PREDICTION OF A RELATIONSHIP BETWEEN BEHAVIORAL THRESHOLD, ACOUSTIC REFLEX THRESHOLD AND LOUDNESS DISCOMFORT LEVEL

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Reg No: 8612

Dissertaticn Submitted In Part Fulfilment For The Final year
Of The Masters Degree In Speech & Hearing
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TO

•••••• Dr.M.M.Vyasamurthy, my mentor and guide

•••••• Sudha, ever my inspiration

•••••• Shobhana and Kumar, the computer people.

CERTIFICATE

This is to certify that this Dissertation entitled "PREDICTION OF A RELATIONSHIP BETWEEN BEHAVIORAL THRESHOLD, ACOUSTIC REFLEX THRESHOLD AND LOUDNESS DISCOMFORT LEVEL" is the bonafide work in part fulfilment for the Degree of Master of science (Speech and Hearing) of the student with Regiater No. 8612

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CERTIFICATE

This is to certify that this Dissertation entitled "PREDICTION OF A RELATIONSHIP BETWEEN BEHAVIORAL THRESHOLD, ACOUSTIC REFLEX THRESHOLD AND LOUDNESS DISCOMFORT LEVEL" has been prepared under my supervision and guidance.

Dr.M.N.Vyasamurthy
GUIDE.

DECLARATION

I hereby declare that this dissertation entitled "PREDICTION OF A RELATIONSHIP BETWEEN BEHAVIORAL THRESHOLD, ACOUSTIC REFLEX THRESHOLD AND LOUDNESS DISCOMFORT LEVEL" is the result of my own study under the guidance of Dr.M.N.Vyasamurthy, Department of Audiology, All India Institute of Speech and Hearing, Mysore and has not been submitted earlier at any University for any other Diploma or Degree.

Mysore.
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TABLE OF CONTENTS

INTRODUCTION

Hearing is a late development in evolution, but it has become the sentinel of our senses, ever on the alert to any sound pattern in space. Bats and some Marine animals, who live in conditions where light is poor have learned to hear objects as well as events using echoes to locate their position and direction. The frequency selectivity of the human ear is remarkably superior to most electronic filters and thanks to these complex neural filters, processing of complex acoustic signals as speech and utilisation of the rich human propensity for acquiring language, is possible.

As is well known, sensorineural hearing loss is Characterised typically by a well defined set of audiological signs and symptoms – elevated thresholds, abnormally rapid loudness growth, subjective tinnitus, poor speech discrimination and a reduction in the temporal summation of energy, (salvi at al. 1983). with the current focus on early identification and management of sensorineural hearing loss, probing the subjective and objective measures that provide valuable information on these lines becomes a necessity for the Audiologist.

Various studies on cases with cochlear pathology have indicated elevated behavioural pure tone thresholds but acoustic reflex thresholds at lower sensation levels than normal hearing subjects (Mats, 1952, Alberti end Kristensen, 1970, Peterson and Liden, 1972, Morgolis and Pepelka 1974, Woodford et al. 1975, Scharf, 1976* Jerger et el. 1972; Olsen at al. 1975; Northern, 1973).

The loudness discomfort level(LDL) as a subjective measure of the lowest intensity level which is judged to cause discomfort has been used (1) to delineate cochlear lesions from other pathologies that yield LDL's at more intense levels (2) to determine the appropriate saturation sound pressure level of a hearing aid that should not be exceeded in terms of amplification. Various studies have indicated reduced LDL's for cases with cochlear pathology as compared to groups of normal hearing listeners.(Miller+ 1972y Dudich, et al. 1975; McLeod and Greenberg, 1979).

Research in the recent past has shown that prediction of sensorineural hearing loss is possible from the acouatic reflex. Hearing sensitivity and Slope of the audiometric configuration may be predicted by observing the relationship between the acoustic reflex threaholds for pure tones and broad band noise (Niemeyer and Sesterhenn, 1974; Jerger, 1974, Schwartz and Sanders, 1974). In the Indian content, Mythlli,(1976) and Kamini (1982) found the noise-tone difference (NTD) to be reduced for sensorineural hearing loss and Raghunath (1977), Sudha K Murthy (1980) and Joan D'Mello (1982) attempted to predict hearing sensitivity from the acoustic reflex.

Purpose of the present study:

1. TO explore the relationship between the results on three Measures vis. Behavioral Threshold, Acoustic Reflex Threshold and Loudness Discomfort Level in a normal hearing and sensorineural hearing loss population,

2. To arrive at a predictive equation between the three variables so as to predict one from the other, if the former is difficult to assess directly, for any reason,

Implications of the study:

The test situation in the clinic is often not to the liking of most children who otherwise may be cooperative and friendly in a more natural environment. Therefore the evaluation of the difficult-to–test population is often a challenging and even frustrating task for the Audiologist. In such a situation, from an objective measure as acoustic reflex threshold (ART) that may be the only feasible measure, the audiologist nay be able to estimates

1. The behavioural threshold for a clear diagnostic picture.
2. The loudness discomfort level for appropriate hearing aid fitting.

REVIEW OF LITERATURE

1. Terminology defined:

1.1: Sensorineural hoaxing loss: Characterised by a well defined act of audiologlcel sign a and symptoms such as elevated thresholds, abnormally rapid loudness growth , subjective tinnitus, poor speech discrimination and a reduction in the temporal summation of energy (Salvi at al. 1983)

Recant single unit studies in the area of Auditory Physiology have provided insight into the underlying mechenisms which may be responsible for these symptoms and helped refine concepts on how acoustic Information is processed in normal and hearing impaired ears. Single unit studies performed on animals with noise or drug induced hearing loss hare revealed significant changes in neural tuning and neural sensitivity. In addition, timing of neural responses is also altered if the data axe evaluated in terms of the intensity above threshold. The pattern of spontaneous activity may also be affected by sensorineural (SN) hearing loss although the discharge patterns over time and the discharge rate Intensity functions at their characteristic frequencies do not seen to be altered in the pathological ears (Salvi, Henderson, Haraemik and Ahroon, 1983).

It is well documented that the frequency selectivity of the normal as is remarkable in comparison to most electronic filters and that processing of complex acoustic signals such as speeeh occurs, thanks to the active role of these neural fllters. One of the most significant chaanges that occurs in ears with sensorineural (SN) hearing loss is the broadening of theae neural filters. Thus, when complex signals such as speech are presented at suprathreshold levels, individual units may be unable to respond to selective components of the signal. Factors such as upward spread of masking may also add to such effeects.

1.2 Acoustic Reflex Threshold (ART}: The lowest intensity level at which the stapedius muscle reflex activity may be elicited is achieved by using an impedance bridge or meter. Though there is no complete agreement, the accoustic reflex is generally regarded as a suprathreshold loudnass reeponse with reflex thresholds occuring in the normal ear at sensation levels of 70 to 90dB (Scharf, 1976).

1.3 Loudness Discomfort level (LDL): The minimum intensity level which ia judged to cause diacomfort (i.e. an infavourable subjective responce) to the patient when applied monaurally at specific pure tone frequencies or in the form of other types of test signal as speech, noise or warble tones.

2.0 Acoustic Reflex Test and Loudness recruitment: since the introduction of ABLB test by Fowler (1937), the measurement of loudness recruitment as a tool in differential diagnosis has received considerable attention. However traditional loudness balance procedures require subjective judgements by the listener which are sometimes tedious and time consuming.

Metz (1946) was the first to suggest the measurement of relative dynamic impedance as a direct objective determination of loudness recruitment. The Metz test was proposed in 1952 as a direct test for recruitment.

While the acoustic reflex threshold occurs at 7O-90dB SI, generally in the normal ear, in the SN impaired ear the acoustic stapedial reflex is obtained at sensation levels(SL's) less than 60db and this is suggestive of recruitment.

Studies by several researchers (Metz, 1952; Kristensen and Jepsen, 1952; Thomsen, 1955; Alberti and Kristenson, 1970; Jerger et al. 1972; Olsen, et al. 1975) have all shown reflex threshold to occur at sensation levels below 60dB as consistent with loudness recruitment.

Metz (1952) argued that because of the rapid growth of loudness at suprathreshold intensities, reflex thresholds in the recruiting ear occur at the seme hearing levels in the normal ear but because of hearing loss in the impaired ear, the reflex thresholds are seen to occur at reduced sensation levels.

Jerger (l972): suggested a linear 1:1 linear relationship between sensation level of the reflex and the degree of hearing loss i.e. in cases who demonstrated loudness recruitment, the reflex SL decreases linearly with each increase in hearing loss and the minimum SL reduction is approximately 25dB.

Martin and Brunette (1980) tested fifteen subjects with unilateral sensorineural hypacuals to determine the sound intensity eliciting the normal reflex in normal and impaired ears and the sound intensity in the normal ear which is equal in loudness to the intensity eliciting the reflex in the abnormal ear. Results of his study suggested that loudness may not be the mediating factor in the acoustic reflex end thus the reflexes at low SL's observed in hearing impaired ears need not be unequivocal indicators of recruitment.

Despite the existing controversy on whether reflex behaves according to the loudness of the activating signal (Ross, 1969, Beedle and Harford, 1973; Peterson and Liden, 1972, Jerger, 1972; Margolis and Popelka, 1974; Block, 1977; 1979; Kartin and Brunette, 1980), there remains a plethora of evidence to suggest that the Metz test can be used successfully as an objective indicator of the phenomenon of recruitment.

Irrespective of whether the test demonstrates recruitment or not, the crucial consideration is the fact that the acoustic reflexes st reduced sensation levels is highly consistent with the presence of cochlear pathology.

Fitz Zaland and Barton have suggested a formula that may provide a more precise classification of loudness recruitment. They defined Difference Ratio Quotient or (DRQ) as : $DRQ = \frac{(A-X) - (B-Y)}{Y-X}$ where A = ART better ear

X = Puretone threshold better ear.

B = ART poorer ear.

Y = Puretone threshold poorer ear.

DRQ of one indicates complete recruitment

DRQ between zero and one indicates partial recruitment

DRQ greater than one indicates hyper recruitment

DRQ of zero indicates no recruitment.

3.0 Sensorineural prediction from the acoustic reflex:

Studies in the resent past have shown that the hearing sensitivity and the slope of the audiometric configuration can be predicted by observing the relationship between the acoustic reflex thresholds for pure tones and broad band noise. In the normal ear, the stapedial reflex for broad band noise occurs at a significantly lower SPL than that required for a reflex response to a pure tone.

3.1 Average hearing loss:

Niemeyer and Sesterhenn (1974) used the formula

HTL(DB) = T - (DXX)

where T = Average ART in dB SPL for pure tones of frequencies 500 to 4KHz

D = T minus ART for BBN

K - 2.5dB constant.

According to Niemeyer and Sesterhaan, hearing threshold level (HTL) was calculated within +10dB in !3% of 223 SN impaired ears, within +5dB in 17% and ± 2dB in 10% cases.

3.2 Hearing level with specific tonal stimuli:

Sesterhann and Breaninger (1977) suggested that by uaing a preactivating stimulus of 6 to 8KHz, threshold can be obtained at a lower sensation level. First, the intensity of the tone is adjusted such that it elicits a reflex. Then the test tone and preactivating stimulus are given simultaneously. The intensity of the preactivating stimulus is constant but the test tone should be reduced until any reflex activity disappeared. The formula suggested is;

Threshold - ART_{F} - K ART_{F} - $\mathrm{AKT}_{(F6/BK)}$

where ART_{F}- is acouatic reflex threshold at the test frequer

K is a multiple for the test frequency

$\mathrm{ART}_{F6/BR}$ is the ART in the presence of preactivating stimulus (6 or 8KHz)

K values - 2.75 for 250 and 500Hz
- 3 for 1000Hz
- 3.5 for 2000Hz
- 4 for 4000Hz

Baker and Lilly (1976) found a regression equation.

$$\text{dB HTL} = 1.11\ \text{ART}_{(\text{BBN SPL})} - 0.81\ \text{ART}_{(1500\text{Hz HL})} + 0.85\ \text{ART}_{(1000\text{Hz HL})} - 0.43\ \text{ART}_{(2000\text{Hz HL})} + 0.25\ \text{ART}_{(4000\text{H HL}} - 64$$

Where HTL - Hearing threshold level
BBN - Broad Band noise level
SPL - Sound pressure level
HL - Hearing level.

However most subjects with hearing impairment do not exhibit acoustic reflex threshold at 4000Hz making the procedure invalid.

3.3 Estimating, magnitude and configuration of hearing loss:

Unlike the earlier investigators, Jerger et al, 1972 found and nonlinear relationship between senorineural hearing loss the acoustic reflex threshold. Jerger et al (1974) proposed a new method called sensitivity prediction by acoustic reflex (SPAR). The unweighted SPAR formula is

$D = PTAR - WN\ AR + C$

where PTAR is pure tone acoustic reflex threshold at 500Hz, 1000Hz and 2000Hz divided by 3

WN AR is white noise acoustic reflex threshold in dB SPL.

C is the correction factor

The weighted formula using low pass filtered noise and high pass filtered noise is $D = \frac{l + m + n}{3}$ where

l = Average ART in SPL for 500, 1K, 2K - ART_{BBN}.

$m = ART_{500HZ}$ in db SPL - ART_{BBN}

$n = ART_{lowest} - ART_{BBN}$

SPAR criteria-Jerger et al. 1974

Noise tone difference	Broad band noise in dB SPL	Prediction
Greater than 20	Anywhere	Normal
15 - 19	Less than 80	Mild-to-moderate
15 - 19	Greater than 80	Mild-to-moderate
10 - 14	Anywhere	Mild-to-moderate
Less than 10	Less than 90	Severe
Less than 10	Greater than 90	Severe
No reflexes		Profound

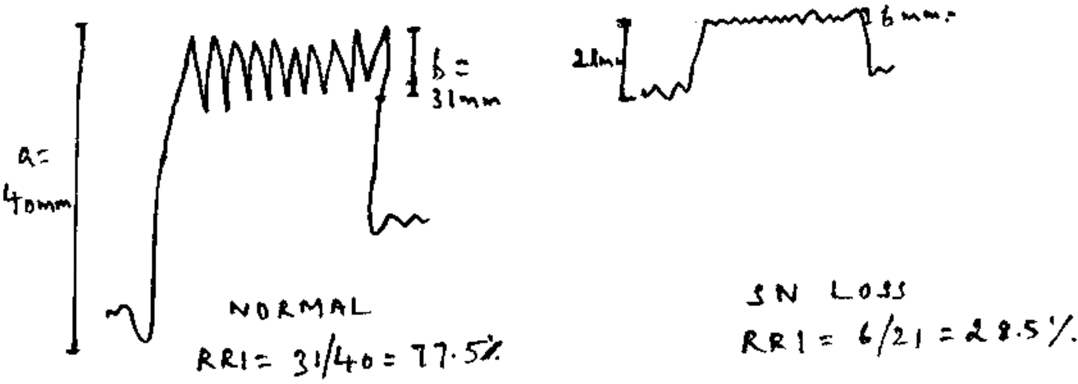
Degree of hasting loss - Jerger, et al. 1974.

Category.	Criteria
Normal	PTA less than 20dB HL
Mild to moderate	PEA from 20 to 49dB HL.
Severe	PTA -from 50 to 84dB HL
Profound	PTA of 85dB HL and more

Jerger et al (1978) present extensive data upon which several conclusions are based regarding variance in accuracy of SPAR predictions. They found that accurate prediction of sen ori neural loss by SPAR is a function of the patient's chronological age. Prediction accuracy is most successful in children upto the age of 10 years and least accurate in older adults. In this study, 100% of the children predicted to have normal hearing did indeed show normal hearing while severe hearing loss was predicted 85% of the time. However prediction of moderate hearing loss in children was less accurate due to the complex effect of SN loss as a function of audiometric configuration, type of signal and degree of loss.

3.4 Reflex latency measures:

Norris et al, 1974 recorded graphically stapedial reflex at 10dB above ART in 22 normals and 22 hearing impaired children at 500, 1000 and 2000Hz. The width of the pulsed component was divided by the total reflex amplitude to obtain Reflex Relaxation Index or RRI in percentage.



Therefore the degree of relaxation is considerebly reduced in the hearing impaired (RRI less than 30%) group.

Leiten, 1974: studied the RRI for 26 normal hearing and 18 SB loss subjects at frequencies 500Hz, lKHz, 2KHz, 4KHz and found (1) Test retest reliability good for both groups at all frequencies (2) Teat in sensitive to identify mild hearing loss (26-40dB HTL) when 30% cut off used (3) A cut off 40% has a better predictive accurracy (4) test valuable in identifying SN losses.

3.5 Indian Studies:

1. Mythili (1975): Compared reflex thresholds for pure tones, narrow band noise and wide band noise in 100 normals and 15 SN loss cases. Reported a reduced noise-tone-differenced(NTD) for SN loss.
   Mean reflex threshold for pure tones = 90.1 dB SPL and for wide band noise 66.7dB SPL.
2. Raghunath (1977): made an attempt to standardize Niemeyer and Sesterhenn's formula but found a number of false positive errors. Hence provided a few multiplication factors which are frequency specific.

3. Sudha Murthy (1980): Assessed usefulness of SPAR in 30 normal hearing subjects from 11.5 to 25 years of age. Reported 98.44% with weighted and 93.75% with unweighted formula.
4. Joan D'Mello (1982): Assessed SPAR for 36 normal hearing children in the age range 5-10 years.

Mean ARTs 500Hz - 95dB HL, lOOOHz - 91dB HL 2000 - 91dB HL

The average ART across frequencies varied from 80dB - 116dB ML

Conclusions: a) Children exhibited lower ART for BBN than pure tones.

b) Noise tone difference (NTD) in children can be used to predict hearing loss.

4.0 Loudness Discomfort Level (LDL):

The measurement of LDL's has received increasing attention over the last decade though a great deal of variability exists in the procedures, applications and expected values. (Hawkins, 1980).

4.1 Terminology: The terms LDL, uncomfortable loudness level (ULL) and threshold of discomfort (TD) are sometimes used synonymously. However since procedural distinctions exist and values reported by different investigators differ widely, one ahould not consider these terms as representing equivalent auditory sensations without examining the instructions and procedures that were employed. The choice of LDL in this study reflects the increasing use of this term (Dirks and Kamm, 1976; Denenberg and Altshular, 1976; Morgan et al. 1974; Morgan and Dirks, 1974; Skinner,1977).

4.2 Objectives: To measure the minimum intensity level which is judged to cause discomfort (i.e. an unfavourable subjoctive responce) to the patient when applied monaurally at specified pure tone frequencies (The procedure is described for pure tones but is also applicable when using other types of test signal eg. speeeh, noise, warble tones).

4.3 Instructions The exact instructions given have a considerable effect on the outcome of the test. In literature, the following distinct types may be found.

a) Initial discomfort: Instructions of this type include the word 'first' and suggest the beginning of discomfort eg. the point when the sound becomes annoying (McCandless, 1973). Called "discomfort" by Silverman (1947).
b) Definite discomfort: Similiar to earlier type but does not use the word 'first' eg. By too loud, we mean when the sound is above the level to which you would choose to listen for any period of time - Morgan et al. 1974. called 'tickle' by Silverman (1947).

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c) Extreme discomfort: Implies pain or severe discomfort eg. 'when you feel like removing the earphones from year ears (silverman, 1947 called this pain "Muscles around eyes start twitching" (Wellengels,1967) "So loud as to cuses physiologicai discomfort" (Newby, 1972).
"When these sounds become too loud and hurt your ear" (Holmes and Woodford, 1977) .

d) According to the British Society of Radiology (1987), the following or equivelent instructions should be used: "I will gradually increases the loudness of the sound in year ear and you must indicate (by pressing the button/ raising your hand) as soon as the sound becomes uncomfortably loud".

e) A more clinically feasible set used in this study: (Method of limits) - "I will gradually increase the loudness of the sound in your ear and you must indicate by raising your hand if louder, lowering if softer and keeping horizontal if constant. If the sound becomes uncomfortably loud, please lift your finger to indicate the same".

4.4 Recommen<u>ded stimuliL:</u> Have included pure tones, noise and speech delivered through standard earphones, insert earphones, sound field, and low impedance hearing aid receivers.

4.5 Methods used: (Morgan, Wilson and Dirks, 1974).

a) Method of limits: The stimulus is under the experimenter's control and the subject simply responds after each presentation. The level of the sound is presented in an increasing (ascending) fashion until the desired LDL is reached.

b) Method of constant stimuli: Presentation of various stimulus levels to the subject is done in a random order. This is not a sequential procedure and a range of intensities based on prior experience may be chosen to locate the LDL.

c) Method of adjustment: Unlike the method of limits here the stimulus is controlled by the subject instead of by the experimenter and the level of the stimulus is varied continuously rather than in discrete steps.

d) Tracking method: In this procedure devised by Bekesy (1960), the level of the stimulus changes at a fixed rate and the direction of level change is controlled by the subject via a push button switch. The switch is pressed when the tone is audible and this decreases the sound level and is released when inaudible to increase the sound level.

e) Objective method: A recent study by Thornton et al(1987) investigated the relationship between Jewett Wave-V latency of ABR and subjective loudness discomfort to ascertain if objective estimation of LDL is possible.

ABR recordings were taken from 8 normal hearing subjects at the stimulus intensity corresponding to their LDL and at stimulus levels from 10 to 30 dB below this. The wave V LIF did not correlate will with LDL. However the slope of this LIF did correlate to a high degree and a predictive model of LDL was derived. similar measuremants taken from 12 cochlear impaired subjects with a range of audiometric profiles showed that subjective LDL's could be predicted using the wave V LIF to an accuracy of ±5dB, using the model derived from normal hearing subjects.

4.6 Applications:

a) Assists in determining the appropriate saturation sound pressure level of the hearing aid chosen for amplification which is suggested as the electroacoustic characteristic mast related to user satisfaction (Franks and Bechman. 1982; Libby, 1983; Walker et al, 1984; Hawkins, 1984). Dillon et al (1984) measured the hearing aid SSPL 90 on two groups - one who reported loudness discomfort when wearing their hearing aid and other that did not. Their results clearly showed that as SSPL 90 exceeded the LDL, loudness discomfort with hearing aid use was reported. Therefore, there is clear agreement on one aspect of the SSPL-90 selection - that it should not exceed the user's LDL. Hence the LDL measurement is critical.

b) Diagnostic application for differentiating cochlear pathologies from conductive, mixed aad retrocochlear pathologies. Dix(1968): Found that in normals and cochlear lesions in whom recruitment was damonatrable by the nature of lesion or by ABLB technique, the LDL's lie within a range of 95–105dB. However in conductive and retrocochlear lesions, the LDL'S could not be established within the maximum audiometric limits of 120dB.

5.0 Relationship between behavioral thresholds, acoustic reflex thresholds and LDL's:

Beedle and Harford (1973) carried out a study to explore the relationship between acoustic reflex growth and loudness growth at 500, 1000 and 2000Hz. Two groups of subjects with ten normal hearing and ten unilateral hearing loss cases resulting from endolymphatie hydrops were tested. Acoustic reflexes were recorded graphically at successive 2dB increments from reflex threshold to an SL of 16dB using an ascending/descending approach. ABLB test was performed at three sensation levels (ref.ART). Results indicated that the slope of the acoustic reflex growth function is much greater and more rapid than that of the unilateral hydrops group. This was attributed to the aged differences between the groups (mean ages for normal and SN loss groups were 24 and 47 years respectively). The growth function, being similar otherwise for both groups, the diagnostic significance is questionable.

Woodford and Holmes (1977)s studied the relation-Ship between LDL and ART in seventy eight subjects with audiological signs consistent with hearing loss of cochlear etiology (mean age of 29.7 years and range of 11-61 years).

Found ART and LEL using a tracking proeedura for pure tone stimuli from 500Hz to 1KHz and wide band noise with a band width of 500Hz and center frequency of 2000Hz.

Within the clinical group, two sub groups: (1) subjects with loss of hearing only at pure tone frequencies higher than 2000Hz. (2) Subjects with loss of hearing extending to frequencies of 2000Hz and below. The idea behind this grouping was that moat in the latter category and only few in the former category would benefit from amplification.

The ART-LDL relationship were close for both groups for pure tones but for narrow band noisee the high frequency hearing loss group shows is greater diffarence between the ART and LDL measures. The individual data indicated the relationship between these measures to be a variable one.

Holmes and Woodford (1977) studied children with hearing levels ranging between 95 and 1056B SPL. The instruction* were given by manual communication and subjects asked to indicate whan the signal became too loud and hurt their ears. such procedural differences may account for the large LDL's (118-128dB SPL) as compared to other studies.

Kallatrom and Caratenaen (1978) studied the perception of loudness and the acoustic reflex in twanty normal hearing adults with thresholds 10dB or better between 500 and 4000HZ (mean age - 25.2 years). Results of this study indicated a direct correlation between the perceived level at which pure tones became loud enough to be uncomfortable and the acoustic reflex threshold. Subjects seemed to indicate a lower intensity When the stimuli are within the comfortable loudness range but when exposed to stimuli which exceed the comfort range, the point at which subjects recognise dis-Comfort lies closer to the stapedial reflex as compared to previous studies.

Kemm et al (1978) studied the effect of SB loss on loudnass discomfort level (LDL) and most comfortable level (MCL) judgements. Pure tone and speech stimuli were used. Median LDL and MCL levels were observed at relatively constant SPL'a for subjects with hearing loss 1ess than or equal to 50dB HL and at progressively higher SPL's with further increase in the degree of hearing loss correlation analysis verified a statistically significant relationship between LDL and the magnitude of hearing loss. The nonlinear relationahip between LDL and hearing loss together with large intersubject variability inthe data suggests that prediction of LDL from hearing loss may often be highly inadequate.

Shapiro (1979) evaluated the relatlonahip between hearing threahold and loudness discomfort level using NBN in 2 groups of patients with sensorineural hearing loss group-1 had thresholds ranging from 25 to 60dB SPL and group-2 had thresholds ranging from 65 to l00dB SPL. NBN centred at 500, 1000, 2000 and 4000Hz was used. The LDLs were found to bo greater for group-2 than for group-l. This finding was not in agreement with woodford and Holmes (1977) and Hoode and Poole (1966) who found no significant differences in LDLs as a function of the degree of hearing loss. Data from this study suggests that patients with tones greater than 60dB SPL may bo able to tolerate hearing aids with greater SSPL's.

Keith (1979) studied the relationship between loudness and theacoustic reflex in normal hearing and cochlear impaired subjects using earphone and sound field conditions. In normals, the most comfortable loudness level (MCL) is elevated by noise while the ART remains at a constant level. However in the cochlear pathology subjects both MCL and ART are elicited at the some level with the LDL occuring at a level 18dB above these measures.

Ritter et al (1979) obtained LDL. and ART for two groups of 10 normal subjects each and one group of 20 adults with SB loss. Pure tones, warble tones and speech stimuli were used in earphone and sound field conditions. One group of normal hearing subjects and the SN loss group were given 'for loud','uncomfortably loud' 'annoyingly loud' instructions while a second group of normal hearing subjects were asked to respond when a sound first starts to become uncomfortable. Results indicated that LDL's regardless of hearing losses were reported at higher SPLs than acoustic reflex thresholds but the magnitude of the differences between the measures varied according to the type of instructions, transducer,test stimulus and hearing sensitivity.

McLeod and Greenberg (1979) obtained acoustic reflex threshold first and a method of constant stimuli for LDL to decide Whether the stimulus was uncomfortably loud (yes), or not too loud 'no). For pure tone stimuli, the hearing impaired group showed URL's at or below ART. Significant differences were found between ART and LDL for each group. A multiple refression analysis indicated significant correlation between ART and LDL. Ranges of prediction error were chosen to investigate the ability of ART to predict LDL. Both pure tone and speech stimuli successfully predicted LDL within ±10dB for all subjects and ±5dB for 75%.

The major findings of this study were:

1. The significant positive correlation between LDL and ART against most other studies.

2. LDL prediction from ART within ±10dB for 100% subjects and within ±54B for 73% subjects.
3. Presence of hearing loss on the average shifted ART more than LDL.

Newman, Keul's multiple comparisons on LDL/ART means for normal and hearing impaired subjects.

subjects	ART	LDL	lKHz	2KHz	Speech
Normal					
lKHz vs 2KHz	ns	ns	-	-	-
1KHz vs speech	*	*	-	-	-
2KHz vs speech	*	*	-	-	-
ART vs LDL	-	-	ns	ns	*
Hearing Impaired					
1KHz vs 2KHz	*	ns	-	-	
1KHz vs speech	*	ns	-	-	-
2KHz vs speech	*	ns	-	-	-
ART vs LDL	-	-	ns	*	*
LDL					
Normal vs SN	-	-	*	*	*
ART	-	-	*	*	*
Normal vs NS					

Table-1 shows the LDL and ART for normal* and SH los*.

Comparision of Loudness Discomfort levels and Acoustic Reflex Thresholds for normal hearing and hearing impaired subjects using different LDL instructions and different acoustic stimuli.

Study	Subjects	Stimuli	Threshold level
Niemeyer (1981) Not defined	Sensori-neural	Puer tones	ART's aapprximately 10-20 dB lower than LDLs
Miller (1972) LDL- instructions varied fey groups	Normal(N=80) Group-l - 20 Group-2 - 20 Group-3 - 20 Group-4 - 20	Pure tones (250-4KHz) speech	SPL LDL ART Group-1 100 99 Group-2 107 97 Group-3 121 97 Group-4 95 100
McCandless & Miller (1972)	Normal(N=15)	Pure tones 500,1000, 2000,4000 speech	(SPL) LDL SRT PT 99dB 95 speech95dB 89
LDL:first indicates experience of discomfort/ annnoyace.	Cochlear (N-20)	Pure tones 500-4KHZ speech	Results similar to above group (80-l00dB HL)
Morgan et al (1974) LDL-too loud uncomfortably loud annoyingly loud	Normal	Pure tones WBN	ARTs consistently lower than LDLs

Study	Subjects	Stimuli	Threshold level			
Wilson and Hopskind, (1973): LDL. net defined	Normal N=20	Pure tones			AM	
		Speech	250	82	84	
			500	84	92	
			1000	87	92	
			2000	84	$1	
			4000	84	84	
			speech t	66	8$	
Dudich et al (1975) LDL((Normal)groups) Too loud, uncomfortably loud, Annoyingly loud.	Normal (N=12)	Pure tones		MS<	AKT(3CW	
		Speech	500	85	95	^PL)
			1000	§4	93	
			2000	84	91	
			Speech	91	83	
LDL(Cochlear) same as above	Cochlear (N=ll)	Pure tones		LDL	ART	
		speech	500	90	102	
			1000	88	97	
			2000	90	100	SPL
			speech	100	104	
LDL(cochlear) Maximum tolerable intensity	Cochlear (N=6)	Pure tones	500	103	97	
		speech	1000	100	95	
			2000	95	96	
			speech	107	98	
Berger(1976) LDL-uncomfortably loud	Normal (N=40)	Pure tones		LDL	ART	
			500	108	97	
			1000	106	92	SPL
			2000	107	93	
			4000	107	93	
Denenberg and Altshuler(1976) LDL-The point at which the cosversation becomes uncomfortably loud	Normal (N=5)	speech		LDL	ART (SPL)	
				90	86	
	Sensori-neural (N=15)			107	95	

Study	subjects	Stimuli	Threshold level		
McLeod(1977) LDL too loud or uncomfortably loud.	(Normal) (N=15)	Paretones		LDL	ART (SPL
		1000	1000	99	95
		2000	2000	98	96
			speech	102	91
				LDL	ART
	Sensori-neural (N=15)		1000	109	109
			2000	110	116
			speech	108	102
McLeod and Greenberg(1979) Uncomfortably loud - yes. Not too loud - no.	Noramal (N=15)	Puretones		LDL.	ART
			1000Hz	98.5	95.9
			2000Hz	98.7	96.1
		Speech		102.7	91.7
	Hearing impaired	Puretones			
			1000Hz	109.3	110.6
			2000Hz	109.7	116.1
		Speech		108.9	102.3

TABLE-3

To explore the above introversial relationships, the following null hypotheses were formulated for this study.

1. No significant differences exist between the normal and hearing impaired groups in terms of the three measures.

2. NO significant differences exist between the results on the three measures within each of the two groups.

3. No significant differences exist between the different degrees of hearing lose in terms of the different measures among the hearing impaired individuals.

METHODOLOGY

1. Subjects:

Twenty students of the All India Institute of Speech and Hearing with a mean age of 19.5 years formed the normal hearing group. The criteria used in their selection as subjects were:

(i) Bilateral pure tone air conduction thresholds no poorer than 20dB HL (ANSI. 1969).

(ii) Presence of normal 'A' type tympanogram and acoustic reflex thresholds bilaterally.

(iii) No clinical history of otological infection or injury or hearing loss.

Twenty individuals with mild to severe degree of sensori-neural hearing loss with a/mean age of 38.8 years formed the hearing impaired group. The criteria used for selection:

(i) Elevated AC thresholds and BC thresholds with BC thresholds within ±5dB of AC thresholds in one or both ears.

(ii) Presence of 'A' type tympanogram and acoustic reflex thresholds bilaterally,

(iii) Clinical hiatory of tolerance problems, tinnitus and poor speech discrimination in noise in one or both ears.

(iv) No history of ear discharge/noise exposure/family history/ metabolic disorders/hypertension.

GSI—16 (DIAGNOSTIC)

MADSEN ZO-174 (IMMITANCE)

In all, twenty normal and twenty sensorineural impaired ears were used to obtain results for this study.

2. Test environment and Instrumentation:

Testing was carried out in the sound treated audiometric rooms of the All India Institute of speech and Hearing, Mysore. Care was taken (1) to provide adequate lighting and ventilation for the test (3) to keep the ambient noise levels within the test room well within the maximum specified levels in dB SPL as per ANSI standards (1977).

Pure tone audiometry for determination of behavioral thresholds and loudness discomfort levels was carried out using GSI-16, a two channel diagnostic audiometer with matched TDH-39 earphones and MX-41/AR ear cushions.

Immittance audiometry, to determine the acoustic reflex thresholds for this study, was done using MADSEN ZO-174, a computerized instrument with microprocessor technology with head set HS-174. TDH-39 earphones and Telephonics P/N 5100017 ear cushions. This instrument measures the acoustic immittance of the ear in terms of sound flow and regers collectively to the measures of acoustic impedance (apposition to sound flow measured in acoustic ohms) and acoustic admittance (measures of sound flow in acoustic mho). Please see photograph

3. Stimuli:

Pure tones of frequencies 500Hz. 1KHz. 2KHz and 4KHz were used as stimuli and routed through the TDH-39 transducer in both the diagnostic audiometer and the immittance audiometer.

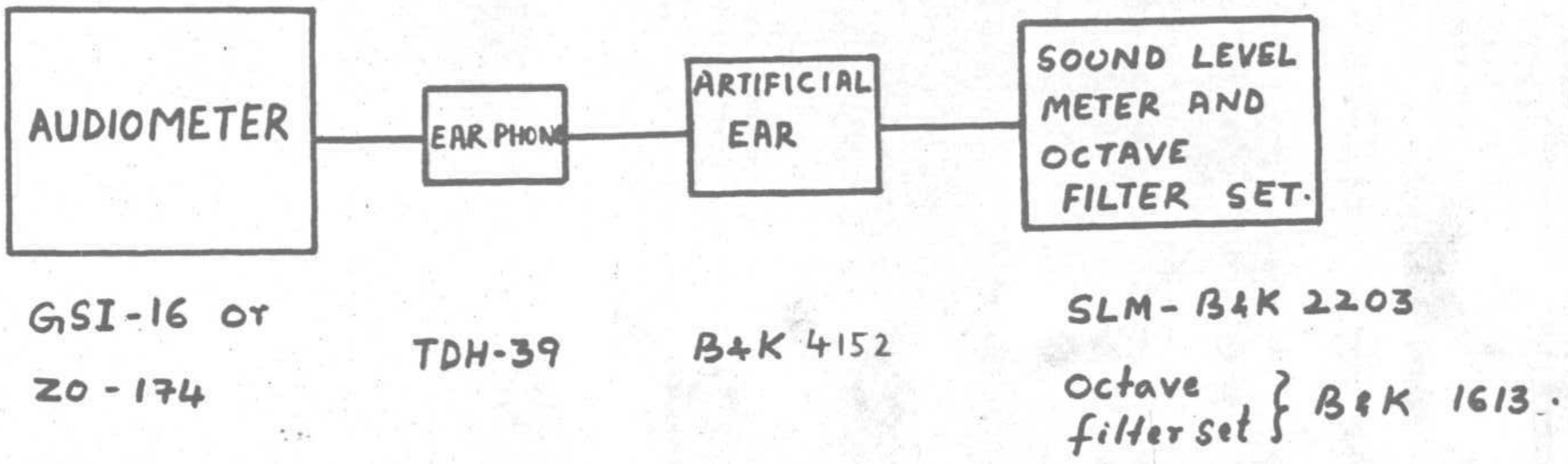
The intensity limits of the diagnostic audiometer were -1OdB to 120dB with attenuation possible in 5dB steps Intensity level of tha pue tone stimuli of the immittance audiometer is incremented automatically in 10dB steps from 70dB to 120dB.
Only low frequency probe tone of 226Hz was used for testing.

4. Calibration:

a) Diagnostic Audiometer GSI-16

(i) Listening check was carried out prior to testing for

- Cracking or wearing of earphone cords
- Loose dials
- Audible mechanical clicks
- Frequency and intensity of the stimulus



Set Up for Calibration

(ii) Biological calibration was done to obtain audiometric zero for 5 normal hearing admits periodically.

(iii) Artificial ear/coupler method.

The acoustic output is routed from the GSI-16 audiometer through the earphone TDH-39 and fed to an artificial ear with a condenser Microphone and 6cc coupler. Output SPL measured by placing the earphone on the coupler and mounting a 500 gram weight on top of the earphone. The output in dB SPL was adjusted using a sound level meter B&K 2203 and octave filter set B&K 1613(see figure).

Linearity Check was carried out in 5dB steps. Harmonic distortion was found to be within ±3% at all frequencies.

b) Immittance audiometer Z0 174.

i) Biological calibration was done by cheeking tympanograms and acoustic reflex thresholds for normal hearing adult subjects periodically to cheek air pressure calibration and avoid leakage.

ii) Electroacoustic calibration was done to ensure.

- Output SPL of the TDH-39 earphone.
- Linearity Check
- Probe tone intensity and frequency.

5. Instructions and procedure:

a) for behavioural threshold - results in dB HL "I wish to determine the lowest level of intensity at which you can detect the following pure tones. Raise your finger, even if you hear the softest signal and drop it when you no more hear it".

The procedure used for determining the pure tone behavioral threshold was the revised Hughson westlake Procedure by Carhart-Jerger i.e. increase in intensity at each frequency was in 5dB steps and decrease in intensity in 10dB steps. The frequencies tested were 500Hz, 1KHz, 3KHz and 4KHz.

b) For Acoustic Reflex Threshold - CONTRA mode result in dBKL. A probe tone with frequency of 226Hz and pure tone stimuli with intensity levels at the 4 frequencies ranging from 70dB to 120dB HL (far contralateral mode) were used for reflex testing.

The contra mode of testing was carried out to obtain the results interms of dB HL.

The following step by step procedure was used.

(1) Select the T&B (Tympanogram and Reflex) mode and CONTRA as the stimuli for the acoustic reflex.

(2) Press AUTO START whan first a tympanogram and then the Acoustic Reflex Threshold for CONTRA mode are recorded.

(3) The frequencies tested are 500Hz, 1KHz. 2KHz and 4KHz stimulus level is incremented automatically in l0dB steps from 70dB HL. to 1296B HL, until a reflex is detected.

(4) The Acoustic reflex threshold for the next frequency is automatically recorded after the CONTINUE button is pressed.

(5) The stimulus level may be changed or repeated completely by using the ERASE button.

Test retest reliability was checked wherever required.

c) For Loudness Discomfort Level (LDL) - Prior training was given with instructions to eliminate difficulty in subjective judgements. The method of limits was used. The intensity of the puretone stimuli (at frequencies 500Hz, 1KHz, 2KHz and 4KHz) were incremented la 5dB steps starting from 8OdB HL till the LDL value was obtained (The maximum audiometric limit was 120dB HL) (Morgan, Wilson, Dirks, 1974).

Following was the instructional set used in this study.

"I will gradually increase the loudness of the sound (tone) in your ear and you must indicate by (i) keeping your hand horizontally at a constant level if the loudness is the same (ii) raising your hand if the loudness is increased, (iii) lowering your hand below the horizontal level, if the loudness is reduced.

Please indicate at the very moment the sound becomes uncomfortable/intolerable by raising your finger".

This procedure was repeated in the same fashion for test retest reliability.

The sensorineural hearing loss group was divided further into four subgroups based on the degree of hearing loss pure tone average at 500Hz, 1KHz, 2KHz) as per Goodman's (1965) Scala for hearing impairment (ANSI, 1969).

	dB HPL
1. Mild	27 - 40
2. Moderate	41 - 55
3. Moderately severe	56 - 70
4. Severe	71 - 90

RESULTS AND DISCUSSION

Data were obtained from the two groups (twenty normal hearing ears and twenty sensorineural impaired ears) on the three measures viz. Behavioural threshold Acoustic reflex threshold and loudness discomfort level at the found frequencies - 500Hz, 1KHz, 2KHz, and 4KHz (Individual data provided in Tables 1 and 4)

The current design ia therefore of a 2x3x4 type as shown below:

Groups (normal and SN loss)											
Behavioral thresholds				Acoustic reflex thresholds				Loudness discomfort levels			
500 Hz	l0Hz	2KHz	4KHz	500 Hz	1 KHz	2 KHz	4 KHz	500 Hz	1 KHz	2 KHz	4 KHz

Statistical analyaia waa carried out using a sound statistical software program - NCSS (NUMBER CRUNCHER STATISTICAL SYSTEM) developed Dr.J.L.Hintze on a WIPRO P.C. system.

fallowing were the statistical operations carried out:

1. statistical summary including mean, standard deviation and minimum and maximum values - shown in table -5 Table 6 shows the normative data obtained from the current study.
2. Repeated measures ANOVA (between groups and between measures) was done as the results on the three measures

NORMAL HEARING GROUP

S.NO.	Behavioral threshold				ART (contra)				LDL			
	500Hz	1KHz	2KHz	1KHz	500Hz	1KHz	2KHz	4KHz	500HZ	1KHz	2KHz	4KHZ
1.	0	0	5	0	90	100	100	100	105	115	120	120
2.	0	0	0	0	90	90	100	100	115	115	120	120
3.	0	5	0	3	100	100	90	100	110	115	115	t20
4.	0	0	0	0	90	100	100	120	110	110	115	120
5.	5	5	0	5	100	90	90	120	105	110	115	115
6.	0	0	5	3	90	90	100	100	110	115	115	115
7.	0	0	0	5	100	100	90	100	105	105	105	115
a.	0	0	0	0	90	100	100	120	110	110	115	120
9.	5	0	0	5	100	100	100	100	105	105	105	1lO
1o.	0	0	0	5	100	100	110	120	115	115	120	120
11.	0	0	0	0	90	100	100	110	100	95	105	110
12.	0	0	0	0	90	100	100	100	110	115	115	120
13	0	0	0	5	90	100	100	100	105	105	115	115
14.	0	0	0	0	100	100	100	100	105	105	115	120
15.	0	0	0	0	90	100	100	100	105	105	110	110
16.	0	0	0	3	100	110	100	100	110	113	120	120
17.	0	0	0	0	100	100	100	110	110	110	115	120
18.	0	0	0	0	100	110	110	120	110	115	120	120
19.	0	0	0	0	100	tOO	tOO	110	110	115	115	113
20.	0	0	0	5	110	110	100	120	115	115	120	120

TABLE - III

SENSORI NEURAL LOSS

S.No.	Type	Behavivoral thresholds				ART(contra)				LDL			
		500Hz	1KHz	2KHz	4KHz	500Hz	1KHz	2KHz	4KHz	500Hz	1KHZ	2KHz	4KHz
1.	Moderate	25	40	50	60	100	100	100	115	120	120	110	120
2.	Mod.Severe	55	65	70	70	90	100	90	115	115	110	120	120
3.	Mod.Severe	65	70	65	80	100	100	90	NR	110	115	115	120
4.	Mod.severe	55	65	55	55	100	100	100	100	100	100	115	115
5.	Moderate	55	55	55	50	100	110	110	100	110	115	120	110
6.	Mod.severe	65	70	50	40	100	110	90	120	110	105	110	110
7.	Mod.severe	65	65	75	70	90	100	100	90	115	120	115	120
8.	Severe	80	75	75	70	110	120	100	NR	110	115	115	120
9.	Mild	40	45	20	20	90	110	100	NR	110	115	120	120
10.	Mod.Severe	75	75	60	60	100	100	100	110	90	95	110	110
11.	Moderate	60	55	35	30	110	110	120	NR	100	100	110	115
12.	Mod Severe	60	65	60	50	105	100	100	90	105	110	100	105
13.	Mod.Severe	65	70	70	65	110	115	100	120	105	105	95	110
14.	Mild	25	30	55	60	80	90	90	110	100	105	105	100
15.	Mild	20	35	50	55	90	90	90	100	100	100	100	100
16.	Severe	75	75	70	65	100	100	90	90	120	120	120	120
17.	Moderate	30	60	65	65	90	90	90	120	65	95	105	105
18.	Moderate	30	50	55	65	e0	90	100	120	100	105	100	100
19.	Severe	80	80	70	70	90	100	115	NR	105	110	110	120
20.	Severe	75	75	80	80	100	100	110	110	105	105	115	120

TABLE-5

Variable	Count	Mean	Standard Deviation	Minimum	Maximum
N_{THS} 500	20	0.5	1.54	0	5
H_{THS} 500	20	55	19.74	20	80
N_{ART} 500	20	96	5.98	90	110
H_{ART} 500	20	96	9.40	80	110
N_{LDL} 500	20	108.5	4.01	100	115
H_{LDL} 500	20	105.75	8.92	85	120
N_{Ths} 1000	20	0.5	1.54	0	5
H_{THS} 1000	20	61	14.47	30	80
N_{ART} 1000	20	100	5.62	90	110
H_{ART} 1000	20	101.75	8.47	90	120
N_{LDL} 1000	20	110.25	5.49	95	115
H_{LDL} 1000	20	108.75	7.76	95	120
N_{THS} 2000	20	0.5	1.54	0	5
H_{THS} 2000	20	59.25	14.35	20	80
N_{ART} 2000	20	99.5	5.10	90	110
H_{ART} 2000	20	99.25	8.92	90	120
N_{LDL} 2000	20	114.75	4.99	105	120
H_{LDL} 2000	20	110.50	7.59	95	120
N_{THS} 4000	20	2.25	2.55	0	5
H_{THS} 4000	20	59	15.27	20	80
N_{ART} 4000	20	108	8.94	100	120
H_{ART} 4000	20	110.5	11.34	90	120
N_{LDL} 4000	20	117.25	3.79	110	120
H_{LDL} 4000	20	113	7.67	100	120

TABLE-6

NORMATIVE DATA FOR ART AND LDL (in dB HL)

1. NORMAL HEARING GROUP

	500Hz	1KHz	2KHz	4KHz
ART	96	100	99.5	108
LDL	108.5	110.25	114.75	117.25

2. SENSORINEURAL LOSS GROUP

	500Hz	1KHz	2KHz	4KHz
ART	96	101.75	99.25	110.5
LDL	105.75	108.75	110.5	113

were obtained from the same set of individuals.
(Results shown in Table-7).

3. Repeated measures ANOVA (between degree of severity of hearing loss and betweem measures) was done for the SN loss group.
   (Results shown in Table-8)

4. T-tests for significance
   a) Unpaired T-test was done to determine whether any significant differences exist for (i) Acoustic Reflex Threshold (ii) loudness discomfort between the normal and SN loss groups.
      (Results shown in Table-9)

   b) Paired T-test was done within each group to determine if any significant differences exist between the measures of ART and LDL.
      (Results shown in Table-10)

5. Correlation and multiple regression:
   Following were the results obtained on analysis:
   The Objective measure of acoustic reflex threshold(ART) was taken as the independent variable and the subjective measures of behavioral thresholds and loudness discomfort level as the dependent variables.

TABLE-7

* Indicates significant

ns - indicates non-significant

	500Hz	1KHz	2KHz	4KHz
Between groups	* (F=79.70)	* (F.177.21)	* (F=145.00)	* (F=122.46)
Within groups	* (F=803.72)	* (F=1134.47)	* (F=1272.77)	* (F=995.69)
Interaction effects.	* (F=93.08)	* (F=175.41)	* (F=188.75)	* (F=137-55)

TABLE-8

* Indicates significant

ns indicates nonsignificant.

	500Hz	1KHz	2KHz	4KHz
Degree	* (F=9.84)	* (F=11.09)	* (F=11.59)	* (F=2.55)
Between measures	* ((F=208.71)	* (F=247.12)	* (F=143.43)	* (F=141.80)
Interaction effects.	* (F=6.27)	* (F#5.10)	ns (F=1.99)	ns (F=1.20)

TABLE-9: Unpaired t-test between groups.

	Normal Vs. S. N. loss			
	500HZ	1KHz	2KHz	4KHs
ART	ns (T=0)	ns (T=0.77)	ns (T=0.11)	ns (T=0.77)
MA	ns (T=1.26)	ns (T=0.70)	ns (T=2.09)	ns (T=2.22)

* indicates significant

ns = indicates non-significant.

TABLE-10: Paired T-test within groups.

	ART vs LDL			
	500Hz	1KHz	2KHz	4KHz
Normal hearing.	* Corr=0.29 T=-9.05	* Corr=0.28 T = -6.40	* Corr - 0.17 T = -12.41	* Corr=0.41 T = -4.79
Sensori-neural loss	* Corr=0.29 T=-3.98	* COrr=0.29 T=3.24	* corr=-0.08 T=-4.48	ns Corr=0.87 T=–0.84

* - indicates significant

ns - indicates not significant.

1. Frequency = 500Hz.

Dependent variable - H_{THS} (Behavioral Threshold of Hearing Impaired Group).

Independent variable - H_{ART} (Acoustic Reflex Threshold of Hearing Impaired Croup).

(i) Correlation =0.61

(ii) Regression equation:

$$H_{THS} = 1.28 H_{ART} - 67.85$$

(iii) Criterion of ±10dB - 60% correct prediction of H_{THS} from H_{ART}

2. Frequency = 500Hz.

Dependent variable - H_{LDL}.

Independent variable - H_{ART}

(i) Correlation - 0.29

(ii) Regression equation

$$H_{LDL}. = 0.27 H_{ART} + 79.46$$

(iii) ±10dB criterion: 75% correct prediction of H_{LDL} from H_{ART}

3. Frequency = 1000Hz.

Dependent variable - H_{THS}

Independent variable -H_{ART}

(1) Correlation - 0.39

(ii) Regression equation

(iii) ±10dB : 50% correct prediction of H_{THS} fron H_{ART}.

4, Frequency - 1000Hz

Dependent variable - H_{LDL}

Independent variable - H_{ART}

(i) Correlation - 0.29

(ii) Regression equation - H_{LDL}.=0.27 H_{ART} +81.24.

(iii) ±10dB Criteria - 80% correct prediction of H_{LDL},

5. Frequency = 2000Hz.

Dependent variable - H_{THS}

Independent variable -H_{ART}

(i) Correlation = -0.107

(ii) Regresion equation - sot valid.

6. Frequency = 2000Hz

Dependent variable - H_{LDL}

Independent variable - H_{ART}

(i) Correlation - 0.08

(ii) Regression equation - Hot valid.

7. Frequency - 4000Hz

Dependent variable -H_{THS}

Independent variable -H_{ART}

(i) Correlation - -0.057

(ii) Regression equation - Not valid.

8. Frequency = 4000Hz.

Dependent variable -H_{LDL}

Independent variable - H_{ART}

(1) Correlation - 0.07

(ii) Regression equation - Not valid.

The findings of the study are as follows:

1. From the repeated measures ANOVA (Table-7) it is evident that

i) In terms of the three merasures viz. behavioral threshold, acoustic reflex threshold and loudness discomfort level, there exist significant differences between the normal hearing and SN impaired groups at all frequencies tested.

ii) Between the above three measures of behavioral threshold, ART and LDL, within each of the two groups there exist significant differences.

iii) interaction effects between the measures and groups also show significant differences.

2. From the repeated measures ANOVA (Table-8) it is evident that

i) in terms of the three measures, there exist significant differences between the different degrees of severity of hearing loss, more at low frequencies,

ii) Within the hearing impaired group, **there exist significant differences between the measures at all frequencies.

iii) Interaction effects own only at 500Hz and 1KHz and not at high frequencies.

** The results seem to indicate that at high frequencies all SN loss cases, irrespsetive of degree of hearing loss behave identically.

3. Acoustic reflex thresholds (ARTs) of the SN hearing impaired group at all frequencies are similar to the Acoustic Regiex Thresholds (ARTs) of the normal hearing group (From Tables 5, 6 and 9) i.e. no statistically significant differences exist between the 2 groups. This is consistent with results obtained by Martin and Brunette (1980) who tested fifteen unilateral SN loss cases to determine the sound intensity eliciting the reflex in normal and impaired ears, and also the sound intensity in the normal ear which is equal in loudness to the intensity eliciting the reflex in the abnormal ear.

   Rangasayee (1975) repotted the stapadial reflex thresholds to be elevated in SN loss cases by approximately 10-15dB as to compensate the loudness loss resulting from the elevated pure tone thresholds.

** The results imply that loudness may not be the mediating factor in the acoustic reflex and thus the reflexes at low sensation levels observed in hearing impaired ears need not be unequivocal indicators of recruitment.

4. From Tables 5 and 6 (statistical summary and normative data) it ia evident that loudness discomfort levels (LDLs) for the SN Impaired group are consistently lower than their counter parts of the normal hearing group. (Miller, 1972; Dudich, et al. 1975).
   However, the results of the impaired T-test in Table-9 show no statistically different LDL's for the two groups. This may be attributed to the heterogeneity of the SN impaired group (evident from the large standard deviations in Table-5 and the significant differences between the degrees of SN loss in Table-8).

5. From Tables 5, and 6 and 10, it is evident that statistically significant differences exist <u>each of the normal hearing and SN impaired groups between the ART and LDL measures **</u>consistent with findings of McLeod and Greenberg (1979) who also found significant differences between the 2 measures for each of their normal and hearing impaired groups.

6. From Table 6, it is evident that presence of hearing loss on the average shifted the loudness discomfort level more than tha acoustic reflex threshold. This is unlike the results of McLeod and Greenberg (1929).

7. From the correlation and multiple regression analysis results, it is evident that:

(1) There exists a significant correlation between BTL, and LDL for the frequencies 500Hz and 1KHz but no significant correlation exists between the measures for 2KHz and 4KHz.

(2) There exists a significant correlation between the Measures of LDL and ART at 500Hz and lKHz but not at 2KHz and 4KHz.

(3) The regression equations obtained to estimate behaviour threshold from ART are:

500HZ: H_{TH} - 1.28 H_{ART} _ 67.85 H_{TH}= Behaviour threshold of hearing impaired.

1KHz H_{TH} =0.67H_{ART} . 7.27 H_{ART} - ART of hearing impaired.

2KHz = No predictive validity

4KHz = No predictive validity.

(4) The regression equations obtained to estimate loudness discomfort level (LDL) from acoustic reflex threshold (ART) are:

500Hz: $H_{LDL} = 0.27\ H_{ART} + 79.46$

1KHz $H_{LDL} = 0.27\ H_{ART} + 81.24$

2KHz: No predictive validity

4KHz: No predictive validity.

The above equation may be rounded off to a general formula:

$$H_{LDL} = 0.27\ H_{ART} + 80$$

** The above four results are consistent with the findings that the acoustic reflex attenuates middle ear transmission of energy most strongly at low fraquencies for tones greater than 100dB SPL but not for frequencies above 1500Hz (Morgan and Dirks, 1975). Hence while estimation at low frequencies ia highly predictable, the high frequencies (2KHz and 4KHz) suffer in comparison.

5. Criterion used for the range of prediction error to predict (a) Behavioral threshold from ART (b) Loudness discomfort level from ART, was ±10dB.

a) The correct estimation of behavioral thresholds from ART was not vary significant (60% and 50% respectively at 500Hz and 1KHz). This is consistent with studies by Jerger et al. (1978) who found that accurate prediction of sensorineural hearing loss is a function of the patient's chronological age. Prediction accuracy is most successful in children upto the age of 10 years and least accurate in older adults.
Hence despite thepoor rate for the adult population as given about, the equation would be highly valid for young children.

b) Correct estimation of LDL from ART was higher (75% and 80% respectively at 500Hz and 1KHz).

** The predictive equations may be used with good predictive validity to estimate the subjective thresholds of Behaviour Threshold and LDL from ART in the difficult to test group validity the multiply handicapped MR and Autistic.

** Significant.

SUMMARY AND CONCLUSIONS

The current study was carried out to explore and predict the relationship between three audiological measures viz. Behavioral Threshold acoustic reflex Threshold (ART) and Loudness Discomfort Level (LDL) in normal and sensorineural hearing impaired listeners.

Twenty normal hearing ears and twenty sensorineural ears were tested at four frequencies - 500Hz, 1KHz, 2KHz, and 4KHz.Behavioral Threshold was determined using the Modified Hughson-Westlake Procedure (Carhart and Jerger, 1959) and loudness discomfort level (LDL was determined using the psychophysical method of limits (Morgan, Wilson aad Dirks, 1974) on a diagnostic GSI-16 audiometer acoustic reflex threshold was obtained at the above four test frequencies using the contralateral automatic tympanogram and reflex (T&R) mode of an immittance audiometer Madsen ZO-174.

Statistical analysis of the above data was carried out using a statistical software program (Number Cruncher Statistical system or NCSS) en a wipro P.C. system.

The following conclusions may be drawn from this study:

1. There exist statistically significant differences between groups (normal and SB loss) and between measures (behavioral threshold, ART and LDL at all frequencies.

3. There exist statistically significant differences between the different degrees of severity of hearing loss (mild, moderate, moderately-severe and severe) and between measures within the SN hearing impaired group.

3. There exist no statistically significant differences between the acoustic reflex thresholds (ARTs) of the normal and SB hearing impaired groups.

4. There exist no statistically significant differences between the loudneas discomfort levels (LDLs) of the two groups, though mean data indicate lower LDLs for the hearing impaired group.

5. There exist statistically significant differance between the acoustic reflex threshold (ART) and loudness discomfort level (LDL) measures for each of the normal hearing and SN hearing impaired groups.

6. Presence of hearing loss on the average shifts the loudness discomfort level more than the acoustic reflex threshold.

7. There exist significant correlations between behavioural threshold and acoustid reflex threshold (ART) at 500Hz

and 1KHz but not at 2KHz and 4KHz. The regression equation obtained to estimate the behavioural threshold of an individual from ART at 500Hz and 1KHz are

500Hz: $H_{TH} = 1.28 H_{ART} - 67.85$ H_{TH} Behaviourathreshold of hearing impaired.

1000Hz: $H_{TH} = 0.67\ H_{ART} - 7.37$ H_{ART}: ART of hearing impaired

At 2000Hz and 4000Hz the regression equations do not have predictive validity.

8. There exist significant correlations between the loudness discomfort level (LDL) and acoustic reflex threshold(ART) at 500Hz and 1KHz but not at 2KHz and 4KHz.

   The regression equation obtained to estimate the loudness discomfort level of sN hearing impaired individual are:

   500Hz : $H_{LDL} - 0.27\ H_{ART} + 79.46$

   1000Hz : $H_{LDL} - 0.27\ H_{ART} + 81.24$

   At 2000Hz aad 4000Hz, the regression equations do not have predictive validity.

9. Predictive accuracy of the regression equations to estimate behavioural threshold from acoastic reflex threshold using a ± 10dB criterion is found to be only 60% and 50% respectively at 500Hz and 1000Hz.

10. Predictive accuracy of the regression equation to estimate the loudneas discomfort level (LCL) from acoustic reflex threshold using a ±10dB criterion is found to be satisfactory (75% and 80% respectively at 500Hz and lOOOHz)

Limitations:

1. The predictive validity of the regression equation is restricted to 500Hz and lOOOHz. Hence implications regarding the amount of hearing loss and required amplification at higher frequencies cannot be drawn,
2. Since only forty ears were tested, there is need to include a greater number of subjects.
3. The predictive accuracy of the regression equations is established for adults and hence needs to be validated for a population of children.
4. A significant amount of individual variability exists among data aad so information from a battery of available tests is to be weighed carefully.
5. Presence of acoustic reflex threshold is mandatory in order to obtain estimates of behavioral threshold and loudness discomfort level. Hence profound losses are not inclusive in this category.

Recommendations:

1. The above results need to be validated for a greater number of ears, particularly of the younger population.
2. Results need to be obtained from different clinical groups of SN loss such as in noise induced hearing loss, ototoxicity, metabolic disorders congenital hearing loss, retrocochlear lesions etc.
3. The validity of the LDL procedure in hearing aid selection needs to be ascertained for a variety of cases.
4. The relationship between the subjective measures of behavioral threshold and loudness discomfort with other objective measures as the latency. Intensity function (LIP) of Jewett V of ABR may be probed.

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