COMPARISON OF EFFICACY OF THREE DIGITAL HEARING AIDS WITH TRIMMER CONTROLS

(REGISTER NO. 02SH0007)

An Independent Project submitted in part fulfillment of the first year M.Sc (Speech and Hearing), University of Mysore, Mysore

ALL INDIA INSTITUTE OF SPEECH AND HEARING
MANASAGANGOTHRI, MYSORE - 570 006

MAY 2003

CERTIFICATE

This is to certify that the Independent Project entitled **"COMPARISON OF EFFICACY OF THREE DIGITAL HEARING AIDS WITH TRIMMER CONTROLS"** is a bonafide work done in part fulfillment for the degree of Master of Science (Speech and Hearing) of the student (Register No. 02SH0007).

Mysore

May, 2003

Director
All India Institute of Speech & Hearing
Mysore - 570 006

CERTIFICATE

This is to certify that the Independent Project entitled **"COMPARISON OF EFFICACY OF THREE DIGITAL HEARING AIDS WITH TRIMMER CONTROLS"** 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

Mysore

May, 2003

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DECLARATION

This independent project entitled **"COMPARISON OF EFFICACY OF THREE DIGITAL HEARING AIDS WITH TRIMMER CONTROLS"** is the result of my own study under the guidance of **Dr. K. Rajalakshmi,** Lecturer, Department of Audiology, All India Institute of Speech & Hearing, Mysore and has not been submitted earlier at any other University for the award of any diploma or degree.

Mysore Register No. 02SH0007

May, 2003

..._A shade under which you find
comfort, security A a sense of belonging.....

for you, Ma & Daddy

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Nanutty, your bubbling laughter, all your letters, all the times you called me "Bhabbaghosh", has helped me remain sane. Don't you ever change, sis.

Pixie... words are not enough to tell you what you mean to me ... all I can say is, you're the very reason I am ME.

TJ, Bagheera, and Gauda Don, time spent with you guys will be locked up and kept forever in my life's box of treasures.

Leeni, Sani, Charles, Thampi and VJ, though miles apart, you're forever in my heart.

Milchechi, I can thank you for lending me your room, I can thank you for listening to my stories (more than once in most cases), I *can*

thank you for all the times you scolded me, but you would still not realize how much you mean to me. So, I wont thank you ... hope you understand.

Amaan, you irritate me, you irk me. But you're as important to me, *as* honey is to the bee ... I miss you.

Thanks, **Gaurav,** for all those times you called me up just to tell me that you were missing me.

I will *never* forget you, **Aai, Baba, Kaku, Kaka, Purva, Amod, Jatin, Shruti Tai** and all the rest of you, for making my stay with you people my most memorable trip to a new place. **Riddhi,** wish you were there too.

Shivaprakash, we started out well, don't know what happened towards the end. But you'll always be considered a very good friend.

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CHAPTER I

INTRODUCTION

World Health Organization (1980) defined hearing impairment as abnormal functioning of the auditory system, disability as the functional consequences of an impairment and handicap as the social consequences of an impairment or disability (Saunders & Cienkowiski, 1996).

A patient can have a significant hearing loss based on pure tone findings, yet might not believe that he has a hearing disability (or at least one that needs to be treated). This can be influenced by the patient's lifestyle, occupation, and the amount of time they spend communicating with others. In some cases, it is denial or simply a lack of awareness of their problem-"I can hear fine, its just that my family members mumble" (Kretschmer, as cited in Donnelly, 1974).

Who is a candidate for hearing aid use? According to Donnelly (1974), this seemingly simple question is one of the most important and, unfortunately, one of the most commonly misunderstood issues in the area of hearing aid fitting. Difficulty in hearing can be thought of as having three dimensions. First, one may have a sensitivity loss, which implies that once a signal is made audible, the person will function well. Second, the individual may have difficulties in frequency, loudness and/or temporal resolution due to hearing loss. In this case, the individual will need a return of audibility but may still have difficulty, especially in difficult listening environments. Third, the individual who may or may not have sensitivity and resolution difficulties may have central auditory processing difficulties. This implies a problem with processing the signal even though it may reach the temporal lobe intact. But we know that an individual cannot possibly use sound if he/she cannot hear it. Therefore, even an individual identified with central auditory processing deficits may benefit from amplification.

An individual is a candidate for personal amplification as soon as communication is affected. After an individual has been identified as a hearing aid candidate based on degree and nature of hearing impairment, a second consideration is the motivation of the patient to use hearing aids. A person might have a significant hearing loss, admit having a communication problem, and yet not be willing to use hearing aids. Motivation of a patient to use hearing aids clearly is a contributing factor for successful hearing aid use. Fortunately, this factor can be influenced significantly by the advice of professionals (Donnelly, 1974).

Goals of amplification

The minimal goals of any hearing aid fitting are to achieve the best possible audibility (ability to hear soft, moderate, and loud sounds) while providing comfort (physical fit, and loudness) and excellent sound quality. In addition, the hearing aid must meet the expectations of the patient (Agnew, as cited in Valente, 1996).

The audiologist, through empirical data, patient needs assessment, and patient expectations, should define the goals of any hearing aid fitting carefully. These goals should dictate the assessment measures, technology selected, and verification and validation measures that will follow hearing aid selection (Hodgson, as cited in Hodgson & Skinner, 1981).

Some information on philosophical position of various professionals with regard to hearing aid fitting can be found in literature of 1950's. Otologists spoke of their role as primary manager for individuals in need of amplification. While not denying the otologists right to serve as the primary case manager for the hearing impaired, audiologists continued to stress the importance of evaluation procedures and standards for such evaluation. Audiologists' participation is favored because the audiologist with training about hearing mechanism, amplifying systems, test interpretation and management expertise is better able to represent the interests of the hearing impaired person (Kretschmer, as cited in Donnelly, 1974).

According to Muller and Strouse (as cited in Schow & Nerbonne, 1996), whenever a subject has to be fitted with an amplification device, trial of several instruments must be carried out. Trial of several instruments should improve the likelihood of the hearing-impaired listener understanding general characteristics of wearable amplification and thus, receiving more benefit from a hearing aid due to this extensive listening experience. On the other hand, Donnelly (1974) acknowledged that comparative hearing aid trials are not the only technique or method available for deciding, which, if any, hearing aid is beneficial for the hearing-impaired adult.

Different procedures for evaluating hearing aids have been used by audiologists in clinical practice. Few of these as cited by Donnelly (1974) are:

1. Assessment of aided versus unaided sensitivity and the comparison of hearing aids on this parameter has been a feature of hearing aid evaluation for many years

(Macfarlan, as cited in Donnelly, 1974). Signals used for comparison of aided and unaided sensitivity threshold consists of pure tones, conversational speech, nonsense syllables, spondaic words (Hirsch, 1952), noise bands, and various filtered or modulated non-speech signals.

2. A commonly suggested clinical procedure is to select a hearing aid with prescribed gain which is approximately equal to hearing impaired individual's unaided Speech Recognition Threshold, in an effort to produce an aided speech threshold which is as close to normal range of sensitivity as possible. This approach focuses clinician's attention on aided sensitivity as a significant factor in satisfactory fitting.

Research suggests that achievement of near normal aided sensitivity may not always be compatible with maximum aided discrimination. Markle and Zaner (as cited in Donnelly, 1974) and Yantis, Milin and Shapiro (1966) investigated the relationship of aided listening to variations in speech input. The authors concluded that maximum intelligibility scores were related strongly to comfortable or preferred listening levels as established by hearing-impaired subject. The importance of suprathreshold rather than threshold performance in hearing aid selection has been stressed repeatedly in hearing aid technology.

3. From the earliest history of hearing aid evaluation materials, attempts at quantification of listener performance have stressed the use of speech sounds and/or sentences, whether spoken or recorded (Fletcher, as cited in Donnelly, 1974). Since reports of mid 1940's, (Carhart, as cited in Donnelly, 1974), spondaic words have been used and recommended most often.

Carhart; Davies et. al,; Hudgins et. al, and Egan, (as cited in Donnelly, 1974): promoted the use of monosyllabic word lists to allow for comparison of aided and unaided listener performance.

But research and clinical reports strongly suggest that if monosyllabic word lists are to be of use in comparative hearing aid trials, they must be presented in presence of competing signal, whether noise, competing speech, or room reverberance (Milin, as cited in Donnelly, 1974), in order to achieve meaningful spread of subject scores or hearing aid ranking.

Use of sentence stimuli has received attention as an alternative to monosyllabic intelligibility tests. Sentences are presumed to resemble conversational speech, which a hearing aid user must contend with in daily living.

Jerger, Speaks and Malmquist, (1966) and Jerger, Malmquist and Speaks, (1966) reported sentence material to be more reliable and subtle measure of listener performance than conventional monosyllabic word lists, especially when applied to measurement of hearing aid performance.

> Listener performance

Chaiklin and Stassen (1968) and Miller and Niemoeller (1967) have reported on individual cases in which subject preference and subject report about particular hearing aid fittings were instrumental in satisfactory hearing aid use. Hendry, Grant and Rupp (as cited in Donnelly, 1974) found majority of their sensori neural hearing loss subjects to prefer the hearing aid, which produced best intelligibility scores for speech in quiet and for degraded speech presented in white noise. Ross (as cited in Katz, 1972) stresses that the lack of experimental evidence about relation between quality preferences of person with sensori neural hearing loss and specific electro-acoustic characteristics. He also suggests that there is merit in including subject preference information if hearing aid evaluation procedure is used.

Verification of **hearing aid performance**

A critical component of prescriptive fitting strategy is to assure that prescriptive gain targets have actually been achieved when the hearing aid is worn. Some type of real ear verification process, therefore, is required (Mueller, Northern & Hawkins, 1997). Perhaps the most reliable method to verify the performance of hearing aid is to measure the output of the hearing aid at the tympanic membrane of the hearing aid user.

Mueller, et al., (1997) state that probe microphone measurements are similar to functional gain, that is, unaided and aided ear canal sound pressure level (SPL) measures can be compared to determine insertion gain, which will be the same value as functional gain. Mason and Popelka (1986), Dillon and Murray (1987) and Humes et. al (1988) have reported that Real Ear Insertion Gain (REIG) and Functional Gain (FG) yield similar values.

According to Mueller et al., (1997), the use of REIG, rather than FG procedure offers several practical advantages:

- Information is obtained across frequency range, not just at discrete frequencies.

- Real ear gain can be determined for patients unable to provide behavioral response.
- Effects of input level on real ear gain can be assessed.
- There is significantly improved test-retest reliability.

Measurements via probe-microphone can produce results in terms of gain or overall output. Fundamental calculation conducted with probe-microphone is REIG. First, Real Ear Unaided Gain (REUG) is found, then the hearing aid is put on and Real ear Aided Gain (REAG) is found. The difference between the two is REIG (http://www.neatnois.com/services.htm#RealEarMeasurement).

In general, probe-microphone measurements are standard for hearing aid verification. Knowing actual SPL at the tympanic membrane is the most efficient method to assure that prescriptive targets have been obtained. Probe microphone measurements can also be carried out for digital hearing aids (Mueller et al., 1997). According to Mueller (2001), probe microphone testing is an important part of hearing aid verification protocol- a tool that assists us with verification of appropriate gain output and also features of hearing aids. Digital hearing aids tend to have more features, so that is all the more reason why probe microphone testing is necessary.

Types of Hearing Aids

The various types of hearing aids presently available can be categorized into three different categories, based on the circuitry utilized by the hearing aid. These are:

I. Analog Hearing Aids:

An analog hearing aid is designed with a particular frequency response based on the audiogram, and uses a continuously varying electrical signal to produce sound. Though there are some adjustments, analog aids amplify all sounds (speech and noise) in the same way.

The way an analog hearing aid functions can be depicted in the following way:

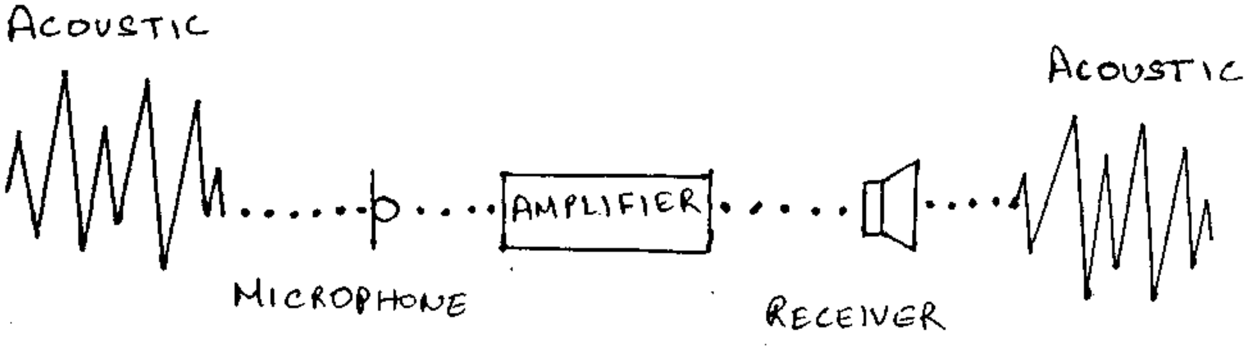

Figure 1.1

II. Analog Programmable Hearing Aids:

These hearing aids have a microchip, which allows the aid to have settings programmed for different listening situations (quiet, noisy, etc). An audiologist uses a computer to program the aid for different situations depending on the individual hearing loss profile, and range for loud sounds.

Some aids can store several programs. One can change settings as environment changes, by pushing a button on the aid, or using a remote control. Aid can be re-programmed if hearing or hearing needs change.

III. Digital Programmable Hearing Aids

These hearing aids have all the features of analog programmable aids, but use "digitized sound processing" to convert sound waves into digitized signals. Computer chip in the aid analyses signal of the environment to determine if sound is speech or noise, and then, makes modifications to provide clear, amplified, distortion free signal. Digital hearing aids are usually self-adjusting. Digital processing allows more flexibility in programming hearing aids so that the sound it transmits matches the client's specific patterns of hearing loss. Digital aids change digital signal into binary numbers (0 and 1). This is analyzed and manipulated by algorithms to perform precise, complex actions, and changed into sound that goes into the ear. These binary numbers can perform numerous complex calculations creating precise, very flexible hearing aids.

Functioning of a digital hearing aid can be depicted in following diagram:

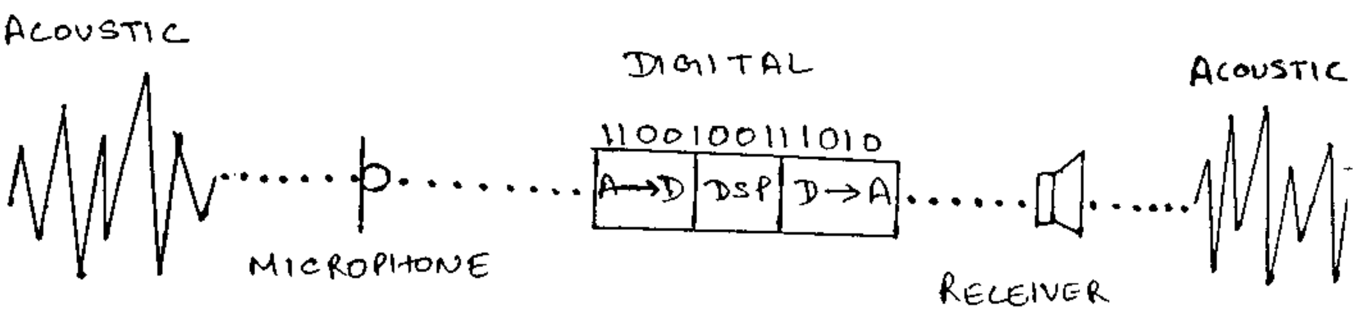

Figure 1.2

Digital Hearing aids with Trimmer Controls: These hearing aids have certain trimmer controls, within a compartment, that can be used for adjustments in various functions of the hearing aid, like an NH Trimmer, which is a low cut trimmer, i.e., it reduces the amplification of the low frequencies, an NL Trimmer, which reduces the amplification in the high frequencies, a G Trimmer, for adjusting the gain of all speech inputs, a T/MT Trimmer, for telecoil, or microphone with telecoil etc. These trimmers can be used for making some adjustments in the hearing aid response, without having to use a computer programmer, to program the hearing aid.

Need for the study

A digital hearing aid with trimmer controls is presumed to have some differences when compared to a conventional high cost digital hearing aid. Also, amongst the low cost digital aids, there is a difference in the costs of the different hearing aids. This difference in the cost may be due to some differences within these hearing aids. Hence, the performance of hearing impaired subjects with different low cost aids needs to be studied, to know if there is any difference in performance with the cost differences.

Also, it is an established fact that one hearing aid with a prescribed gain may not be suitable for all the subjects who fall within its fitting range. Again, different hearing aids with the same amount of gain may not result in similar results with the same subject. Therefore, there is a need to study the same hearing aid across different subjects falling within its fitting range, and to test different hearing aids with the same subject. In this way, we can find out if there is any difference in the performance of the subjects corresponding to the hearing aid cost.

Another major issue to be kept in mind is that as low cost digital hearing aids are a new concept in the hearing aid industry, any study done on them would be of much importance for dispensing of low cost devices to the needy people.

Aims of the Study

The present study is a preliminary attempt to:

(i) Compare three digital hearing aids with trimmer controls across two different degrees of hearing loss and to find out which hearing aid suits which population the best,

(ii) To find out whether there is any relation between the audiologist's ranking and the subjects' ranking of the hearing aids,

(iii) To find out whether there is any relation between the cost of the hearing aids, and the performance of the subjects.

CHAPTER II

REVIEW OF LITERATURE

Even though digitally controlled analog circuits contain digital logic for switching functions, they process the signal in the analog form. To make changes in the acoustics of the circuit, the programming in DCA (Digitally Controlled Analog) hearing aid circuitry opens and closes electronic switches within the integrated circuit amplifier (Cudahy & Levitt, as cited in Sandlin, 1994).

There is a limit to the amount of changes and the range of the changes that can be made in analog circuits. Even though programmable hearing aids offer the most adjustability and flexibility in current state-of-the-art hearing aids, they still use analog circuit concepts that have existed for many years. The next major change in digital hearing aid adjustment technology comes with the arrival of practical general purpose Digital Signal Processing circuitry (www.nidcd.nih.gov/health/hearing/hearingaid.asp).

The recommended terminology for hearing aids that use digital circuitry for both signal processing and controlling of functions is a "Digital Signal Processing" (DSP) hearing aid (Conger, 1990).

Altering the values of the capacitors and resistors changes the electro-acoustic characteristics of conventional analog and programmable circuits. The electro-acoustic characteristics of DSP circuits are changed by altering the mathematical algorithms, or series of computer instructions, that control the digital signal processing circuitry. Viewed simplistically, a DSP hearing aid consists of a sub-miniature computer inside the hearing aid case. By using the basic mathematical functions of delay, addition and multiplication, very sophisticated signal processing can be performed (Cudahy & Levitt, as cited in Sandlin, 1994).

Amplitude limiting is one of the features of a digital hearing aid. This can be done by setting a maximum allowable value for the samples contained in the digital representation. According to Sandlin (1994), an alternate method of output limiting is to adjust the amplification constant of the hearing aid in inverse proportion to the short-term energy of the signal, thereby reducing the gain as signal level is increased. The first of these two methods is the digital equivalent of peak clipping (a technique commonly used in older conventional hearing aids): the second method is the digital equivalent of amplitude compression (a technique used regularly in modern conventional hearing aids).

As quoted in Advances in Hearing Instruments Technology, Compression Limiting was first introduced in the late 193O's,but did not become popular until the 1960's. Compression Limiting circuits have high knee points (60dB or more) and high compression ratios, greater than 4:1. Compression Limiting aids amplify sounds in a linear manner (1:1, unity slope) until the input signal reaches the threshold of compression (knee point, TK). Compared to peak clipping hearing aids having similar input-output characteristics, Compression Limiting aids process signals with markedly less distortion at high output levels. Literature suggests that compared to peak clipping aids, compression limiting aids provide improved speech recognition as the output signal approaches saturation. Compression limiting can also be done using certain other circuits, like:

(i) Wide Dynamic Range Compression (WDRC): It was first introduced in early 1970's but became popular only in the late 1980's. It is characterized by low knee points (less that 60dB SPL) and low compression ratios, less than 4:1. Here, compression occurs over a wider range of inputs, where the objective is to compress the wide dynamic range of signals at the input into a more restricted dynamic range at the output.

(ii) Full Dynamic Range Compression (FDRC): This is essentially the same as WDRC, except that the term "full" suggests that the entire dynamic range of speech is in compression (e.g. knee point of 45dB SPL or lower),

(iii) Adaptive Compression: This refers to a compression system that has a variable (or dual) release time that is dependant on the duration of the input signal.

Digital hearing aids consist of two major components: 1) hardware; or the physical hearing aid itself; 2) software; or the instruction set stored inside the hearing aid that tells the hardware how to perform.

(i) Hardware: The following figure illustrates the basic block diagram of a DSP hearing aid. This diagram has no potentiometers or switch adjustments. All the changes in frequency response shaping and other signal conditioning take place inside the DSP block.

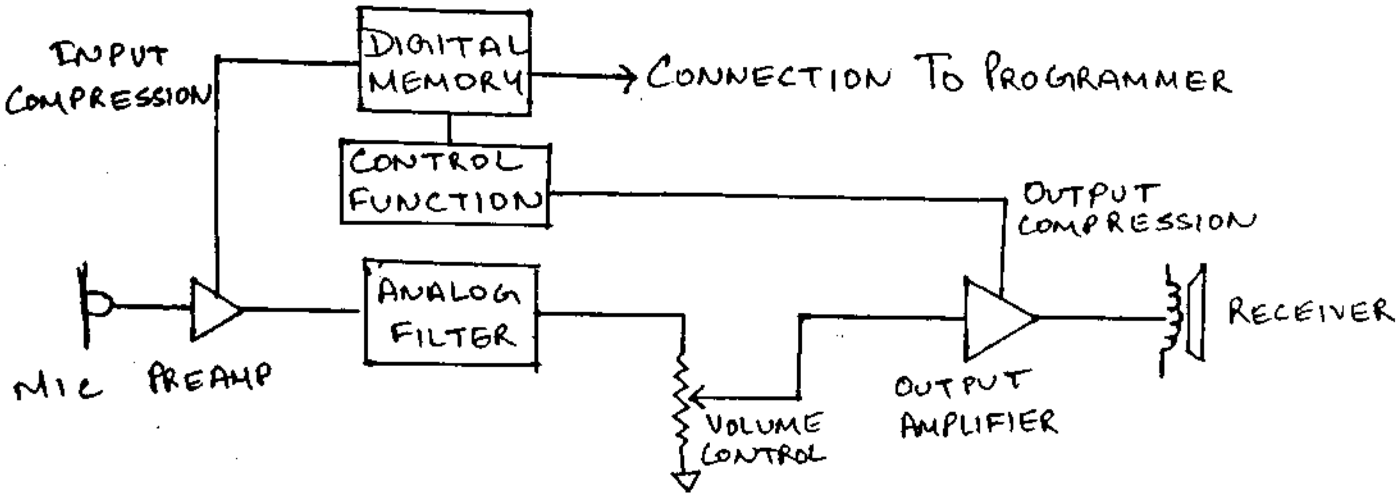

Figure 2.1

To translate the analog signal received by the microphone in a usable form that the DSP can understand, it is necessary to convert the analog from the microphone into a string of binary codes, consisting of 1 's and O's. This is the function of the "Analog-to-Digital" (A/D) converter. When the DSP has performed its mathematical tasks, the signal is converted back to the analog domain by an inverse process called "Digital-to-Analog" (D/A) conversion.

(ii) Software: The major hardware component of a DSP Hearing Aid is the "Digital Processor". This software is a set of instructions stored inside the hearing aid that tells the processor how to process the signal. In some hearing aids, these instructions are loaded into the hearing aid memory from an external "programmer", often based on a Personal Computer (PC). Multiple instruction sets, each one containing processing for a particular environment, may be stored and may be selected by the user (often via a switch or push button), depending on the listening situation (http://www.asha.org/hearing/rehabilitation/digital_about.cfm).

DSP hearing aids can perform precisely the same functions as analog filters or compression circuits. Thus, a DSP hearing aid could be built that is distinguishable to the user from today's analog hearing aids. In this way, the hardware could be built as one universal circuit and then, individually programmed to account for all the fitting variations that are required for different patients. However, the real power of digital signal processing is that by manipulating the calculations inside the DSP processor, variations in the circuit can be made that are not possible in conventional analog hearing aids. These adjustments may include formant enhancement, improved spectral contrast, alteration of consonant-vowel ratios, and manipulation of the time domain. Sophisticated signal processing schemes can be customized for individuals to perform any conceivable processing in either the time, amplitude or frequency domain (Sandlin, 1994).

A lively conversation in a crowded restaurant, a daughter's wedding vows, a grandchild's first word-the most exhilarating, as well as the most intimate moments of our lives occur in company of others.

Digital technology is the newest innovation, allowing for a finer sound discrimination and selectivity than analog hearing aids. Digital is the future, and the future is here now. A digital amplifier takes an analog signal, digitizes it and does wonderful things to it. The result is a better hearing for our patients (Travis, 1999).

David Kirkwood (2001) conducted a survey for the Hearing Journal, of the hearing aid dispensers' report on digital hearing aid use by their customers. Most dispensers in the journal's survey reported greater patient satisfaction with digital hearing aids. Hearing aid dispensers' polled by the Hearing Journal gave their vote of confidence to digital instruments for their effectiveness in increasing patient satisfaction. More than three quarters of them said that their patients were more satisfied with a DSP instrument than "other advanced, non-digital hearing aids".

Patient satisfaction: 78% dispensers' said- in general, patients fitted with digital hearing aids were either "somewhat more satisfied" with DSP i.e.30% of the patients, than with advanced analog products. 3% patients were "somewhat less satisfied", 19% were "equally satisfied" and 0% was " much less satisfied".

Dispensers' were asked to compare patient satisfaction with Digital and Analog hearing aids in specific areas. DSP hearing aids fared well, especially in sound quality. 89% were "more satisfied" with digital hearing aid, 42% were "much more satisfied", 10% said there was little difference between digital and analog hearing aids, and only 1% said they were "less satisfied" with digital hearing aid.

82% patients preferred digital hearing aids for listening comfort and 70% for preventing feedback. When asked to state the advantages of DSP aids, 72% patients reported improved speech quality, and 76% reported flexibility and less distortion.

Schum and Randi (2002) conducted a blind study of hearing aid technology. The three levels of hearing aids used were: an analog programmable aid, a Wide Dynamic range Compression (WDRC) hearing aid, and a second generation Digital Signal Processing (2G-DSP) hearing aid.

Patients performed significantly better with the 2G-DSP aid, compared to linear hearing aid on every dimension studied in the blinded design. This establishes the superiority of the advanced digital design of this product. The 2G-DSP outperformed digital WDRC on several dimensions (i.e. overall performance, easiest to use all day, physical comfort, acoustic feedback, and various measures of speech understanding in noise.

Ringdahl, Magnusson, Edberg, Thelin, and Israelsson (n.d.) did a study in which three hearing aids i.e. digital non-linear, digital linear, and analog hearing aid, were evaluated by severely hearing impaired subjects.

25 severe-to-profound hearing-impaired subjects evaluated performance. Speech recognition was significantly better with either type of digital hearing aid than with analog hearing aid. Subjects' preferred the non-linear hearing aid to the linear aid, when rating sound quality of speech and music. The preference of digital non-linear and linear hearing aids was dependant on presentation level of background noise when rating speech recognition.

Cost of Hearing Aids

A rule of thumb is that hearing aid cost increases with more complex and sophisticated circuitry and small size (Punch, 2001).

Hosford-Dunn and Halpern (n.d.) reported that increased circuit sophistication generally raises cost of hearing aid.

According to Punch (2001), prices of analog /analog programmable aids have remained steady or reduced, but of DSP hearing aids have increased. Relatively high costs of the DSP aids suggest that costs are linked to technological aspects that are most actively under development at a given time in the hearing aid industry.

The advent of digital hearing aids with trimmer controls, more commonly known as "low cost digital hearing aids" due to their lesser cost, in the hearing aid industry is a very recent phenomenon. Until now, the term "Digital Hearing Aid" has brought to one's mind, the image of a highly sophisticated and very costly instrument. But now, these low cost aids also boast of sophisticated technology similar to conventional digital aids, but at much lower costs.

In the west, in a study done in 1993, 44% of non-hearing aid users indicated affordability was "somewhat" or "definitely" a reason for not purchasing a hearing aid. In another study done in 1998, 28% of non-users indicated they could not afford a hearing aid.

In the Indian context too, it is not feasible for most people to buy a conventional (high cost) digital hearing aid, and therefore, with the introduction of new low cost digital aids, more clients are going to be attracted towards them.

Hence, the need of the hour is to study these low cost digital aids, as not many studies have been done regarding the performance of hearing impaired individuals with these low cost digital hearing aids.

CHAPTER III

METHOD

I. Subjects

A total of ten subjects with sensory neural hearing loss were taken up for the study. They were divided into two groups based on their degree of hearing loss:

Group 1: Consisting of 5 subjects with Moderate Sensori Neural Hearing loss

Group 2: Consisting of 5 subjects with Moderately Severe Sensori Neural Hearing loss.

The subjects were in the age range of 49 years to 80 years, with a mean age of 65.2 years. Subjects fulfilling the following criteria were chosen for the study:

a) They had normal intelligence.

b) They were native speakers of Kannada

c) Their Speech Recognition Thresholds correlated with their pure tone thresholds.

d) They had good Speech Identification Scores.

II. Instrumentation/Test material

- A calibrated clinical audiometer, Madsen MA-53, was used for hearing aid testing.
- FONIX 6500-C Hearing Aid Test System was used to find the Real Ear Insertion Gain for each subject with each hearing aid. It was also used to match the gain of the hearing aid to the target gain based on the Prescription Formula, POGO, given by McCandles and Lyregaard, 1983.

- A set of 15 questions, used in the Department of Audiology, All India Institute of Speech and Hearing, for hearing aid evaluation, was used in this study. The questions were divided into 3 sets of 5 questions each, to be used in random, for the three hearing aids. A set of 15-paired words was also used, after dividing it into 3 sets of 5 paired words each. The questions and paired words are given in Appendix I and Appendix II respectively.
- Three digital hearing aids with trimmer controls, (HA1), (HA2), and (HA3) were used for the study.

III. Test environment

Real ear Measurement was done in an acoustically treated room. Hearing aid evaluation was done in a sound treated 2-room situation.

IV. Procedure

A. Real Ear Insertion gain was found using the following method:

1) Subject was seated comfortably and was instructed to remain still. The loudspeaker was placed at a distance of 12" from the subject's ear, at an azimuth of 45°, at ear level. The reference microphone was placed directly above the ear to be tested. Then, leveling of reference microphone was done.
2) After this, the probe-microphone was placed in the ear canal, with the microphone extending 5mm beyond the ear canal opening.
3) Then, the Unaided Response of the subject was found.
4) Then, target was created based on the subject's audiogram.

5) Following this, the hearing aid was placed in position, making sure **that** the probe microphone was not disturbed. The trimmer controls were placed in the "default settings" position.

6) Then, the Aided Response was found. The Insertion Gain Curve was obtained (difference between aided and unaided response). This curve was matched with the target gain curve by adjusting the volume or trimmer controls, as applicable.

B. 1) Next, the subject was made to wear the hearing aid (at the best fit position) and the 3 sets of questions were presented to him/her, at 45dBHL, one set per hearing aid. The subject's score for each hearing aid was obtained, by assigning one point for a correct response, and zero for a wrong response. If repetition of a question was required, that was also noted. Similarly, score was also obtained for Paired Words.

2) The subjects were not informed regarding the cost of the three hearing aids.

3) The results obtained were subjected to statistical analysis.

CHAPTER IV

RESULTS AND DISCUSSION

The results obtained from the study were subjected to statistical analysis. The mean and standard deviation scores were calculated for scores obtained by the subjects in Group 1 and Group 2, with each of the three hearing aids.

The scores obtained show that, for nine of the ten subjects, the best performance was with HA1, with a mean score of 4.9, for both the groups. The performance with HA2 and HA3 did not vary considerably, especially for Group 2, with Group 1 having means of 4.6 for HA2 and 3.4 for HA3, and Group 2 having means of 4.3 for HA2 and 4.4 for HA3. This is to say, the performance of the subjects with HA1 and HA2 was similar. But there was a difference seen regarding which hearing aid (HA2 or HA3) resulted in better performance, between the two groups. In Group 1, HA2 resulted in better performance whereas in Group 2,HA3 resulted in better performance.

This shows that whatever differences may exist between HA2 and HA3, it has not resulted in much significant difference in performance in Group 1 and Group 2, though Group 1 found HA2 better and Group 2 found HA3 better.

This difference may be due to certain internal differences in the two hearing aids due to which they suited one group better than the other, but discussion of these differences is beyond the scope of this study.

Percentage of total scores obtained by subjects of Group 1
with the three hearing aids HA 1, HA2 and H A3

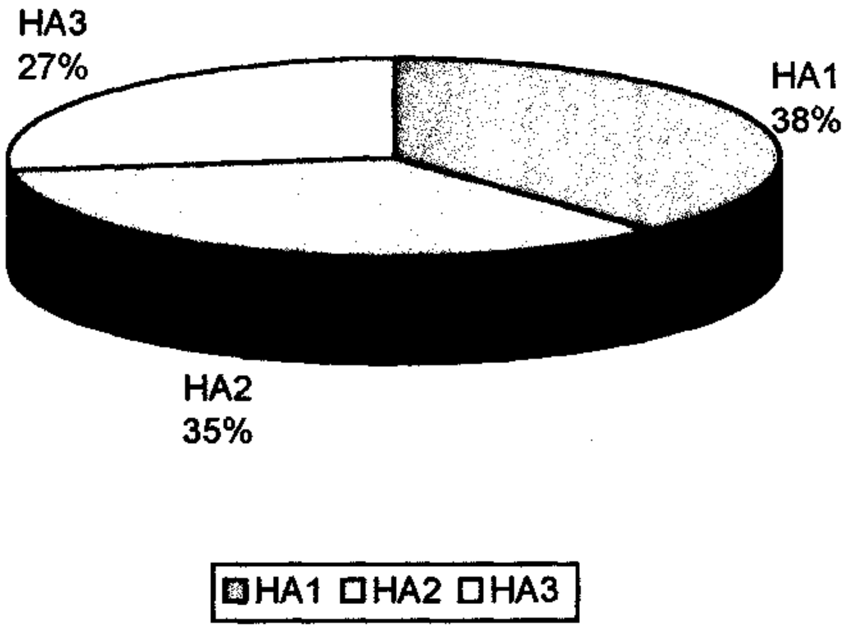

Figure 4.1

As can be seen from Fig 4.1, the maximum scores of the subjects of Group 1 was obtained with HA1, the second most scores were obtained with HA2 and the least scores were obtained with HA3. The mean of scores obtained by HA1 was 4.9, HA2 was 4.6 and HA3 was 3.4

Percentage of total scores obtained by subjects of Group 2 with the three aids HA1, HA2 and HA3

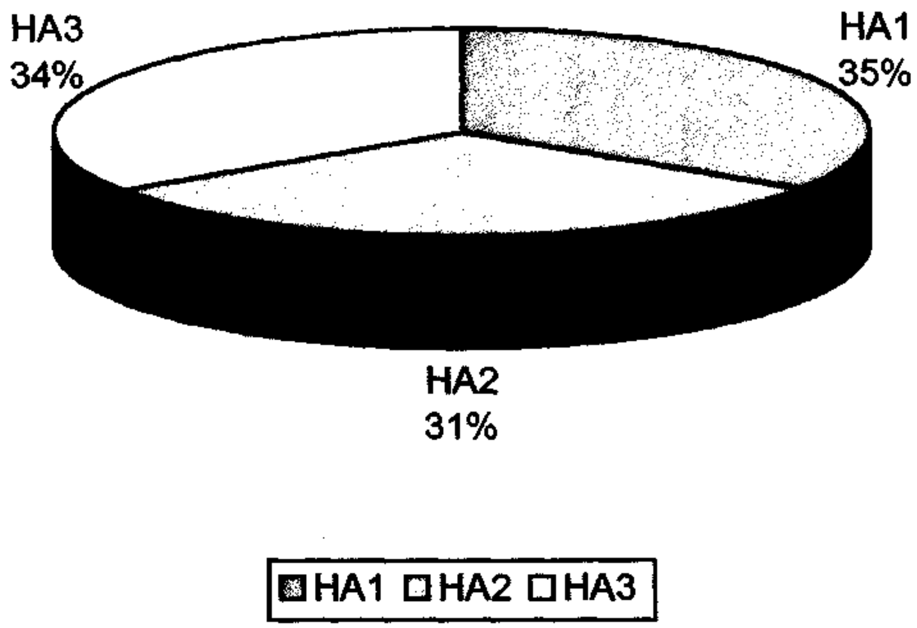

Figure 4.2

As can be seen from Fig 4.2, the maximum scores of subjects of Group 2 was also obtained with HA1. But here, unlike in Group 1, second most scores were obtained with HA3 and least scores were obtained with HA2. The means of scores obtained with HA1 was again 4.9, HA2 was 4. 3, and HA3 was 4.4.

Variation in performance of subjects of Group 1 acorss the three Hearing Aids, HA1, HA2 and HA3

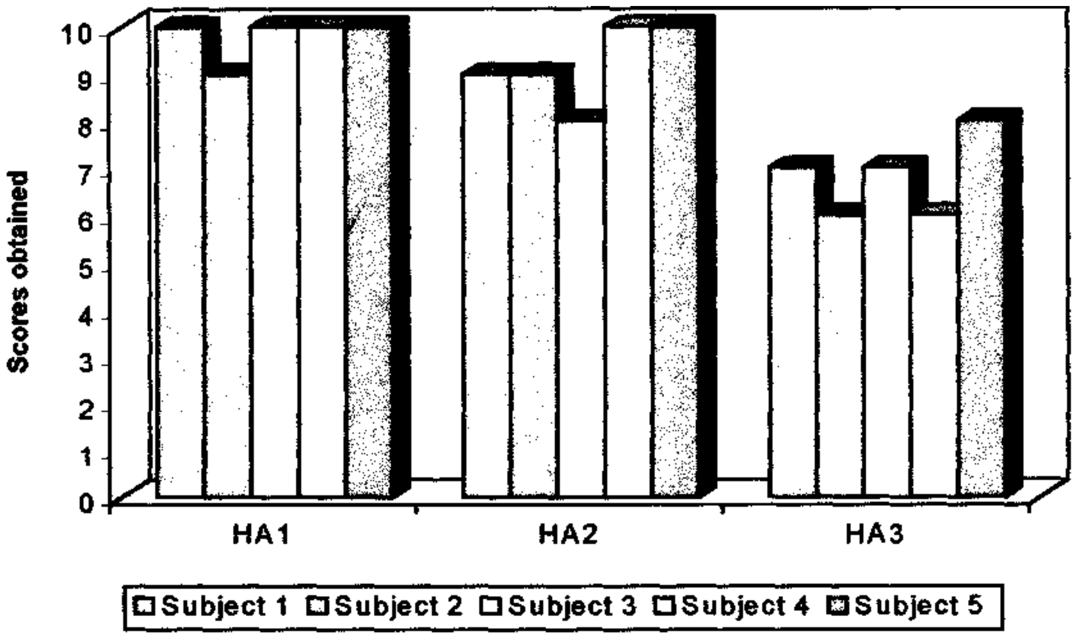

Figure 4.3

Variation in performance of subjects of Group 2 across the three Hearing Aids, HA1, HA2 and HA3

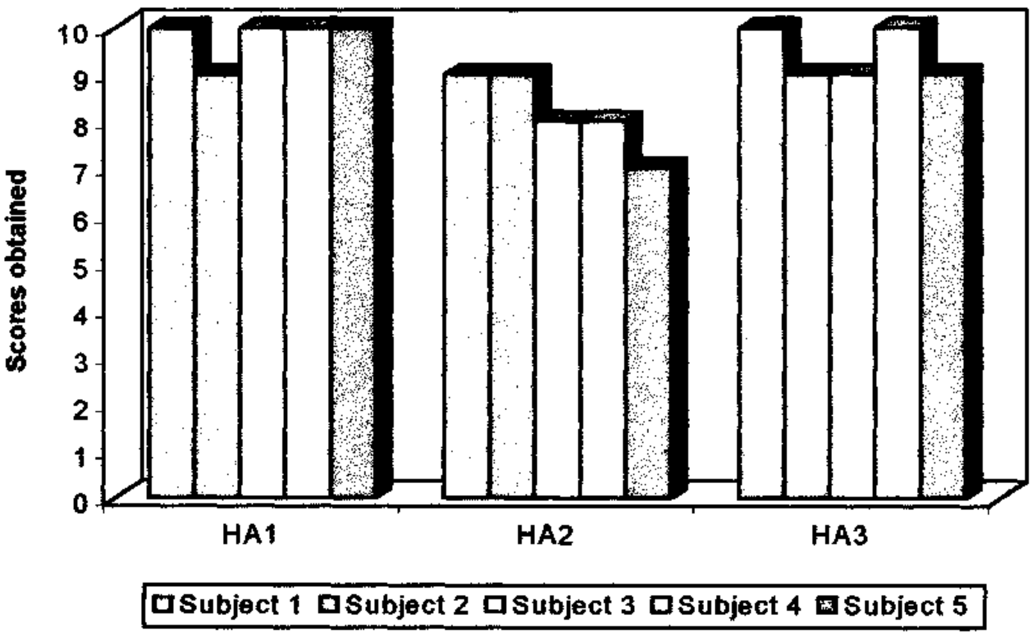

Figure 4.4

Figure 4.3 and 4.4 show the variation in performance scores within the subjects, with the three hearing aid. As can be seen, both in Group 1 and 2, there is not much difference in performance within the subjects. For Group 1, Standard Deviation values for HA1, HA2 and HA3 were 0.30, 0.49 and 0.49 respectively. For Group 2, the Standard Deviation values for HA1, HA2 and HA3 were 0.30, 0.67 and 0.46 respectively.

This selection was compared with the hearing aid ranking by the subject, in order of preference. It was found that the hearing aid ranked as "First" (I) by 9 of the ten subjects was HA1. But there was difference in the hearing aid ranked as "Second" (II) and "Third" (III) between the two groups. Group 1 ranked HA2 as second and HA3 as third whereas Group 2 ranked HA3 as second and HA2 as third. Though the performance of the subjects varied slightly with HA2 and HA3, they showed consistent preference for one of the two hearing aids.

This finding suggests that while doing hearing aid evaluation for adult clients, subject preference is an important factor, and should be considered as an integral aspect in hearing aid selection.

When the hearing aid ranking of the Audiologist was compared with that of the subjects, it was found that both in Group 1 and Group 2, only one subject, in each group, differed in his ranking from that of the Audiologist. This can be seen in the following tables:

Table 4.1

Group 1	HA1	HA2	HA3
Audiologist Subject	I I	II II	III III
Audiologist Subject	II II	I I	III III
Audiologist Subject	I I	II II	III III
Audiologist Subject	I I	II II	III III
Audiologist Subject	I I	II III	III II

Table 4.2

Group2	HA1	HA2	HA3
Audiologist Subject	I I	II II	III III
Audiologist Subject	I II	II I	III III
Audiologist Subject	I I	III III	II II
Audiologist Subject	I I	III III	II II
Audiologist Subject	I I	III III	II II

Hence, it again implies that subject preference should be included in hearing aid evaluation. This can be validated by the study done by Chaiklin and Stassen (1968) and Miller and Niemoeller (1967), and, who reported on individual cases in which subject preference and subject report about particular hearing aid fittings were instrumental in satisfactory hearing aid use. On the other hand, Ross (as cited in Katz, 1972) stresses the lack of experimental evidence about relation between quality preferences of person, and specific electro-acoustic characteristics. But it does not imply that subject preference should not be used.

The subjects were also asked to compare the three hearing aids with regard to how their own voice sounded to them. It was found that this ranking was the same as the overall ranking of the three hearing aids, for all the subjects. This can be thought of as indicating that subject preference for a particular hearing aid does not only depend on how they hear external sounds, but also on how they perceive their own voice. Hearing others' speech/other sounds is not the only factor considered.

The results obtained were also compared with the cost of the hearing aid, to see if there was any relation between the cost of the hearing aid and the performance of the subjects. It was found that the hearing that resulted in the best performance with nine of the ten subjects, i.e., HA1, was the least costly of the three hearing aids used in this study. On the other hand, the hearing aid that was the most costly, i.e., HA3 did not show the best performance as would have been expected, if cost were a factor related to the performance. This shows that cost is not an important factor related to the performance of subjects with that particular hearing aid. Hence, we can say that just because one hearing aid is more costly than another, it does not necessarily mean that that hearing aid will result in better performance of the subjects.

It was also found in this study that, that, for all the subjects, the hearing aid evaluation was carried out with the hearing aid trimmer controls in the "best fit" position as determined from the Real Ear Insertion Gain measurements, where the gain of the hearing aid was matched with the target created based on the audiogram of the subject. No change in the settings had to be made for any of the subjects, while hearing aid evaluation was carried out.

This suggests that REIG is a reliable method to decide on the gain required, and can and should be used as a part of routine hearing aid evaluation procedures. This can be especially useful in cases for the evaluation of digital hearing aids with no volume control, regarding the adjustments of the gain with trimmer controls.

All the testing was done in a blinded format, where the subjects were not told the cost of any hearing aid, so their responses were not obscured by the knowledge of the costs.

As digital hearing aids with trimmer controls is a very new concept in the hearing aid industry, not many studies have been done which can be used to validate the results of this study. There is a long way to go before we can generalize these results to all the Moderate and Moderately Severe sensori neural hearing loss subjects, because there are not many studies to give empirical evidence for this study, and also because the number of subjects used in this study is very small, one cannot directly infer about the generalization of the results to Moderate and Moderately Severe sensori neural hearing loss subjects, just based on the results of this study.

V

CHAPTER V

SUMMARY AND CONCLUSION

A hearing aid is a device that is used for amplification of sounds, for subjects who have a hearing loss that is significant enough to warrant amplification. There are different types of hearing aids. The most simplest and earliest is the Analog Hearing Aid, in which a continuously varying electrical signal produces sound. This type of hearing aid amplifies all sounds (speech and noise) in the same way. The most recent and technologically sophisticated is the Digital Programmable Hearing Aid, which uses "Digitized Sound Processing" to convert sound into digitized signals. These hearing aids are usually self-adjusting.

Within the digital hearing aids, the most recent technological advancement is the introduction of digital hearing aids with trimmer controls. The hearing aids have trimmer controls which can be manipulated with a screwdriver to make certain adjustments in the hearing aid response. But the main feature of these hearing aids is their cost; these hearing aids cost much less than their conventional counter parts. Due to a lack of studies done with these hearing aids, this study was taken up, to help in future prescription of these hearing aids.

In this study, two groups of five subjects each were taken, where one group had Moderate sensori neural hearing loss and other had Moderately Severe sensori neural hearing loss. The performance scores of these subjects was found, across the three hearing aids used in this study. The subjects were also asked to rank the hearing aids in order of preference. This ranking was compared with the audiologist's ranking of the hearing aids for each subject.

It was found in this study that, nine of the ten subjects ranked Hearing Aid 1 (HA1) as first. Group 1 ranked HA2 as second and HA3 as third, whereas Group 2 ranked HA3 as second and HA2 as third. In Groups, the difference between scores obtained with HA2 and HA3 was not significant. In Group 1, slight difference in performance was noted. Within each group too, the variation in performance among the subjects was also very minimal. This shows that though all the ten subjects fell within the fitting range of all the three hearing aids, their performance with the 3 hearing aids was not same. In the hearing aid ranking, it was found that except for one subject each in the 2 groups, all the subjects' ranking was the same as the audiologist's ranking implying that subject preference is an important factor in hearing aid selection. Also, the fact that the least costly hearing aid did not result in the poorest performance and the most costly hearing aid did not result in the best performance of the subjects, implies that cost of the hearing aid is not directly related to performance with that hearing aid.

Hence, it can be concluded that comparative hearing aid evaluation should be done to select an appropriate amplification device for a client. Also, subject preference and probe-microphone measurements should be included in the evaluation procedure. It can also be inferred from this study that cost of hearing aid is not related to its performance. But further research in detail has to be done in this field to be able to generalize these results to the whole population of Moderate and Moderately Severe sensori neural hearing loss patients.

Scope for further research

1. This study was done on a very small population. Hence, the results of this study cannot be directly generalized to the whole population of Moderate and Moderately Severe sensori neural hearing loss patients. Hence, further studies need to be done on larger groups of subjects, to be able to generalize the results obtained.
2. Further studies can also be done, by taking different specific configurations of hearing loss, within the Moderate and Moderately Sever subjects, e.g. flat hearing loss, downward sloping hearing loss, upward sloping hearing loss, etc.

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APPENDIX I

Questions used to find the Performance Scores of the subjects with the three Hearing Aids.

Set I

1. ನಿಮ್ಮ ಹೆಸರು ಏನು ?
2. ನಿಮ್ಮ ವಯಸ್ಸು ಎಷ್ಟು ?
3. ನಿಮ್ಮ ಮನೆಯಲ್ಲಿ ಯಾರು ಯಾರು ಇದ್ದಾರೆ ?
4. ನೀವು ಬೆಳಿಗ್ಗೆ ಏನು ತಿಂಡಿ ತಿಂದಿರಿ ?
5. ನೀವು ಟೀ ಕುಡಿದಿರೋ ಅಥವಾ ಕಾಫಿ ಕುಡಿದಿರೋ ?

6. ನೀವು ಏನು ಕೆಲಸ ಮಾಡುತ್ತಿದ್ದೀರ ?
7. ನಿಮ್ಮ ಮನೆಯಲ್ಲಿ ಎಷ್ಟು ಜನ ಇರುವರು ?
8. ನಿಮಗೆ ಎಷ್ಟು ಜನ ಮಕ್ಕಳು ?
9. ನೀವು ಬೆಳಿಗ್ಗೆ ಎಷ್ಟು ಗಂಟೆಗೆ ಏಳುವಿರಿ ?
10. ಇವತ್ತು ಯಾವ ವಾರ ?

11. ನಿಮ್ಮ ಯಜಮಾನರು / ಹೆಂಡತಿಯ ಹೆಸರು ಏನು ?
12. ನಿಮ್ಮ ಮಕ್ಕಳು ಏನು ಮಾಡುತ್ತಿದ್ದಾರೆ ?
13. ನೀವು ಇಲ್ಲಿಗೆ ಹೇಗೆ ಬಂದಿರಿ ?
14. ನಿಮ್ಮ ಊರು ಯಾವುದು ?
15. ನೀವು ಇಲ್ಲಿಗೆ ಯಾಕೆ ಬಂದಿರಿ ?

APPENDIX II

Paired Words used to find the Performance Scores of the subjects with the three Hearing Aids.

Set 1	ಮರ	-	ಗಿಡ
	ಕಲ್ಲು	-	ಮಣ್ಣು
	ತಾಯಿ	-	ತಂದೆ
	ಗಂಟು	-	ಮೂಟೆ
	ಅಂದ	-	ಚಂದ

Set 2	ಅತ್ತ	-	ಇತ್ತ
	ಮನೆ	-	ಮಠ
	ಹೊಲ	-	ಗದ್ದೆ
	ಬೆಟ್ಟ	-	ಗುಡ್ಡ
	ನಡೆ	-	ನುಡಿ

Set 3	ಈಗ	-	ಆಗ
	ನಮ್ಮ	-	ನಿಮ್ಮ
	ಆಸ್ತಿ	-	ಪಾಸ್ತಿ
	ಕಷ್ಟ	-	ಸುಖ
	ಗುರು	-	ಶಿಷ್ಯ

APPENDIX III

The three Hearing Aids used in this study were :

HA1 - Siemens 203

HA2 - Elkon Easy

HA3 - Hansaton Starlite