05R |
| 7 | D AVC | R 1 | 77.20 | 45.20 | 32 | 30.39 | .05A |
| 8 | OS | D6471 | 75.40 | 74.40 | 1.00 | 30.39 | .05R |
| 9 | OS | R I | 75.40 | 45.20 | 30.20 | 30.39 | .05R |
| 10 | D6471 | R I | 74.40 | 45.20 | 29.20 | 30.39 | .05R |

OES = Oticon Extra Super

OS = Oticon Super

D AVC = Danavox AVC

D6471 = Danavox 6471

R1 = Rionet

A = Accepted

R = Rejected

N 1 = Mean of Hg. aid 1

N 2 = Mean of Hg. aid 2

H 1 = Hg. aid 1

H 2 = Hg aid 2

These results show that there is a significant difference in performance between two pairs of hearing aids i.e., between Oticon Extra Super and Rionet Danavox AVC and Rionet Hearing Aid.

The mean performance of these hearing aids were used to rank order them as follows :

| S.No. | Rank | Mean performance | Hearing Aid |
|---|---|---|---|
| 1 | A | 84.70 | OES |
| 2 | B | 77.20 | D AVC |
| 3 | C | 75.40 | OS |
| 4 | D | 74.40 | D 6471 |
| 5 | E | 45.20 | R1 |

Since the performance of hearing aids can be altered very much by the presence of noise the second part of the study was an attempt to find out the efficiency of these hearing aids under different levels of noise. As a prerequisite to this analysis, it was decided to rule out any possible difference in performance among the three levels of presentation because if there is no difference among the three levels of presentation, any one level could be used to find out the difference among hearing aids. In order to find out this, the Friedman’s test was used. The hypothesis was “there is no difference in performance among the three levels of noise.

The statistical calculations at each level are given here as follows:

1.At Odbs/N

| | |
|---|---|
| F table value .05 level | 9.48 |
| F observed value | 15.75 |

F(obs) F(tab)

F(Observed) value is greater than F table value

1. At - 5dbs/N

| | |
|---|---|
| F table value .05 level | 9.48 |
| F observed value | 13.98 |
| F(obs) | F(tab) |

F(Observed) value is greater than F table value

3. At - 10dbs/N

| | |
|---|---|
| F table value .05 level | 9.48 |
| F observed value | 14.12 |
| F(obs) | F(tab) |

F(Observed) value is greater than F table value

Hence there is significant difference in performance of hearing aids when different levels of noise administered.

Since there is difference among the performance of hearing aids at three levels of presentation, the difference among the hearing aids was tested at each level separately. In order to find out whether there is difference among hearing aids at each level – 1. The Mann Whitney test and 2. Krushak – Wallis one way analysis test were employed. The results are as shown below:

| Srl. No. | At 0 db S/N | At – 5 db S/N | At – 10 db S/N |
|---|---|---|---|
| 1 | A > B | A > B | A > B |
| 2 | A > C | C > A | A > C |
| 3 | A > D | A > D | A > D |
| 4 | A > E | A > E | A > E |
| 5 | B > C | B > C | B > C |
| 6 | D > B | D > B | D > B |
| 7 | E > E | B > E | B > E |
| 8 | C > D | C > D | C > D |
| 9 | C > E | C > E | C > E |
| 10 | D > E | D > E | D > E |

A = Oticon Extra Super Hearing Aid
B = Danavox AVC Hearing Aid
C = Oticon Super Hearing Aid
D = Danavox 6471 Hearing Aid
E = Rionet Hearing Aid
> = Greater than
< = Lesser than
– = Equal to

The means of performance of these hearing aids at these three successive levels listed the aids in terms of proficiency as follows :

| Sl. No | Hearing Aids | At O db S/N % Mean performance | Rank | At–5dB S/N % Mean performance | Rank | At – 10dB S/N % Mean performance | Rank |
|---|---|---|---|---|---|---|---|
| 1 | Oticon Extra Super | 50.4 | A | 39.2 | A | 29.6 | A |
| 2 | Danavox AVC | 45.6 | B | 36 | B | 24 | B |
| 3 | Oticon Super | 44 | C | 35.6 | C | 23.5 | C |
| 4 | Danavox 6471 | 40.8 | D | 30.4 | D | 21.6 | D |
| 5 | Rionet | 32 | E | 24.8 | E | 18.5 | E |

Discussions

The results of this study shows that it is possible to evaluate the efficiency in performance of hearing aids using the behavioral procedure and rank them in term sof their proficiency. This is based on the assumption that the physical differences among hearing aids can be reflected in behavioral tests (Jeffers and Smith 1964). Shore, Bilger and Hirsh (1960) showed that, when CID w22 and recorded FB word list spoken by Rush Highes were used to evaluate hearing aid performance the reliability of these messures was ".............. not good enough to warrant the investment of a large amount of clinical time with them in selecting hearing aids". The investigator did qualify this conclusion however, by noting that reliable differences might be found among factors "not yet...........claimed to be measurable by the audiologist". However, the results of the present study shows that it is possible to qualify the hearing aids through behavioral teats and the performance difference, which was consistent, could be measured. The results of this study in further supported by Jeffers and Smith (1964) that the physical differences among hearing aide can be reflected in behavioral tests. Oticon Extra Super hearing aid was found to be superior in performance to other hearing aids used probably because of its greater fidelity and lower internal noise. The probable reason to obtain very poor scores with Rionet hearing aid may be because of poor fidelity, greater distortion and greater internal noise. Hence the performance of a hearing aid depends much on physical characteristics, (Ref : Appendix). Harris, Haines, Kelsey and Clack (1961) employing various types of degraded speech showed significant correlations between error scores on CID sentences and some physical measures of hearing aid performance especially harmonic distortion. Jerger, Malmquist and Speaks attempted to investigate a performance task that would reliably distinguish the difference among hearing aids and whether on the basis of the performance task, can these aids be rank ordered. The results showed that the physical differences among three hearing aids were reflected behaviorally by the PAL-8 task, which further supports the present study. Sung and Hodgson (1971) found that the hearing aid with the better high frequency response produced better intelligibility for monosyllabic words regardless of the mode of signal input.

The configuration of the frequency response curve in the region of 1.5 to 3 Kc/s appeared to be associated with the intelligibility of monosyllabic words. In the light of the above study and the results obtained here, it could be possible to state that the frequency response of Oticon extra super and Danavox AVC at this range is well maintained. Hodgson and Sung (1972) showed that monosyllabic tests are more sensitive to difference in frequency response of hearing aids. However, Jerger, Malmquist and Speaks have commented that although the hearing aids were rank ordered meaningfully on the sentence intelligibility inverse proportion to the harmonic distortion, performance differences were not systematically reflected with monosyllabic word test results. Recent study of Jerger et al (1972) has indicated that it is possible to device a behavioral measure that will in fact differentiate among hearing aids with differing physical characteristics. The present study also concludes that it is possible to check the quality of a hearing aid through behavioral tests. Tillman, Carhart, Wayne and Olsen studied the discrimination for monosyllabic words heard against competing sentences at the same sensation levels during unaided and aided listening conditions. Unaided measures included SRT and monosyllabic discrimination, were obtained by sound field testing conditions. They have concluded that the intelligibility of monosyllabic words in quite was somewhat poorer during aided listening than during unaided listening even though the sensation level was held constant. This also supports the findings of this study that there is a reduction in discrimination under aided conditions than without it.

Since the hearing aid is usually worn by the patient outside the controlled environment where it is subjected to perform in a background of noise, these hearing aids were also tasted for their performance using three levels of noise, 0 db S/N, -5 db S/N and -10 db S/N respectively. The results led us to formulate the following conclusions :

1. Intelligibility of speech through hearing aids earn be impaired in a background of competing message

2. The extent of reduction in intelligibility depends on the signal to noise ratio

3. At the earn signal to noise ratio, the performance of different hearing aids would be different

These results have also been supported by the study findings of Bleaker and Huizing in 1953, by Carhart in 1946, by Davis et al in 1946, by Schubert in 1960 and by Jerger in 1971.

# CHAPTER V

## SUMARY & CONCLUSIONS

The aim of the present study was to judge the quality of Indian hearing aids through behavioral teats. Five Indian hearing aids were selected which ranged in its physical characteristics. Next the psychoacoustic laboratory word lists were selected. The list was administered to 100 subjects to select familiar words. Using the selected familiar words four equivalent lists of 25 words each were composed. These monosyllables were first records on a H1-F1 tape recorder (Sony Cassette) and later re-recorded after it was transduced through a hearing aid, measuring amplifier (B & K 2607) to another tape recorder. The input to the hearing aid was kept constant for all the hearing aids. All the hearing aide were set to gain half of their average at speech frequencies. The list of words transduced through the above five hearing aids were presented via earphone (TDH 39) using Beltone audiometer (Model 15 CX). 100 normal subjects whose thresholds were below 15 dB from 250 to 4000 CPs were selected for the study. After puretone audiometry, using recorded speech materials both SRT and speech discrimination were obtained. These subjects were then presented with the monosyllable words rerecorded through hearing aids. Each subject was given only one list of hearing aid transduced monosyllabic words at 35 dB SRT. 20 subjects were tested for each hearing aid. The difference in the discrimination score between unaided and aided conditions was taken to assess the performance difference among hearing aids.

In the second part of the study twenty five subjects were tested for the aided discrimination in the presence of a competing signal. Three signal to noise ratio, at 0 dB S/N, at –5 dB S/N and at –10 dB S/N were used. The discrimination of the subjects with the hearing aid in quiet and in the presence of noise were compared. Suitable statistical methods were used to compute the significance of difference.

Using the "two way classification with multiple but equal number of observation per cell" statistical method it is found that the hearing aids differ in performance depending on the physical character. The difference was significant between Oticon Extra Super and Rionet and Danavox AVC and Rionet hearing Aids. Hearing aids were rank ordered based on their performance using the mean performance.

| Rank | Hearing Aids |
|---|---|
| A | Oticon Extra Super |
| B | Danavox AVC |
| C | Oticon Super |
| D | Danavox 6471 |
| E | Rionet |

Hearing aids could be further differentiated when they were made to perform under difficult situations like the performance in the back-ground of noise.

Limitations of the present Study

1. Clinical cases were not included in the study to evaluate their behavior in such similar situations
2. All the hearing aids available to the country could not be included due to difficulty in acquiring them

## Future Research Possibilities

1. Testing various clinical cases, the validity of this test to be used as an alternative procedure to prescribe hearing aid to hard of hearing can be studied.

2. The effect of modifications of ear moulds on Speech intelligibility can also be studied objectively using this procedure.

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# APPENDIX

| Sr. No | Octave Bands in Hz | Max.allovable Noise levels in DS SPL ISO | Noise Levels in the room in dB SPL |
|---|---|---|---|
| 1 | 75 - 150 | 31 | 18 |
| 2 | 150 – 300 | 25 | 17 |
| 3 | 300 – 600 | 26 | 15 |
| 4 | 600 – 1200 | 30 | 9 |
| 5 | 1200 – 2400 | 38 | 11 |
| 6 | 2400 – 4800 | 51 | 10.5 |
| 7 | 4800 – 9600 | 51 | 10 |

Noise Levels in the Sound Treated Room

CHARACTERISTICS OF THE SELECTED HEARING AIDS

| Sr. No | Make of the Hearing Aid | Average gain | Frequency Response | Maximum output | Harmonic Distortion at 500,800,1000 C/s |
|---|---|---|---|---|---|
| 1 | Oticon Extra Super | 62 dB | 200 C/s – 5000 C/s | 130 dB | 10% |
| 2 | Oticon Super | 55 dB | 200 C/s – 5000 C/s | 128 dB | 8% |
| 3 | Rionet | 45 dB | 200 C/s – 5000 C/s | 106 dB | 15% |
| 4 | Danavox 647 I | 56 | 200 C/s – 5000 C/s | 118 dB | 10% |
| 5 | Danavox Deluxe AVC 647 I | 58 | 200 C/s – 5000 C/s | 120 dB | 8.7% |

CHARACTERISTICS OF THE SELECTED HEARING AIDS

| Sr. No | Make of the Hearing Aid | Average gain | Frequency Response | Maximum output | Harmonic Dist-ortion at 500,800,1000 C/s |
|---|---|---|---|---|---|
| 1 | Oticon Extra Super | 62 dB | 200 C/s – 5000 C/s | 130 dB | 10% |
| 2 | Oticon Super | 55 dB | 200 C/s – 5000 C/s | 128 dB | 8% |
| 3 | Rionet | 45 dB | 200 C/s – 5000 C/s | 106 dB | 15% |
| 4 | Danavox 647 I | 56 | 200 C/s – 5000 C/s | 118 dB | 10% |
| 5 | Danavox Deluxe AVC 647 I | 58 | 200 C/s – 5000 C/s | 120 dB | 8.7% |