EFFECTS OF DAMPERS ON SPEECH PERCEPTION IN BEHIND-THE-EAR HEARING AID USERS

RegisterNo. M9913

An Independent Project Submitted as part fulfillment
for the First year M.Sc. (Speech & Hearing) to University of Mysore.

ALL INDIA INSTITUTE OF SPEECH AND HEARING,MYSORE 570006
MAY - 2000

Certificate

This is to certify that the independent project entitled "Effects

Hearing Aid Users" is the bonafide work done in part fulfillment for tbe degree of faster of Science (Speech and Hearing) of the student with Register No. M9913.

Director

Mysore

May:2000

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Certificate

This is to certify that the independent Project entitled "Effects of Dampers on Speech Perception in Behind The Ear Hearing Aid Usrers " has been prepared under my supervision and guidance.

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Declaration

9 *hereby declare that this independent Project entitled "Effects of Dampers on Speech Perception in Behind The Ear Hearing Aid Users" is the result of my own study under the guidance of Dr. K. Rajalakshmi , Lecturer, department of Audiology,All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier at any other University for any other diploma or degree.*

Register No. M*9913*

Mysore

May 2000

DEDICATION

Dedicated to
my Parents,
Beuls & Ajith

with all my love and
gratitude

ACKNOWLEDGEMENT

I extend my deepest gratitude to Dr. K. Rajalakshmi, lecturer in Audiology. All India Institute of Speech and Hearing, Mysore. For constrantly guiding me through out this project.

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"Dear Beula, Ajith, Vinay, Harneesh, Komal, Kaveri, Lerumal, Prachi, Suresha, Jaya, Purnima, Lakshmi, Vinay Chandu and all my other friends"

Thanks a lot for your ideas, suggestions, inspiriration and encouragement during the course of this whole project.

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To,

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Introduction

Acoustics is defined as the science of sound. This science of sound captures our attention when communication is involved. Sound transmission has an important role to play in communication. This is extremely so in the rehabilitation of the hearing impaired with respect to the use of hearing aids.

Technological advancement in the field of amplification systems has seen drastic improvements in frequency responses and sound quality of hearing aids over recent years and further improvement can still be made by modifying the sound channel from the hearing aid to the tympanic membrane. For the researcher and dispenser as reported by Gerling (1981) (cited in Balakrishna, 1992), the new earmold technology has some basic philosophical considerations. They are,

a) To preserve the normal, eardrum- free field transfer.
b) To preserve the balance between the high-and low frequencies acoustically in a normal speech spectrum.
c) To extend the high frequencies in the wearable hearing aids.
d) To minimize the standard peak in hearing aid responses at 1000-1500 Hz for many mild to moderate losses.
e) To gradually slant upwards the frequency responses of a hearing aid.
f) To keep the output of an aid with in the client's dynamic range.

These are accomplished by adjusting the frequency response of the hearing aid with special attention to the earmold and assisted plumbing. Individual adjustment to low-, mid- and high frequencies with the use of venting, damping and horn effects can respectively be accomplished.

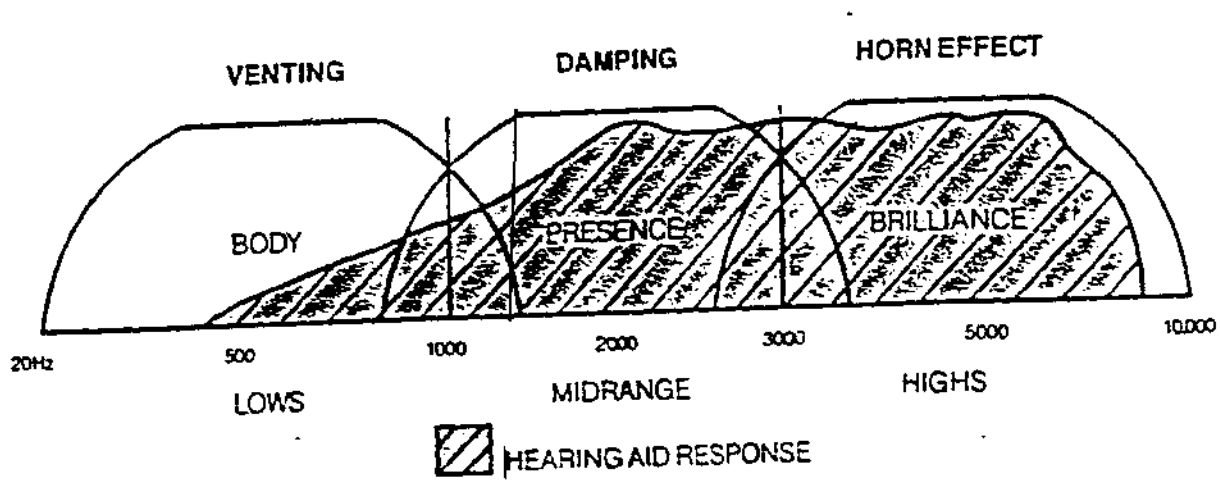

Fig 1.1 : Earmold acoustics - control areas.

Libby (1981) indicated in the above figure that venting is the primary control below 1000 Hz; damper's region of control is approximately 1000 Hz to 3000 Hz, the horn effect is the dominant control factor above 3000 Hz.

Damping

Tubing resonance and Helmholtz resonance (produced by the acoustic compliance of the air cavity in front of the hearing aid receiver) causes sharp peak around 1000 Hz in the output of the behind-the-ear (BTE) hearing aids as measured in 2cc couplers and 2000 Hz or higher for in-the-ear (ITE) hearing aids (skinner, 1988, as cited in Balakrishna, 1992).

These can be exited by sharp transient sounds, causing a ringing or echoing sound. Various acoustic resistances or damping elements have been used to smoothening the frequency response of the hearing aid-earmold system and to control gain and saturation output.

The effect of acoustic dampers on hearing aid responses is determined by;

1) The location of damper in the acoustic transmission system,
2) The number of dampers used, and
3) The value of the acoustic resistance, higher value causing more flattening of peaks

- (Lybarger, 1985).

Cox (1979) has given detailed explanations of the resonant characteristics of a tube which is closed at one end (receiver) and open at the other end (end of the earmold bore). This helps us to understand better how the exact placement of the resistor in the ear molds tubing affects the frequency response and SSPL.90 curves.

The resonant frequencies of a tube open at one end can be given by the equation

$$F=(2k-l)V/4L$$

Where, V= velocity of sound,

L= the effective length of the ear hook pathway, and

k = The mode of resonance.

If, for example, the ear hook-tutting effective length is about 75 mm, then the first three modes of resonances are :

$$F_{k}=1 \ 1100 \text{ Hz}$$

$$F_{k=2} \ 3300\text{Hz}$$

$$F_{k} =_{3} 5500 \text{ Hz}$$

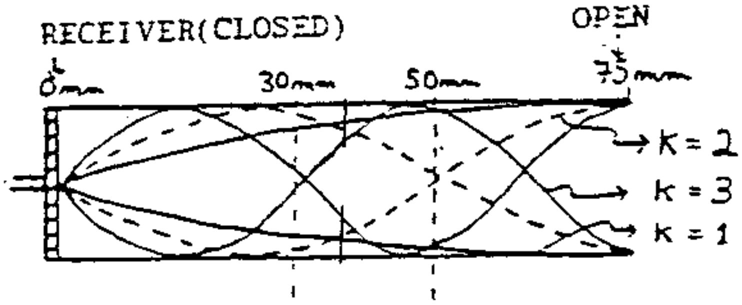

Fig 1.2 : Exhibiting the standing wave patterns of the first three modes of resonance for a 75 mm tube which is closed at one end and open at the other.

The volume velocity of a sound is maximum at a point where there is an antinode and minimum where there is a node. From this we would anticipate that an acoustic resistance element placed at an antinode for particular resonance mode would cause the maximum possible damping for that resonant peak, where as the same element placed at a node would be relatively ineffective in damping the resonant peak.

In the above figure I.2, the ear hook nub is approximately 30mm from the closest end (receiver). Placement of an acoustic resistor in the ear hook, will have a larger effect on damping 1100 Hz (the k=l curve) and 3300 Hz (the k=2 curve). If acoustic resistance were inserted further down the tubing, approximately 25 to 30 mm from the end of the ear mold bore. The 1100 Hz resonance would slightly more damped than if at the ear hook. The 5500 Hz resonance would be maximally damped, and the 3300 Hz resonance would be left intact i.e, minimum damping] The figure.1.3 given below shows the effect of damper placement on the frequency response of the hearing aid in the mid-frequency range.

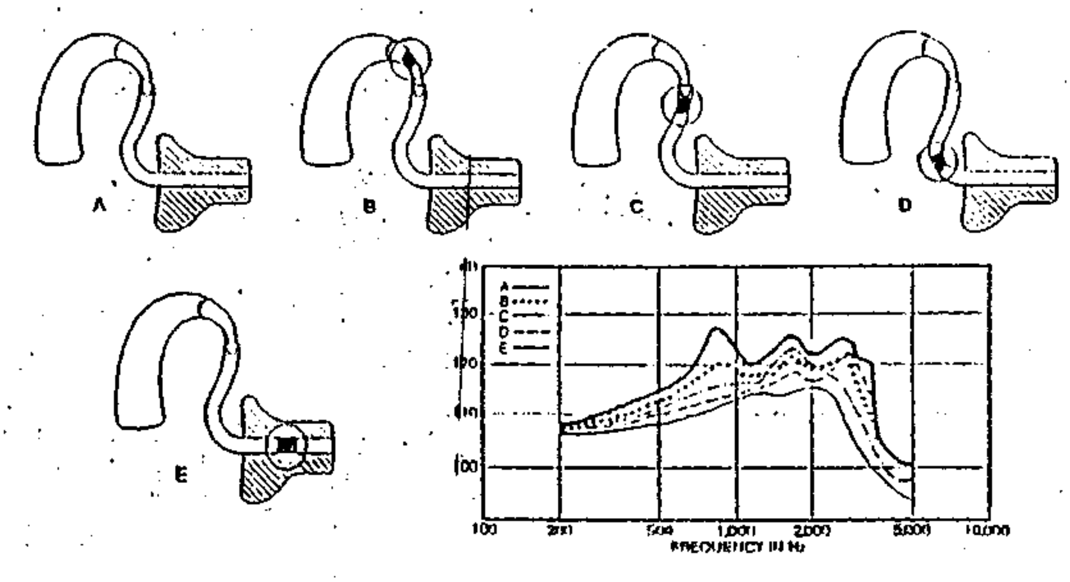

Fig L3 : An example of effect of damper location on hearing aid frequency response.

Killon (1981) said that the problem encountered in attempting to damp the peaks introduced in to the frequency response by tubing resonance is that no one location may be adequate to damp all peaks completely. Such a lack of damper effectiveness occurs whdn the damper is located at a velocity minimum in the standing wave corresponding to me resonance peak. One solution to this problem is to use two dampers spaced so that one or the other will be effective at each frequency of interest. Mother solution is to use single damper, located at a best compromising position in the tubing, and simply accept a somewhat less smooth frequency response curve.

Killion (1981), Cox (1979), L Chasin (1983) reported that a single damper placed at the tip of the ear mold would reduce the peaks at all frequencies, but such a location is generally ruled out since cerumen and moisture may accumulate in the damper resulting in a radical change in its properties, or complete blockage of sound input tube.

As is well known the higher the value of damping resistance, the greater the reduction in sound transmitted down the damped tube. However, the proper choice of resistance will reduce the undesired resonance peaks near 1000 Hz effectively without appreciably reducing the output at other frequencies as shown by the top two curves in figure.1.4. Further increase in resistance tends to reduce output at all frequencies, as illustrated in the lower curves in figure.1..4.

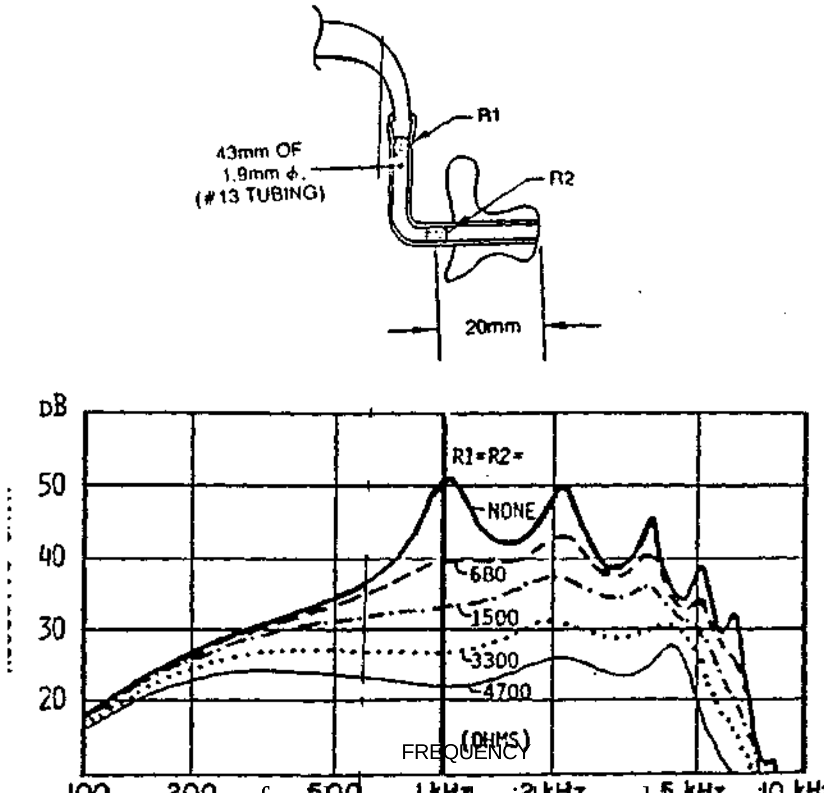

Fig 1.4 : Frequency response of wide band aid with earmold damping as shown, measured with a 2 cm^3 coupler (HA-1 Configuration).

7 **Damping Materials**

1) Lamb's wool: This is one the earliest damping materials. It is usually Placed in the ear hook or tubing and is typically used on a trial and error basis. It is an effective and inexpensive method of damping, but the effect can be very unpredictable. Greater the density of packing, greater is the damping effect on the frequency response of the hearing aid.

2) Sintered steel pellets: These are small cylinders of stainless steel, welded together in such a manner that their specified resistance in acoustic ohms offers specific amounts of attention. Goldstein (1980) used sintered filters, which are available in different colors and provide progressively greater degree of attenuation at 1000 Hz (orange = 3dB, green = 6dB, brown = 9dB, yellow = 12dB, grey = 15dB, and red = 18dB). The greatest attenuation occurs at 500 Hz to 1000 Hz and as the sintered filter is placed further down the transmission line, it provides greater attenuation.

3) Star damper: This is a flexible material that is usually placed in the ear hook and does not permit moisture build up because its design allows drainage of moisture. This damper provides some gain at 2700 Hz to compensate for the loss of ear canal resonance. This damper must be cut to different lengths and subjected 10 electro-acoustic measures to assure that the desired effect has been achieved.

4) **Fused mesh dampers** : Knowles electronics introduced fused mesh dampers to reduce the gain and output to acceptable levels and smoothen the frequency response. (Gastmeier l981, Killion, 1982, 1988, as cited in Valent, et al., 1996). The fused mesh damper is a finely woven plastic screen held in place by a stainless steel screen and enclosed in a 2.5mm long and 0.2 mm wide metal ferrule. The fused mesh damper provides a pure acoustic resistance and negligible reactance and therefore, does not attenuate the high frequency region of the frequency response. This was one of the problems with previous materials used for damping. They were originally designed to fit snugly inside a #13 tubing which has an internal diameter of 1.95mm.

These dampers are available in six discrete resistances of 680, 1000, 1500, 2200, 3300, and 4700 ohms, which are color coded as white, brown, green, red, orange, and yellow respectively. Briskey (1982) reported that 680, 1500, 2200, 3300, and 4700 ohms dampers reduces average full-on gain and SSPL 90 by 3, 4, 5, 6, and 9dB respectively.

Effect Of **Damping**

Usually, dampers are employed in a hearing aid-earcanal coupling system with the intention of reducing the sharp resonant peaks in frequency response to achieve a smooth and gently rising frequency response (Cox 1979, Chasin, 1983).

• Killion (1981) suggested two distinct uses of acoustic dampers

a) Reduction of sharp response)eaks, especially the generally undesirable peak near 1000 Hz, and

b) Attenuation of the hearing ails output. In both cases the gain and the maximum output are equally affected, and the result is usually a relative increase in the high frequency response.

- Killion (1988) (cited in Valent et. al., 1996) reported using two fused mesh dampers (one at the tip of the ear hook and another at the threaded end) to reduce the gain and output by approximately 15dB and provide a smoother frequency response.

- Libby (1979), Teder (1979) ind Chasin (1983) reported mat damping the peaks in the frequency response and SSPL 90 curve will allow the audiologists to increase the "Head room" (i.e., output) of aid and expand the range of linear amplification

- Gastmeier (1981) has demonstrated that if damper is used (about 1500), the resultant gain characteristics of a typical hearing aid provide a flat insertion gain. That is mere is enough gain to just over come the losses due to insertion of an occluding ea rmold.

- Killion (1981) reported that pne commonly overlooked effect off damping is a reduction in the tendency towards feedback in high gain hearing aids. Since whistling due to acoustic feedback normally occurs at the frequency of a response peak, the use of earmold damping can often increase the usable broadband gain.

- Cox and Gillmore (1986) suggested that a smoothed hearing aid frequency response result in better speech intelligibility and or reproduction quality than an unsmoothed response.

REVIEW C F LITERATURE

Hearing aid fitting is an art as well as science.

Libby (1981) suggests that the goal of a hearing aid fitting should be to enable listeners to achieve maximum speech intelligibility and "natural" sound quality, so that they are not aware of wearing the aid until it is removed.

There are several efforts to develop effective strategies, among which the real ear measurements and articulation index (AI) have been the relatively new comers to the field of hearing aid fitting.

Real ear measures provide a rapid and accurate means of verifying the effect of hearing aid or earmold modification. As modifications are made, sequential insertion gain measures can be made in order to determine whether the desired goal has been reached. There is no question regarding the performance stability and repeatability that can be achieved in a hard wall coupler or ear simulator. It should not come as a surprise, however, to find that these systematic changes arc not easily replicated in the human ear canal (Austin, Kasten, and Wilson, 1990 ; Tecca, 1995).

Changes in frequency response of hearing aids can now be evaluated not only through functional and insertion gain measurements, but also by changes that are reflected in the AI (Zelnick, 1991). The AI was originally designed as a means of predicting speech intelligibility in quiet and noise for listeners with normal hearing. However, Pavlovic, Studebaker, and Sherbecoe (1986) computed AI for sensorineural heaing impaired people and concluded that, although exact speech discrimination scores can not be elicited from the AI, for most clients an improvement in the AI will reflect improvement in speech intelligibility.

At one time, calculation of AI was considered to be too complicated and confusing to be employed routinely n every day clinical practice. In recent years simplified version of AI have)een introduced by Mueller and Killion (1990), Pavlovic (1991), and Humes (1991) (cited in Kuk, 1996) which easily can be used to predict both aided and unaided speech understanding. All three of this method employs a series of dots placed on a conventional audiogram, which represent the average speech spectrum. The density of dots is related to importance of that particular frequency for understanding speech.

The important function for nor sense syllables is used in the method of Mueller and Killion (1990), while the important function for average "everyday'* speech is used in the Pavlovic (1991) procedure.

However, in the past 2 CC couplers have been used to study the hearing aid system responses on speech perception. The potential problem in the hearing aid response seems to be the tubing resonance peaks.

It has been suggested that a smoothed hearing aid frequency o/p results in better speech intelligibility and/or quality than unsmoothed response (Killion 1982; Dilion,1983? as cited in Cox and Gilmore,1986). This suggestion is used primarily on the notion that prominent peak typically found at 1000 Hz in undamped systems may result in :

a) Upward spread of masking effects,

b) Emphasis of low frequency distortion on products, and

c) Generation of high frequency dis tortion products,

especially in an extended bandwidth instrument or when the hearing aid is exposed to high level inputs (Libby, 1979; Gastmeier, 1981). Suppression of this peak by damping should reduce these effects and improve the over all fidelity of the system.

Several investigations may be cited in support of this hypothesis.

Jerger and Thelin (1968) (cited in Bornstein, et al., 1983) examined 21 hearing aid frequency responses and devised a measure representing the smoothness of frequency response which they termed Index of Response Irregularity (IRI). Synthetic sentences were processed through these frequency responses and played back through earphones to normal hearing persons and persons with impaired hearing. Two important results should be noted. First, as the frequency response become more irregular, synthetic sentence identification (SSI) decreases for mrmal hearing listeners. The effect of this electro- acoustic parameter on speech intelligibility was greater than any of the other electro-acoustic variables inve stigated. Second, the relationship between IRI and SSI decreased as hearing loss increased. Although this investigation contributed to present knowledge, it is limited in applicability to hearing aid fitting due to the playback of speech through earphones without compensation to provide an etymotic response, other uncontrolled electro- acoustic differences between hearing aids and the limited high frequency range of hearing aids in 1968.

Smaldino (1979) (as cited in Bornstein, et al., 1983) found that a significant decrease in speech intelligibility occurred as response irregularity increased for 220 normal hearing persons using Kent state university speech Discrimination test.

Bornstein, Randolph, Maxon and Giolas (1981) administered two measures of speech intelligibility, the nonsense syllable test (NST) and the Triword test of intelligibility (TTI) to 18 normal hearing listeners at a signal to noise ratio of +5dB. The competing signals were cafeteria noise and a 12-speaker babble for the NST and TTI. respectively. Both speech and competing stimuli were processed through two frequency responses; a smooth frequency response and irregular frequency response with a high frequency range through 5625 Hz and then recorded on a magnetic tape. The irregular frequency response consisted of four peaked located at 1000, 2000, 3150 and 5000 Hz. All peaks were uniformly one-third octave wide and l0dB in amplitude. The processed speech and competing signals were presented to listeners in sound field at 0-degree azimuth. Their results revealed that for both tests the speech intelligibility scores were *5%* better for the smooth frequency response.

Dillon and Macrae (1984) (cited in Cox and Gilmore, 1986) described three studies of the effect of response irregularity on the quality of continuous discourses, employing 5 to 7 normal hearers and 3 hearing subjects. They reported that a 6 dB 1/3 octave wide peak at 1000 Hz produced a very slight drop in speech quality where as a : 2 dB peak resulted in a strongly negative response. However, peaks and valleys of 6 to 12 dB at 2000 Hz resulted in very small speech quality degradation.

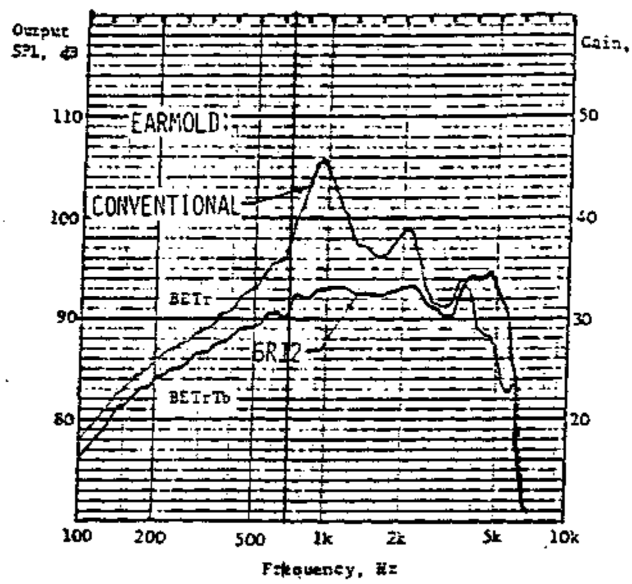

Fig Re.1 : Comprehensive frequency response of each experimental aid measured using 2 cm^3 acoustic coupler (60 dB input, maximum gain setting) (from Lawton & Cafarelli 1978, as cite d in Killion, 1981).

Lawton & Cafarelli (1978) (cited in Killion, 1981) compared speech discrimination and sound quality judgement obtained from a group of 28 hearing-impaired subjects listening to speech. Through hearing aids coupled through convention earmold (# 13 tubing to the tip of the earmold and no damping) and 6R12 earmold (produce a 10 - 15 dB reduction in the height of the typical response peak near 1000 Hz and about 5 dB increase in output in the 4000-6000 Hz region). Not only did the average speech discrimination score improve slightly with the use of a 6R12 earmold, but also 24 of their 28 subjects preferred the sound quality with the 6R12 earmold.

Regarding clinical experience, Libby (1981) found that 70% of a clinical caseload preferred a hearing aid with a damped 8CR earmold and 20% could not tell the difference. The 8CR earmold reportedly provide a smooth, wideband response through 8000 Hz. Killion (1981) reported a better sound quality judgement is often obtained with 8CR earmold. This comes about because the 8CR-earmold produces a peak in the hearing aid output at 2700 Hz. This enhancement relative to performance achieved with a conventional earmold is intended to compensate for the loss of the "typical" ear canal resonance caused by the insertion of the earmold. As mentioned earlier, research has suggested that improve 1 speech intelligibility, greater clarity of speech, and increased users satisfactic n will result when using dampers.

However, Decker (1975) reported no significant differences in word recognition scores (W-22) for 10 subjects who listened to the monosyllabic words using broadband and high-freqiency emphasis hearing aids with and without the insertion of sintered filters.

Cox and Gilmore (1986) reported that damping could improve speech intelligibility and / or sound quality by reducing the effect of the upward spread of masking. Suppression of the peaks by damping should reduce these effects and improve the overall fidelity of amplification. They utilized 10 subjects with sensorineural hearing loss, who evaluated 1-1/2 minutes of male connected discourse embedded in multi talker babble presented at 55 and 70 dB Leq using a paired comparison paradigm. In general, they reported that damping the frequency response did not provide improved clarity of speech or a more advantageous preferred listening level. However, they reported that reducing resonant peaks by damping could be useful in reducing feedback.

The conventional 2 CC couple measurements when used for fitting have yielded somewhat unsatisfactory responses form the hearing aid users, because of individual anatomical variation; in the human ear canal. Hence these measurements may be inappropriate for evaluating the effect of undesirable responses of a hearing aid system (such as the tubing and the earmold) or the effect of response smoothening.

There is a dearth of literature regarding the usage of real ear measurements or articulation index procedures to study the effects of response smoothening on speech perception.

The aims of the present study were to

1. Evaluate the effectiveness of dampers using paired comparison method in different listening conditions.

2. Evaluate the effectiveness of dampers using articulation index.

METHODOLOGY

This study was undertaken to evaluate the effect of dampers on speech clarity and intelligibility in behind-the- car (BTE) hearing aid users.

Subjects

Twenty individuals with acquired bilateral sensorineural hearing impairment served as subjects. Ages ranged from 18 to 86 years, with a mean of 48.7 years. Hearing losses ranged from mild to sever with a mean three - frequency (500 Hz, 1000 Hz and 2000 Hz) pure tone average of 59 dB HL in the test ear. The test ear was the ear in which the hearing aid was being used by the patient. All the subjects were users of BTE hearing aids prescribed after detailed evaluation in All India Institute of Speech and Hearing.

The test ear was randomly selected. Eight right and twelve left eais were used. All subjects were native speaker; of Kannada who also knew to read and write Kannada.

Test Stimulus

The test stimulus consisted of a continuous discourse Kannada passage (see appendix), recorded in a sound treated room, using a professional recorder (Sony TCFX - 170) with an external microphone (Legend HD 800) kept at a distance of 10 cm from the mouth of the speaker. A female native talker of Kannada, whose speech contained no distinctive regional characteristics, spoke the stimulus. The completing stimulus was speech noise.

The continuous discourse was presented in 3 different conditions at normal conversation level (70 dB SPL)

1) In quiet.

2) In the presence of noise (SNR = 0 dB).

3) In the presence of noise (SNR = +7 dB).

Instrumentation

- The subjects personal hearing aids or their commercially available substitute hearing aid withou: altering any output functions (i.e. at linear mode) were used.

- Custom made skeleton earmolds were used to couple the hearing aid to the users ear.

- Knowles electronics fused mesh dampers were used for smoothing the hearing aid frequency response. The acoustic resistance and screen color codes of the dampers used were as follows;

Acoustic Resistance	Screen Color Code
680 Ohms	White
1000 Ohms	Brown
1500 Ohms	Green
2200 Ohms	Red

- Frye electronics calibrated Fonix 6500 - C, real ear analyzer was used for the selection of dampers (ANSI, 1987)

- Madson electronic calibrated clinical audiometer 0B822, along with TDH - 39 ear phones housed in MX - 41 / AR ear cushions were used for threshold estimation (ANSI, 1989).
- The instrumentation involved in presentation of speech stimuli is shown in the block diagram given below.

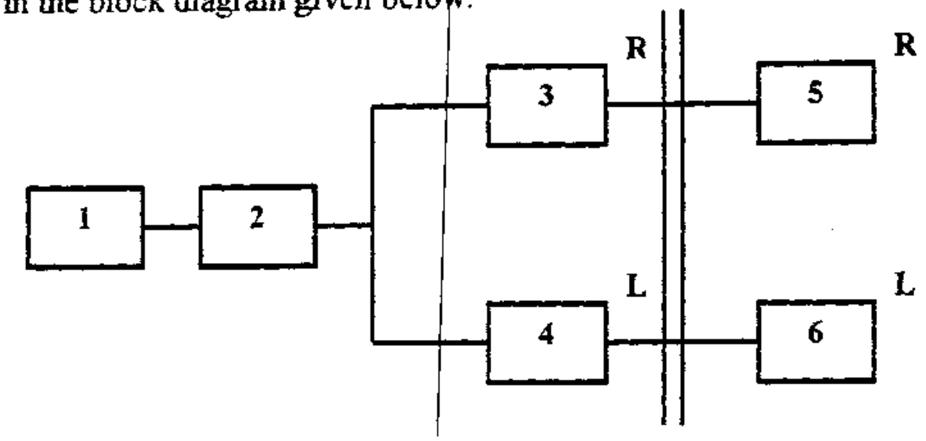

Fig M.I: Block diagram of instrumentation used for speech stimulus presentation.

1 = Two channel cassette deck (Philips, AW 606)

2 = Madson electronic two channel clinical audiometer (OB 822)

3& 4 = Madson electronics amplifiers (PA 5010)

5 & 6 = Madson electronics loud speakers.

R = Right.

L = Left.

Test environment

Real ear measurement was carried out in a quiet room, whereas subjective performance was evaluated in a sound treated double room. The ambient noise was measured and it conformed to meet the recommendation by ANSL 1991.

Procedure

1. Threshold Estimation

Subjects audiometric air-conduction thresholds at octave and mid octave frequencies from 250 Hz to 8000 Hz were measure using modified Hugdson-Westlake procedure (Carhart and Jerger.1959).

2. Selection of Dampers

Dampers were selected based on probe microphone measurements using a prescriptive formula "Prescription of Gain and Output" (POGO).

The measurements of insertion gain and frequency response were as follows;

a. Feeding the pure tone air conduction thresholds of the subject in the insertion gain optimizer created he target gain curve.

b. The subject was seated comfortably and his / her head was positioned at 45° angle from the loud speaker at a distance of twelve to eighteen inches.

The reference microphone was placed directly above the test ear with the help of a Velcro headband around the subject's head. The probe microphone was attached to the Velcro button on the ear hanger. The tube of the probe microphone was measured and marked at 3 — 4 mm past the canal opening of the earmold. The probe tube was then inserted (with out the earmold or aid) in to the ear canal so that the marked point is at tragal notch. In this condition using speech - weighted, noise at 60-70 dB SPL unaided measurement was done. The curve obtained is called Real Ear Unaided Response (REUR).

c. The BTE hearing aid without dampers was attached to the earmold. The earmold was then placed in the subject's test ear without altering the position of probe tube. In this condition, aided measurement without dampers was done. The curve obtained is called the Real Ear Aided Response (REAR).

d. The difference between the REAR and REUR curves gives the undamped Real Ear Insertion Gain (REIG). The instrument do this automatically and plots an undamped REIG curve on the same graph containing POGO target gain curve. The gain at each frequency was also noted.

e. The measured undamped REIG curve was compared with the target gain curve at mid- frequencies. If the subject's measured undamped REIG values are more than target gain values in the mid frequencies then the dampers of same acoustic resistances were placed one at the tip of earhook and another at the canal entrance of the earmold by trial and error to smoothen the frequency response of hearing aid. the aided measurement was repeated as that mentioned in step c and d to obtain damped REIG. This process was repeated with different dampers until the damped REIG curve matches approximately with the POGO target gain curve in the mid- frequencies. The dampers selected in this manner were used for further subjective evaluation. The procedure is exemplified in the following figures.

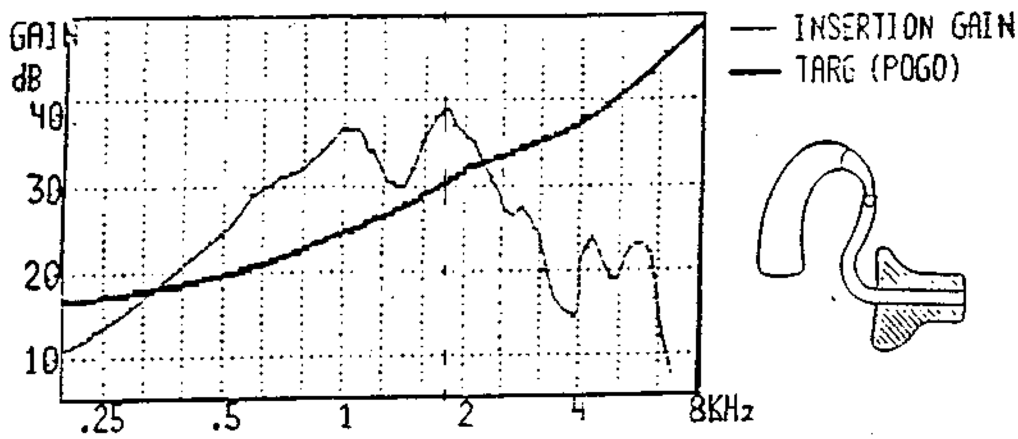

Fig M.2. : REIR without dampers

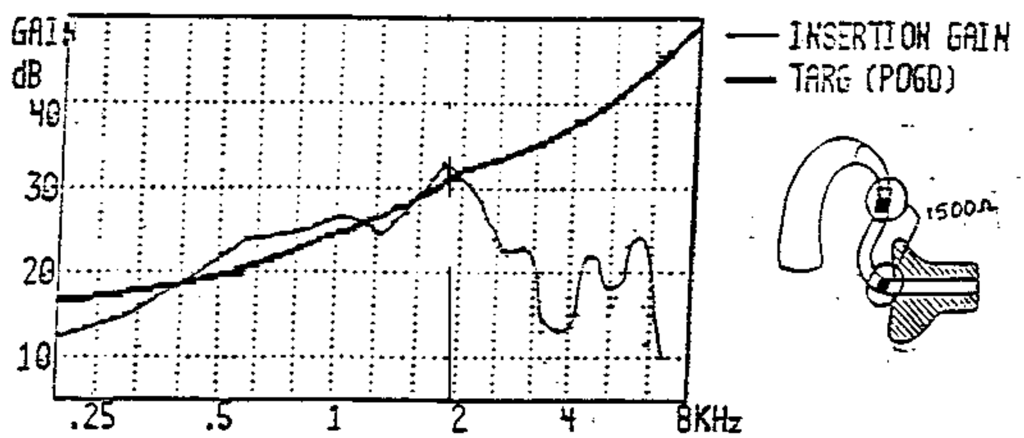

Fig M.3 : REIR with campers giving the best results

The above figures show the insertion gain curves, for with and without damper condition , against the target gain curve for a subject.

3. *Calculation of Articulation Index*

The audiogram provided by Pavlovic (1991) for calculation of AI by the Ad method was used.

AI calculations were made in the following manner.

a. The unaided earphone threshold measured for octaves and mid- octaves using standard clinical procedure was plotted on the audiogram.

b. The predicted damped and undamped aided thresholds were obtained by adding the damped and undamped REIG values respectively, to the unaided thresholds at each frequency on the ludiogram.

c. Similarly, the target aided thresholds were derived by adding POGO target REIR values to the unaided threshol is at each frequency on the audiogram.

d. For all the three shifted audiogram, (damped, undamped and target aided thresholds), the AI was calculated by counting the number of dots that fell below the threshold marking on the audiogram and divided by 100. If the shifted threshold line intersects a dot. the dot was still included in the count if more than half of it is downward from the threshold.

The following figure M.4 shows the method of calculating the AI from the data obtained on a subject for damped, undamped, and target REIR conditions.

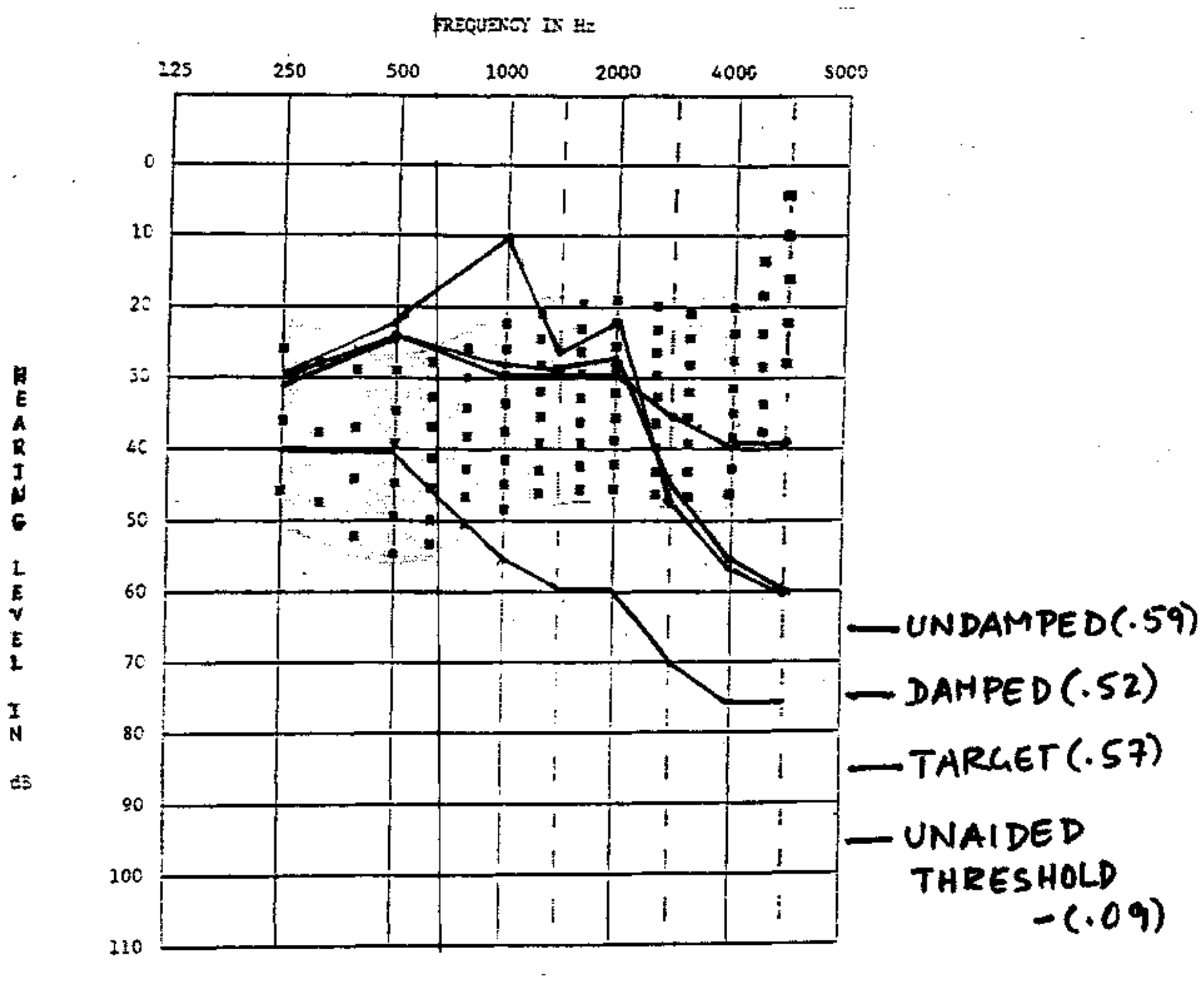

Fig M.4 : Illustration of the Ad count - the -dot method of Al for undamped, damped and target REIR conditions.

4. *Subjective Evaluation*

The subjective preference of damped or undamped hearing aid frequency response was evaluated using a method of paired comparison. This method has been shown to produce reliable and sensitive judgement of hearing aid processed speech intelligibility and quality

(Studebaker, Bisset, VanOrt and Hoffnung, 1982).

Subjects were seated comfortably in a sound treated room. Stimuli were presented through the loud speaker ke at at a distance of one meter from the patient's head using an azimuth of 45°. Both the continuous discourse and speech noise was presented through the same loudspeaker.

Prior to data collection the subjects were instructed as below.

Instruction

"You will listen to a short passage (See Appendix) played back twice in two conditions (once in quiet and two times in the presence of noise). Every time with a different hearing aid (damped and undamped). As the passage is played back, I will indicate to you which hearing aid is damped (No. 1) and which hearing aid is undamped (No. 2). After you have listened through both hearing aids, you must indicate which hearing aid (1 or 2) yields most clear, pleasant natural sounding, and more intelligible speech. You must indicate one preference even though you may find these two sounds very similar. I will gladly repeat the presentation if you so desire. Do you have any question ?"

Subjects were allowed to listen to each sample as long or as frequently as desired. Instructions were given both orally and in writing. Damped Vs Undamped comparison were made by each subject in three conditions

1. In Quiet
2. 'O'dBSNR
3. +7dBSNR

RESULTS

The present investigation was performed in an attempt to check whether hearing impaired listeners prefer the speech intelligibility or quality of damped hearing aid response over that of undamped hearing aid response.

L AI for Damped and Undamped Aided Thresholds

As seen in table R.l. The mean, standard deviation (SD) and range of AI values were obtained for all the three measurement conditions.

The mean AI values were 0.458, 0.479, and 0.338 for the undamped target and damped thresholds respectively.

Table R.1: The mean, SD and rang: of AI values

	Mean	SD	Range
Undamped	0.458	0.151	0.09 - 0.63
Target	0.479	0.167	0.16-0.80
Damped	0.338	0.164	0.04 - 0.57

The wilcoxon matched pairs 't'- test was administered to find if there was any significant difference between mean of AI's of any two-measurement conditions. The Number Crunching Statistical System (NCSS - Version 3.4) was used for this purpose.

The result showed a significant difference between means ($P < 0.01$) for comparison between target Vs damped and undamped Vs damped AI scores, but the difference was not significant ($P > 0.05$) for comparison between undamped Vs target AI scores.

II. Preference for Damped Vs Undamped Response

Damped Vs Undamped comparisons were made in three conditions. On each condition the subjects indicated the response that provided the best speech signal. The number of subjects choosing the damped hearing aid response in each condition is depicted in the figure R. 1.

- *In Quiet Condition* : 15 of the 20 subjects preferred the undamped response , 5 subjects preferred damped response
- *In condition with - 7 dB SNR* : 4 of the 20 subjects preferred the undamped response, 16 subjects preferred damped response.
- *In condition with '0' dB SNR* : 2 of the 20 subjects preferred the undamped response, 18 subjects preferred damped response.

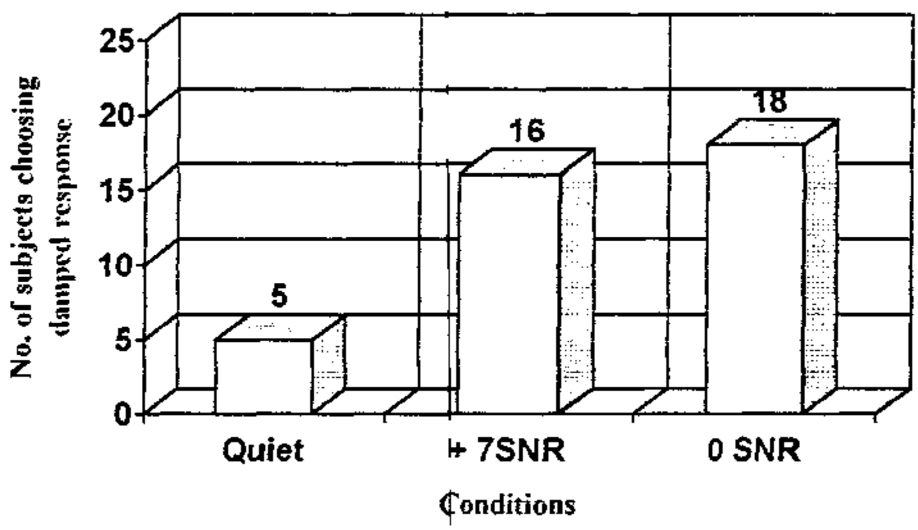

Fig R.4. : The bar diagram indicating the number of subjects preferred the damped response in 3 listening conditions

DISCUSSION

The Aci method of AI described here is easy to administer, score and interpret. Humes (1991), (cited in Kuk, 1996) also concluded that these methods were good relative predictors of speech-recognition performance for aided listening in quiet condition.

The Effectiveness of the AI

The observed AI was significantly different for comparisons target Vs damped and undamped Vs damped . In the former comparison the mean AI was higher in condition target than that of damped , because of lesser gain at higher frequencies. In the latter comparison also the mean AI scores for damped condition was lower than that of undamped . This could be because of unsmoothened peaks in the mid- frequency region of undamped contributing for more AI scores. This difference between means when analyzed for undamped Vs target condition was not significant. The better response at high frequencies in target condition and the unsmoothened peaks of the undamped condition at mid frequencies may occupy approximately equal number of dots thus leading to the ir difference.

The Effectiveness of Subjective Preference

As expected from the scores of damped and undamped aided AI, subjective preference for undamped aided response was more (15 of 20 subjects preferred undamped response) in quiet listening condition. This outcome suggests that the strong mid frequency resonance that occurs in undamped hearing aid frequency response does not have the deleterious effects on speech clarity in quiet. This result appears inconsistent with the results of the studies of response irregularities revived earlier. However, in all of these investigations, the relationship between frequency response irregularities and speech intelligibility or quality was es:ablished primarily using normal hearing subjects. Jerger and Thelin, (1968) (cited in Bornstein , 1983) tested hearing impaired as well as normal hearing subjects and noted that the relationship between response irregularities and speech intelligibility was much weaker in the hearing impaired subjects. Dillon and Macrae (1984) (cited in Cox & Gilmore, 1986) used three hearing impaired subjects (in addition to 5 normal hearers). Two were reported to give results similar to normals and 1 was essentially insensitive to response irregularities. The results of Decker (1975), Cox & Gilmore (1986) along with these reports suggest that the effect of frequency response irregularities on speech intelligibility or quality are less for hearing impaired listeners than for normal hearing subjects. This could be because speech spectrum noise that is used for acoustic measures has a long term crest factor (the difference in peak SPL and overall root mean square SPL) of 12 dB at 1000 Hz to 1400 Hz and 16 to 17 dB at 300 to 400 Hz (Dunn and White, 1940, as cited in Valent,1996). This suggests that the long term spectrum of conversational speech used at 70 dispel for the present study may had a peak SPL as high as 82 dB SPL (i.e. 70 dB + 12 dB) at 1000 Hz to 1400 Hz. This peak SPL value along with the mid frequency resonance near

1000 Hz would have easily saturated the hearing aid even at a low gain setting leading to saturation distortion.

In undamped hearing aid response saturation distortion might have occurred even in quiet condition, but the effect of saturation distortion on speech recognition may be more evident when speech materials are presented in a background of noise (Kuk,lP96;Valent, et al.,1996). The results of the present study are consistent with this suggestion.

This conclusion appears va id only in quiet listening condition, whereas in noisy listening condition majority of the subjects preferred the damped hearing aid response. This may be because of reduced gain and output leading to an increase in head room or smoothening in frequency response which are favourable for a successful hearing aid usage (Libby, 1979 ; Teder, 1979 ; and Chasin, 1983).

SUMMARY AND CONCLUSION

The combination of earhook, tubing, earmold and hearing aid constitute the hearing aid system as a whole. The benefit due to the hearing aid depends on individual component characteristics. Because of the resonatory characteristic of earhook, tubng and earmold there are several peaks added to the hearing aid response alone. These peaks were found to have deleterious effects on the speech percept on through hearing aid (Dillon, 1983, as cited in Cox and Gilmore,1986).

Gastmeier (1981) has shown that the acoustic resistance of a damper. Can multiply the peaks and have different effects when placed in different positions of the resonatory system. Several authors have suggested that dampers can also be used to increase the headroom to reduce the feed back etc., even though there exists equivocal data regarding the preference for damper by hearing aid user. (Libby,197S; Chasin,1983; Cox and Gilmore,1986). All these studies have used subjective procedures for a damper. There is a dearth of literature on the usage of am objective procedure for selecting dampers and eveluating its effectiveness.

Hence the present study aimed at evaluating the effectiveness of dampers, using

1) Paired comparison procec ure in different listening conditions and

2) AI in quiet

Twenty subjects with sensonneural hearing loss ranging from mild to severe degree of hearing loss were include d in the study.

The real ear measurements were done for the purpose of selecting Dampers and for calculating AI. The effectiveness of a selected damper was evaluated through a paired comparison method (Damped Vs Undamped) in three different conditions Viz., Quiet, OdB SNR,and +7dB SNR for a recorded continuous discourse. The A.I was calculated for damped (D), undamped (UD) & target (T) conditions. The results indicated that the 15/20 listeners did not prefer a damper in quiet. Most of the listeners preferred a damper in the presence of noise. The mean A.I values obtained for damped and undamped; damped and target was significantly different. The mean difference for target Vs undamped was statistically not significant. From this study it can be concluded that,

1) Dampers were effective in the presence of noise rather than in quietand

2) The A.I can be used to predict the subjective preference in quiet.

The present study has the following limitations.

1) The results of the present study might be understood in the context of sensorineural hearing loss as a whole. The results might not be applicable to individual categories based on either the degree or the configuration of hearing loss.

2) The AI results can be generalized only to quiet conditions.

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APPENDIX

CONTINUOUS DISCOURSE USED FOR PAIRED COMPARISION

" ಬೆಂಗಳೂರು ನಮ್ಮ ರಾಜ್ಯವ ಒಂದು ದೊಡ್ಡ ಊರು. ಈ ಊರನ್ನು ನಮ್ಮ ರಾಜ್ಯದ ಬೊಂಬಾಯಿ ಎನ್ನುವರು. ಇಂಡಿಯಾದ ದೊಡ್ಡ ನಗರಗಳಲ್ಲಿ ಇದೂ ಒಂದು. ಈ ಊರನ್ನು ನೋಡಲು ಜನರು ಬೇರೆ ಬೇರೆ ರಾಜ್ಯಗಳಿಂದ ಬೇರೆ ಬೇರೆ ಊರುಗಳಿಂದ ಬರುವರು. ಇದಲ್ಲದೇ ನಮ್ಮ ರಾಜ್ಯಥಲ್ಲಿರುವ ಬೇಲೂರು, ಜೋಗ್, ನಂವಿ ಇವುಗಳನ್ನು ನೋಡಲು ಜನರು ಬರುವರು. ಈ ಥಾಡಿನಲ್ಲಿ ರೇಷ್ಮೆಯನ್ನು ಬೇಳೆಯುವರು."