To My Dearest
Dad and Mum

Clinical Usefulness of Sensitivity Prediction by Acoustic Reflex (SPAR) in Evaluating Hearing in Children

A Dissertation
Presented to
University of Mysore

In partial Fulfillment
of the Requirements for the Degree
Master of Science in Speech and Hearing

by
Joan D' MeHo
May 1982

CERTIFICATE

This is to certify that the dissertation entitled CLINICAL USEFULNESS OF SENSITIVITY PREDICTION BY ACOUSTIC REFLEX (SPAR) IN EVALUATING HEARING IN CHILDREN is the bonafide work submitted in part fulfilment for M.Sc, in Speech and Hearing of the student with Register No. 6

(Dr.N.Rathna)
Director
All India Institute of
Speech & Hearing
Mysore-570 006

CERTIFICATE

This is to certify that this dissertation has been prepared under my supervision and guidance.

Date:

(M.N.Vyasamurthy)
Guide

DECLARATION

This dissertation is the result of my own study undertaken under the guidance of Mr. M.N. Vyasamurthy, Lecturer in 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. Register No. ^

Date : iy-<^-SN3

ACKNOWLEDGEMENTS

I express my gratitude to Mr. M.N.Vyasamurthy for his valuable guidance.

I wish to say "thanks" whole heartedly to Mr. S.S. Murthy who managed to find time to help me set up the instruments despite his busy schedule.

And several others who were influential throughout the course of study are acknowledged - they are, Dr.N.Rathna, who willingly granted a month's long leave for data collection, Dr. (Miss).S.Nikam, to whom I ran very often for instruments and calibrating equipment, Dr. S.R. Sabhapathy, who permitted me to test children during ENT posting, Miss M.S. Malini, who patiently scrutinized the entire written and typed scripts of this study, and my special thanks to Mr. Dayalan for all his help and encouragement at every stage of this study.

The most definitive help came from the staff of Demonstration School, Mysore Mr. T.G.Satyanarayana, Headmaster of that school who allowed me to take the children for testing. Special thanks are due to Mr. Paul Chander who really helped me in reaching the children.

Mr. E.P. Balakrishna, Mr. B.Gururaj, Mr.S.N.Raju, Mrs. Indira prpkash and Miss Jayashree helped me at various phases of this study.

Miss Suma, Miss Hema, Mr. M.S.Jagadish, Miss Shobha and Miss Viji are thanked for lending helping hands during data collection. Mr. Vasu, Asst. Librarian, CFTRI is responsible for the neat figures.

Thanks are due to Dr. L.A.Weatherby, Dr.Bennette and Dr. C.D.Chun for sending their reprints.

I thank Mr. Subbanna for his expert typing.

The deepest gratitude and appreciation goes to the most tolerant children.

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TABLE OF CONTENTS

LIST OF TABLES

List of Figures

Figure Page

Chapter 1

INTRODUCTION

Children are wonderful, special and stimulating little things. They are extremely co-operative and friendly in their natural environment. But most often it is not the case when a young one visits the audiologist. At times, for an audiologist evaluation of hearing in little ones can be challenging and often frustrating (Lamb and Dunkel, 1976; Northern and Downs, 1978). A quiet and shy child suddenly grows into an agitating, violent creature at the threshold of the audiometric rooms. Most often audiologists spend their time in taming these young ones. This is most often the case with the "easy-to-test" ones.

The frustrations are enhanced when the audiologist is called upon to evaluate hearing of a so called "Hard-to-test" child. Children do not easily wear headphones. Even if they do, they may not respond appropriately. An intelligent audiologist might soon learn to look for alternate mode of response. Although experience and insight would come in handy in most such situations (Northern and Downs, 1978) this may prove disappointing in some children.

One might be unable to draw any conclusions regarding the child's hearing based on the observations made. In

...2

behaviour observation, non-auditory response could be mistaken for auditory ones; that is, a non-auditory stimuli may accompany auditory stimuli and this may yield consistent normal thresholds for example hearing thresholds in a deaf child may be mistaken as normal thresholds which the audiologist may be unaware. Therefore, traditional approaches have limitations because they depend heavily upon the psychological status of the child.

Audiologists who have been confronted with tiring but stimulating experiences have been working hard and have designed and are designing a number of tests which would require minimum co-operation from the child.

At present, impedance and evoked response audiometry could be counted as the most favored ones by the audiologist. Favored because of their reliability and validity. Owing to its wide applicability and simplicity impedance is preferred to evoked response audiometry.

and Hayes
Jerger/(1970) have recommended a cross-check principle, i.e., whenever possible it is preferable to administer other tests such as behavioral observation audiometry and evoked response audiometry in addition to impedance audiometry.

Impedance audiometry is a highly sensitive, diagnostic tool used in the identification and differential diagnosis of middle disorders, cochlear and retrocochlear lesions and in identifying accurately brain stem lesions. It is also useful in predicting hearing loss.

Earlier studies aimed at the prediction of hearing loss in adults (Niemeyer and Sesterhenn 1972, 1974; Jerger et al, 1974). Of late, many investigators have applied this procedure to predict hearing loss in younger age groups, (Margolis and Popelka, & Wiley 1975; Abahazi and Greenberg, 1977; Margolis and Fox, 1977; Hall, 1978; Himmelfarb et al, 1978). This prediction of hearing loss seems to be extremely encouraging while testing the difficult-to-test young children (Popelka and Margolis, 1975; Jerger and Hayes, 1976; Keith, Murphy and Martin, 1976, 1977; and Niswander and Ruth, 1977).

Jerger et al., (1974) introduced "Sensitivity prediction by Acoustic Reflex" (SPAR).They reported SPAR could detect hearing loss with reasonable accuracy. This stimulated a number of investigators employing SPAR as an objective measure of evaluating hearing in children (Jerger et al., 1978; Hall, 1978, 1980; Himelfarb et al., 1978; Hall and Bleakney 1981). While the original SPAR (Jerger et al. 1974) has been employed by a few, some others have made use of modified SPAR and the rest used some other novel methods like regression equations and a bivariate plot co-ordinate system (Hall and Bleakney, 1981).

In essence all SPAR methods depend upon the basic principle that hearing thresholds can be detected using

...4

noise-tone-difference in acoustic reflex thresholds. SPAR helps in predicting magnitude of hearing loss and regression equation helps in predicting hearing threshold level in decibel.

Hearing loss prediction by acoustic reflex is affected by degree of hearing loss (Jerger et al., 1974; Kieth, 1977; Hall, 1978), central auditory dysfunction (Margolis and Fox, 1977), age factor (Schwartz and Sanders, 1976; Handler and Margolic, 1977; Kieth, 1977; Margolis and and Fox, 1977; Hall, 1978; Jerger et al, 1978; Norris, 1980) minor middle ear dysfunction (Jerger et al, 1978; Hall, 1978, 1980; Hall and Weaver, 1979), and time error (Jerger et al, 1978).

There is evidence to the reduced accuracy of predicting hearing levels based on noise-tone difference (Jerger et al, 1978). Accuracy is better in children than in adults, especially the normal hearing levels (Jerger et al, 1978; Norris, 1980).

Keeping this in mind, this study was restricted to children. As we all know that prediction of hearing loss is more essential in children than adults, an Audiologist responsibility in testing young children does not terminate at the audiologic test suite, but actually begins (Murphy and Shallop, 1978).

...5

It is felt that there is a great need to study the usefulness of SPAR in predicting hearing loss in young children in India. Hence the study was taken up.

In India, no study has concentrated on SPAR in young children although some investigators have attempted to predict hearing loss using acoustic reflex (Raghunath, 1977; Sudha Murthy, 1980).

Objective of the study.

This study wag undertaken to find answers to the following questions.

1. Do the children exhibit low reflex thresholds for broad band noise than for acoustic reflex thresholds for pure tones.
2. Can the difference between reflex thresholds for pure tone and the reflex threshold for broad-band noise be used to predict thresholds of hearing in children with sensori-neural hearing loss.
3. Can a criteria based on pure-tone reflex thresholds, broad-band-noise reflex threshold be established for normal hearing and children with hearing loss.

Brief plan of the study:

Thirty-six children served as subjects (19 males and 17 females). All had normal hearing thresholds 20 dBHL at octave frequencies 250 Hz to 8000 Hz.(ANSI,

...6

1969). The subjects were in the age range of 5 to 10 years. Three subjects with moderate sensori-neural hearing loss were also tested to check if they could be distinguished from the normal hearing group. The subjects selected met the following criteria, A-type tympanogram normal compliance, reflex thresholds at normal hearing levels and with a negative history of any ear complaints. Pure-tone thresholds were obtained using modified Hughson-Westlake procedure(Carhart and Jerger 1959). Tympanometry, static compliance and reflexometry for pure-tones and broad-band noise were determined. From the existing relationship between acoustic reflex threshold for pure-tones and broad-band-noise the auditory sensitivity using the unweighted SPAR method was used. The criteria for prediction is the 1977 SPAR. The data thus collected is analysed statistically to judge the validity of this technique.

Constructs used in the study:

1* Pure-tone: is a sound produced by an instantaneous sound pressure which is a simple sinusoidal function of time.

2* Broad-band Noise: is a sound in which energy is present over a wide range of frequencies with equal energy per cycle.

3. Hearing Level (HL): refers to dial reading of the audiometer. Here the audiometric zero is taken as the reference.

...7

4. Sound pressure Level (SPL): is an expression of pressure of the sound with reference to 0.0002 dyne/cm^2.

5. Critical band; is the restricted band of frequencies surrounding a pure tone. When the SPL of the tone and noise are equal, the tone is barely perceptible.

6* Pure-tone threshold: is the least audible sound pressure level often defined as the level of a sound at which it can be heard by an individual 50% of the time.

7. Acoustic Reflex Threshold (ART): is the intensity in dB SPLs which is just capable of inducing a reflex contraction of stapedius muscle as induced by compliance change in the impedance of the tympanic membrane (Jepsen, 1963).

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* taken from Pedcrick N Martin: Introduction to Audiology, Englewood Cliffs, N.J: Prentice-Hall, 1975^. ^ ,

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Chapter 2

REVIEW OF LITERATURE

The concept of predicting hearing loss from acoustic reflex had its beginning in 1972 at Budapest where Niemeyer and Sesterhenn introduced it. However, the report of this finding was published in 1974 (Popelka, 1981). This came in handy for hearing specialists who were looking for a non-behavioral, non-invasive, inexpensive method of hearing measurement (Popelka, 1981) and generated great enthusiasm all over the world of hearing specialists. This was followed by several conferences and journals which developed their major focus to this novel procedure. And at present, it is considered as an essential part of hearing evaluation.

Though initial attempts were only on adults (Niemeyer and Sesterhann, 1974; Jerger et al 1974a), recent interest is on children as evidenced by the abundant literature (Margolis and Popelka, 1975; Jerger and Hayes, 1976; Keith et al 1976; 1977; Abahazi and Greenberg, 1977; Margolis and Fox, 1977; Niswander and Ruth, 1977).

Basic principle:

Acoustic reflex threshold level is systematically related to the band width of stimulus. For tonal stimuli, the reflex threshold remains constant for normal ears and upto 30 or 40 dB HL in ears with hearing loss. After 40 dB HL the reflex threshold for tone is almost directly related to magnitude of hearing loss. For broad-band-noise, the reflex threshold is directly related to hearing level upto 60 dB HL and thereafter it is relatively constant (Popelka, 1981).

In a normal ear, broad-band-noise or white noise can elicit acoustic reflex threshold at 20 to 25 dB lower than the levels required with tonal stimuli. This is known as Noise-tone-difference (NTD) and was reported in 1960's (MØller, 1962; Fisch and Schulthers, 1963; Dallos, 1964; Lilly, 1964; and Djupesland et al, 1967) and carefully defined by Deutsh, 1972; Peterson and Liden, 1972; Mythili, 1976; Hall, 1980). Niemeyer and Sesterhenn (1974) made use of noise-tone-difference for the reflex thresholds to predict hearing loss.

Another concept used for predicting hearing loss is the critical-band concept; that is, the acoustic reflex threshold does not change for a frequency within a particular band width. Expansion of band width beyond 'critical band width' results in better acoustic reflex threshold. This is also true for pure-tone threshold. In case of sensori-neural hearing loss there is widening of critical bands plus there is a high frequency hearing loss. Hence, the NTD is reduced in ears with sensori-neural hearing loss (Niemeyer and Sesterhenn, 1974;

...10

Jerger et al, 1974a; Djupesland et al, 1975; Mythili, 1976; Popelka et al, 1976; Schwartz and Sanders, 1976; Hall, 1978; Jerger et al, 1978a; Hall and Weaver, 1979; Hall and Bleakney, 1981; Popelka, 1981).

Based on the above principles four methods for predicting hearing loss has emerged.

1. Estimating hearing level for specific tonal stimuli (Baker and Lilly, 1976; Raghunath, 1977; Sesterhenn and Breuninger, 1977; Rizzo and Greenberg, 1979).
2. Estimating average hearing loss (Niemeyer and Sesterhenn, 1974).
3. Estimating magnitude and configuration of hearing loss (Jerger et al, 1974a;).
4. Differentiating normal hearing from sensori-neural hearing loss (Popelka and Trumpi, 1976; Handler and Margolis, 1977; Margolis and Fox, 1977).

1. Estimating average hearing loss:

Niemeyer and Sesterhenn 1974 reported of an approach to estimate hearing loss. The basis for this method is, the difference between reflex thresholds for tone and broad-band-noise in relation to average hearing sensitivity. One group of normal hearing and another group of varying degree of sensori-neural hearing loss were the subjects of the study. They determined reflex thresholds for tones from 500 to 4000 Hz. (octave frequency) and for broad-band noise. They did not report reflex thresholds

...11

as a function of hearing level. They expected the difference between reflex thresholds for tone and noise to be 17 dB. And this 17 dB, decreased linearly as hearing loss increased. The difference between hearing sensitivity for tones and reflex thresholds for tones also decreased linearly in relation to hearing loss. The rate at which these two functions differed is by a factor of 2.5 . Using this, they introduced a formula.

Hearing Threshold = pT AR - 2.5(PT AR - WB AR)

where

PT AR - average acoustic reflex threshold for frequencies 500 to 4000 Hz. in dB's (ISO, 1964)

WB AR - Acoustic reflex threshold for broad-band noise in dB HTL where Zero dB HTL is equal to 22 dB SPL

Limitations:

1. It is valid in case of normal and moderate sensori-neural hearing loss.
2. The multiplication factor covers a wide range and can introduce error (Popelka, 1981).
3. They tested only one ear and hence between individual and between ear variation was seen.

Also, these investigators employed another technique of low-pass and high-pass broad-band noise instead of wide range broad-band noise. Accuracy of this method was not reported. However, errors in prediction are reported (Keith, 1977; Margolis and Fox, 1977) such as normal hearing being identified as hearing loss or over estimation of

...12

mild-to-moderate loss.

2. Estimating hearing level for specific tonal stimuli:

Sesterhenn and Breuninger (1977) suggested a different approach towards threshold prediction which is the modification of Niemeyer and Sesterhenn's method. They proposed that by using a preactivating stimulus of 6 to 8 KHZ., threshold can be obtained at a lower sensation level. First, the intensity of the tone is adjusted such that it elecits a reflex. Then the test tone and the 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 difference between the normal and the reduced reflex threshold varied from 30 dB at 0.125 Hz. to 20 dB at 4000Hz. in normal hearing subjects. The difference between the two reflex thresholds (with and without preactivation) is termed as dl_2 .

The difference between the hearing threshold and the normal reflex threshold is called dl_1 . The formula used is:

$$\text{Threshold}_{(F)} = \text{SRT}_{(F)} - k \quad \text{SRT}_{(F)} - \text{SRT}_{(F8KHz)}$$

where

Threshold (F) - Threshold for a particular frequency

$\text{SRT}_{(F)}$ - Stapedius Reflex Threshold for test frequency

k - Multiple for the test frequency

$\text{SRT}_{(F6\text{ or }8KHz)}$ - Stapedius Reflex Threshold in presence of preactivating stimulus, i.e. 6 or 8 KHz.

...13

The k values vary with frequency.

k - 2.75 for frequencies 250 and 500 Hz.

k - 3 for 1000 Hz.

k - 3.5 for 2000 Hz.

k - 4 for 4000 Hz.

The overall accuracy of this method is test in normals and profound sensori-neural hearing loss subjects and least accurate in moderate sensori-neural hearing loss. The results are similar to that reported by Niemeyer and Sesterhenn (1974) and Jerger et al, (1974a)

Raghunath (1977) did a similar study. This will be discussed in detail a little later.

Baker and Lilly (1976) method is commonly known as Regression Equation. They studied 125 hearing impaired adult population. A formula was constructed using acoustic reflex threshold obtained for broad-band noise and tones of 500 Hz., 1000 Hz., 2000 Hz. and 4000 Hz. The noise and tone signals were weighted diffrentially according to their contribution of the hearing threshold level prediction. Their original formula is:

dB HTL = 1.11ART BBN SPL - 0.81 ART 500 Hz.(HL)+ 0.85 ART
1000Hz.(HL) - 0.43 ART 2000 Hz.(HL)+ 0.25 ART
4000 Hz.(HL) - 64.7

where,

HTL = Hearing Threshold Level
BBN = Broad Band Noise Level
SPL = Sound pressure level
HL - Hearing level

...14

The difficulty with the above formula was that majority of the subjects with hearing impairment do not exhibit acoustic reflex threshold at 4000 Hz. and makes it invalid. Lilly (1977) introduced a new set of predictive equations for single signal or various combinations of acoustic reflex thresholds of 500, 1000 and 2000 Hz.

For accurate predictions, he advised the use of many reflex threshold values. Also separate equations for traditional pure-tone audiometry prediction was also developed.

Rizzo and Greenberg (1979) have computed a best formula after developing series of regression equations. That is -

$$\mathrm{dB\ HTL} - 0.216\ \mathrm{ART\ HPN\ SPL}) - 0.078\ \mathrm{ART}\ 500\ \mathrm{Hz}\ (\mathrm{HL})^2 - 7.515^2$$

where,

HPN = High Pass Noise 1800 to 6000 Hz.

ART = Acoustic Reflex Threshold

HTL = Hearing Threshold Level.

All these methods have the ideal of predicting hearing threshold level in dB. Also the median error is reported to be very less. Zero dB in the case of Lilly, (1976) and -2dB in case of Hall, (1978). According to Hall, (1978), a closer examination of these regression

...15

equations have really not overcome the "false-positive" encountered by Niemeyer and Sesterhenn (1972) approach. With normal hearing, it predicted mild loss (false-positive) and underestimated severe losses (false-negative). The exact source of error in these equations is unclear. There may be two fundamental problems in this approach.

That there is a linear relationship between the hearing threshold level and relative acoustic reflex threshold levels for noise and tones. According to Jerger et al, 1972; Hall and Weaver, 1979, there is no linear relationship between sensori-neural hearing loss and the acoustic reflex threshold. That is, with increasing hearing loss, acoustic reflex threshold for broad-band noise becomes worse while for pure-tones they are constant or may be improved for hearing loss of 45 or 55 dB HTL. Therefore, linear regression equation with sensori-neural hearing loss gives unequivocal results. They consider only one broad-band noise threshold for four pure-tone factors which is also a factor influencing broad-band noise as a predicting factor (Hall, 1980)

2. The population they used was not homogenous in terms of degree of sensori-neural hearing loss or for chronological age.

May be the regression equations are effective in predicting hearing loss in children and are less effective in its use with adults.

...16

3. Estimating Magnitude and configuration of hearing loss:

Jerger et al (1974a) proposed a new method for predicting hearing loss which was termed as SPAR. They tested 1156 subjects with an age range of 3 to 91 years. They obtained acoustic reflex thresholds for pure tone and broad band-band noise. On 113 subjects, they also determined the low pass and high pass reflex thresholds. They named the formula unweighted SPAR.

$$D = PT\ AR - WN\ AR + C$$

where

PT AR - is pure tone acoustic reflex threshold at 500, 1000 and 2000 Hz. divided by 3

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

C - is the correction factor

In 1974, Jerger et al proposed the weighted formula. They used the Madsen Z073 electroacoustic bridge with a filter cut-off at 2600 Hz. for low and high pass noise.

$$D = \frac{1 + m + n}{3}$$

where

1 = average reflex threshold in SPL for 500, 1000 and 2000 minus reflex threshold for broad-band noise

m = Acoustic reflex threshold in SPL for 500 Hz. minus Reflex threshold for broad-band noise

n = The lowest acoustic reflex threshold in SPL among 500, 1000 and 2000 Hz. minus reflex threshold for broad-band noise.

A biological correction factor is added to the difference score D.

...17

Interpretation: Normal hearing subjects obtained a difference of 20 or more. Mild-to-moderate hearing loss subjects obtained a score of 10 to 19. Severe sensori-neural hearing loss group obtained a score of 10 or less. If the D (Noise-tone difference) was zero or less, it was suggestive of profound sensori-neural hearing loss.

The difference between low pass and high pass reflex thresholds were used to determine slope of the loss. If the difference was positive, it indicated flat loss. A difference ranging from -1 to -5 meant a steep slope.

The frequencies 1000 to 4000 Hz. were considered to assign the type of configuration. A 5 dB difference in this frequency region was considered as flat loss. A difference of 6 to 40 dB is considered as gradual slope. A difference greater than is categorized as steep slope.

The biological correction factor has to be computed in each clinic for their respective electro-acoustic instrument. To obtain this correction factor Jerger et al (1974a) recommends that reflex thresholds for pure-tone and noise should be obtained on 10 young normal hearing subjects. The difference between acoustic reflex threshold for 500, 1000 and 2000 Hz. and broad-band noise should be subtracted from 25 the original norm. The value obtained is the correction factor for the electro-acoustic instrument in use.

...18

The 1974 SPAR criteria is interpreted as follows:

From Jerger et al, 1974a

Noise-tone difference	Broad-band noise in dB SPL	Prediction
≥20	Anywhere	Normal
15-19	< 80	Normal
15-19	> 80	mild-to-moderate
10-14	Anywhere	mild-to-moderate
< 10	< 90	mild-to-moderate
<10	> 90	Severe
Reflexes not observed		Profound

The degree of hearing loss is categorized as for SPAR interpretation:

From Jerger et al, 1974a

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

The original SPAR was revised by Hall (1978) and it is referred to as 1977 SPAR. The 1977 SPAR takes into account absolute reflex threshold for 1000 Hz. tonal stimuli.

...19

The 1977 SPAR criteria is as follows:

From Hall, 1978

Noise-tone difference	Broaa-bana noise	Prediction
≥20 and 1000 Hz. ART ≤ 95 dB HL	Anywhere	Normal
<20 or 1000 Hz. ART>95 dB HL	≥95dB SPL	mild-to-moderate
<20 or 1000 Hz. ART>95 dBHL	>95dB SPL	Severe

According to this criteria, this method takes into account the absolute reflex threshold for 1000 Hz. A threshold of more than 95 dB HL at 1000 Hz. always predicts a loss regardless of acoustic reflex threshold for broad-band noise. So, if one has tobe predicted as normal hearing, he requires an NTD 20 and 1000 Hz. reflex threshold of 95 dB HL or less. If either of these criteria is not met or none of these is met, then consider the acoustic reflex threshold for broad-band noise. If it is 95 dB SPL or more, then mild-to-moderate loss is predicted. If the acoustic reflex threshold for broad-band noise is more than 95 dB SPL, it is suggestive of severe hearing loss.

SPAR seems to be a clinically popular method as revealed by the number of published reports. The accuracy rate of SPAR is 65 to 70%. Moderate errors occur at the rate of 25-35%. In 2 to 5% of the population, serious errors occur. False-positive errors also occur. The in-

...20

clusion of 1000 Hz. reflex threshold criteria in 1977 SPAR eliminates serious under-estimation of hearing loss (Hall, 1978).

4. Differentiating normal hearing from sensori-neural hearing loss:

Bivariate Plot Co-ordinate system:

It was introduced by Popelka, Margolis and Wiley in 1976. This method also uses two stimuli - pure-tones and noise. It permits prediction of hearing sensitivity in different frequency regions. The bivariate plot method refined further by other investigators (Handler and Margolis, 1977; Margolis and Fox, 1977). The Niemeyer and Sesterhenn method, SPAR and regression equation are based on absolute or relative differences between acoustic reflex threshold for tone and noise. But the bivariate plot method employs a noise-tone ratio.

Rationale: Reflex threshold for normal ears differed from sensori-neural ear in 2 ways (Popelka et al, 1976). Therefore,

1. Reflex thresholds tended to be elevated in the frequency region of the sensitivity loss.
2. Increased signal band width seemed to have relatively less effect on acoustic reflex thresholds in sensori-neural ears.

The bivariate plot method incorporates simultaneously these two above mentioned changes in the reflex thresholds.

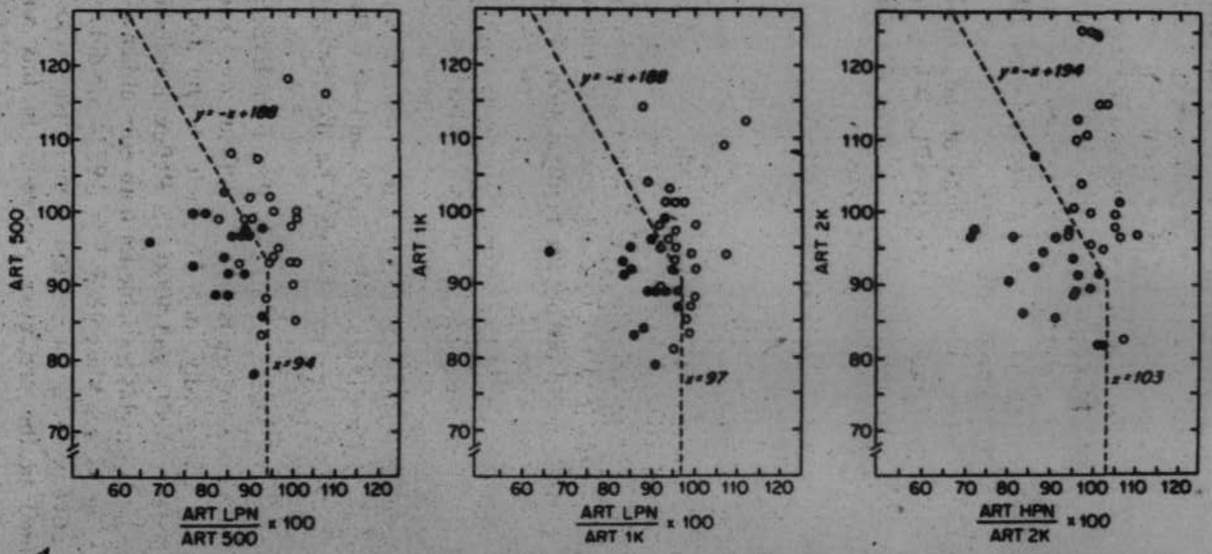

Fig. 1 Bivariate plots. ART 500, ART 1K, and ART 2K = the acoustic-reflex threshold in dB SPL for 500, 1000, and 2000 Hz, respectively. ART LPN and ART HPN = the acoustic-reflex threshold in dB SPL for low-pass and high-pass noise respectively. Filled circles = normal ears. Open circles = average sensorineural hearing loss ≥ 32 dB. (Reprinted from R. H. Margolis & C. M. Fox, "A comparison of three methods for predicting hearing loss from acoustic reflex thresholds," *Journal of Speech and Hearing Research* 20:241–253, 1977.)

As shown in figure (1), the vertical axis represents acoustic reflex threshold in SPL for a given tone and the horizontal axis represents 100 times the ratio of the acoustic reflex threshold (SPL) for a noise band and acoustic reflex threshold (SPL) for a tone (Hall, 1980).

In a sensori-neural hearing loss case, elevation of noise reflex threshold and tone reflex threshold will increase the noise-toneratio and therefore the reflex value shifts outward on the abscissa. By plotting these values, the sensori-neural hearing loss subjects cluster in the upper right portion of the graph while, normals cluster in the left lower portion of the graph. The line separating the two regions is the intersection of two line segments. According to Handler and Margolis, (1977) the X-segment value is referred to as K_1 and Y segment values as K2. This is obtained for 500, 1000 and 2000 Hz.

To increase its accuracy, a threshold for low-pass noise (frequencies below 2600 Hz.) is used in the noise-tone ratio for 500 and 1000 Hz signals while, high-pass noise (frequencies above 2600 Hz.) is used for 2000 Hz. signal. The 4000 Hz. is not used as it does not increase the efficiency of the technique. So only the patients acoustic reflex threshold data for 500, 1000 and 2000 Hz. are plotted in the 3 graphs.

...22

According to Margolis and Fox 1977, the bivariate plot indicates

1. Only a loss but not the degree of loss as in SPAR and Nimeyer and Sesterhenn methods. Normal range is upto 32 dB. Hence mild loss cases go undetected.
2. Hearing loss of sensorineural type varies with frequency. Predictions at each frequency is helpful but 4000 Hz. is a common region for sensori-neural loss which is not included here.
3. False-positive is relatively minimized. That is, False-Positive was only 6% (Margolis and Fox, 1977). But false-negative findings is usually high.
4. The usefulness of this method has not yet been standardised using a large clinical population.

In addition to above, the bivariate plot method gives inadequate information about sensorineural hearing loss, when the behavioral thresholds are inconsistent due to functional loss in adults. Also, hearing loss scale is dichotomized and the intersecting lines and slope of the line segments are determined by interception and not by any formal optimisation method (Hyde et al, 1980).

Factors influencing prediction of hearing loss:

There are 5 factors which have serious effects on hearing loss prediction. They are;

1. degree of loss.
2. minor middle-ear disorders.
3. central auditory disorder.

... 23

4. Time error
5. Age

1. Effect of loss: There is some percentage of under or over estimation of hearing sensitivity by the methods used for prediction of hearing loss. Prediction of normal or severe or profound sensori-neural hearing loss is done with greater accuracy by SPAR. More errors occur for mild or moderate loss prediction (Jerger et al, 1974a; Schwartz and Sanders, 1976; Keith, 1977; Tsappis, 1977; Van Wagoner and Goodwine, 1977; and Hall, 1978).

Niemeyer and Sesterhenn equation makes similar predictions as SPAR (Keith, 1977).

The bivariate plot system identifies sensori-neural hearing loss from normal hearing subjects with minimum predictive errors than methods based on NTD (critical band phenomenon) [Schwartz and Sanders, 1978].

2. Effect of Minor Middle-ear disorders: The criteria of normal middle-ear suggested by Jerger (1970, 1972) is a A-type tympanogram with a distinct peak at or near normal atmospheric pressure (0 to -100 mm.H_20 pressure). Normal static compliance range of 0.03 to 1.60 cm^3 . Reflex thresholds for pure-tones can be elicited at 85 to 95 dB HL. And reflex threshold for broad band noise at 65 to 85 dB SPL.

Minor middle ear disorder affecting prediction of hearing loss is a factor of recent origin. The two common minor middle ear problems are relatively compliant tympano-

...24

gram and slight negative middle ear pressure. These are likely to elevat reflex threshold for noise and tone. The minor middle ear disorder influence NTD which in turn decreases the predictive accuracy.

Hall and Weaver, (1979) reported contralateral reflex threshold elevation due to high compliant middle-ear systems. Pure-tone acoustic reflex threshold were elevated by 3-5 dB, and acoustic reflex threshold for broad-band-noise were elevated by 2-5 dB. Findings in this study for pure-tone signals agreed with Martin and Combs (1974) earlier report.

Hall (1978) studied the effect of highly compliant tympanic membrane on 1974 and 1977 SPAR. He found over-estimated predictive accuracy of hearing loss due to minor middle ear disorder. But this did not affect the accuracy of Baker and Lilly equation, the reason for this is not available. The possible reason attributed is that regression equation does not depend on the NTD or absolute levels of any acoustic reflex threshold strictly and hence minor middle ear disorders does not influence the hearing loss.

In short, minor middle-ear problems may seriously reduce the accuracy of predictive methods based on NTD and absolute reflex thresholds.

...25

3. Central auditory disorder and its effects:

A brain stem lesion primarily affecting lower brain stem auditory nuclei and pathways will exhibit elevated or absent acoustic reflexes on contralateral stimulation (Griesen and Rasmussen, 1970; Borg, 1973; Colletti, 1975; Bosatra, Russolo, Poli, 1976; Jerger and Jerger, 1977; and Jerger, Jerger, Hall, 1979). This elevated reflex threshold affects prediction of hearing loss. There is no report of central auditory disorder (CAD) on acoustic reflex threshold for tones and noise. In CAD, bearing loss prediction by acoustic reflex must be interpreted cautiously (Hall, 1980).

4. Time Error:

Jerger et al (1978a) reported that time error is also a factor influencing prediction of hearing level from acoustic reflex. Usually, acoustic reflex threshold for pure-tones and then for broad-band noise is obtained. The sensitivity of the apparatus or reflex magnitude might change due to swallowing, gradual loss of hermetic seal and body movements. This influences the reflex threshold measurement.

5. Effect of Age;

The chronologic age influences (1) Pure-tone sensitivity (Bunch 1929; Goetzinger et al, 1961; and Hayes and Jerger 1979 (a.b.); (2) Speech understanding (Gaeth, 1948; Goetzinger et al, 1961; Pestalozza and Shore, 1955; Jerger, 1973; and Hayes and Jerger, 1979a) and (3) auditory brain

...26

1. Owing to the highly compliant tympanic membrane which acts as a shunt for low frequencies and thus hinder reflex change.
2. May be because of a high acoustic resistance of the neonates ear.

In short, there is no lower age limit for reflex elicitation, provided appropriate probe frequencies are used.

The effect of age on acoustic reflex threshold for tone and noise causes reduction in the NTD (Hall, 1978; Jerger et al, 1978). Because of this age effect on NTD, the predictive accuracy of SPAR technique decreases. On the other hand, Baker and Lilly regression equation is not strictly based on NTD. Hence age effect is less while using this method.

SPAR method shows an age effect for 0 to 20 years. SPAR accuracy was tested as a function of age in 537 subjects. All subjects had normal hearing, ie., 25 dB from 250 to 8000 Hz., and normal middle ear function. Results of this particular study showed that SPAR is more accurate in youngest group and accuracy decreases as a function of age unlike adult population (Hall, 1978; Jerger et al, 1978).

Himelfarb et al (1978) report that the difference between wide-band noise and the average tonal reflex

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...26

stem response (ABR) (Beagley and Sheldrake, 1978; Rowe, 1978; Stackard, Stackard, Sharbough, 1978; and Thomsen, Terkildsen, Osterhanmmel, 1978). The effect of acoustic reflex measurements is not excluded (Hall, 1981).

Acoustic reflex threshold measurement with a 220 Hz. probe tone on one week old neonates showed that acoustic reflexes could not be elicited in most of them (Alfred, Mc Candless and Weaver, 1974; Bennett, 1975; Keith, 1973; Keith and Bench, 1978; Stream, Stream, Walker and Breningstall, 1978). Also experiments done during first year of life also failed to elicit reflexes or differentiate reflexes from artifacts (Abahazi and Green-berg, 1977; Dedmon and Robinette, 1973).

Himelfarb, Shanon, Popelka and Margolis (1978) used a modified equipment and reported that acoustic reflexes could be elicited in neonates using a 220 Hz. probe-tone but they found that the acoustic reflexes were slightly elevated.

Weatherby and Bennett (1980) experimented on 44 neonates aged 10-169 hours using 220 Hz. to 2000 Hz. probe tones and broad-band noise. They found that mean acoustic reflex threshold decreases from 77.3 dB SPL at 400 Hz. to 66.2 dB SPL for 2000 Hz. tone. The data of these investigators show that acoustic reflex is alive and present at birth and can be used for predictive or diagnostic use. The absence of reflex with a 220 Hz probe tone is because

...27

1. Owing to the highly compliant tympanic membrane which acts as a shunt for low frequencies and thus hinder reflex change.
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In short, there is no lower age limit for reflex elicitation, provided appropriate probe frequencies are used.

The effect of age on acoustic reflex threshold for tone and noise causes reduction in the NTD (Hall, 1978; Jerger et al, 1978). Because of this age effect on NTD, the predictive accuracy of SPAR technique decreases. On the other hand, Baker and Lilly regression equation is not strictly based on NTD. Hence age effect is less while using this method.

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Himelfarb et al (1978) report that the difference between wide-band noise and the average tonal reflex threshold is about 23 dB in infants and 9 dB in neonates. In the Niemeyer and Sesterhenn (1974) and Jerger et al (1974) methods rely on a difference of 15 to 25 dB between acoustic reflex thresholds for noise and tonal stimuli in normal ears. Hence these two methods are not useful in auditory screening in neonates.

Hall and Bleakney (1981) found the 1977 SPAR makes more accurate predictions in older age group. Age effect was slight for 1974 SPAR. Of the regression equations, Rizzo-Greenberg regression method showed the greatest age related decrease.

In essence, SPAR studies are more accurate in very young children.

Earlier Indian Studies:

As it is, the number of studies in India on Impedance Audiometry is rare. Rarer still is the number of studies related to prediction of hearing loss.

Mythili (1975) made the initial attempt in this area. She made a comparative study of reflex thresholds for pure-tones, narrow-band noise and wide-band-noise in 100 normal hearing and 15 subjects with moderate sensori-neural hearing loss. She reported mean reflex threshold for pure-tones was around 90.12 dB SPL and for wide-band noise around 66.7 dB SPL. She observed reduced noise-tone difference in subjects with sensori-neural hearing loss.

... 29

Raghunath (1977) made an attempt to standardize Niemeyer and Sesterhenns formula. He found that it yielded large number of false-positive errors. Hence he computed new multiplication factors which were frequency specific.

Sudha Murthy (1980) assessed the usefulness of SPAR in 30 normal hearing subjects who ranged from 11.7 to 25 years of age. She used both weighted and unweighted formulas. She reported 98.44% accuracy with weighted formula and 93.75% with unweighted formula.

As the review suggests there is a great need for prediction of hearing loss in young children. Fortunately the accuracy is more in young children. Hence the present attempt.

Chapter 3

METHODOLOGY

The methodology was planned to determine normative data for sensitivity prediction by acoustic reflex (SPAR) for Indian Children.

Subjects:

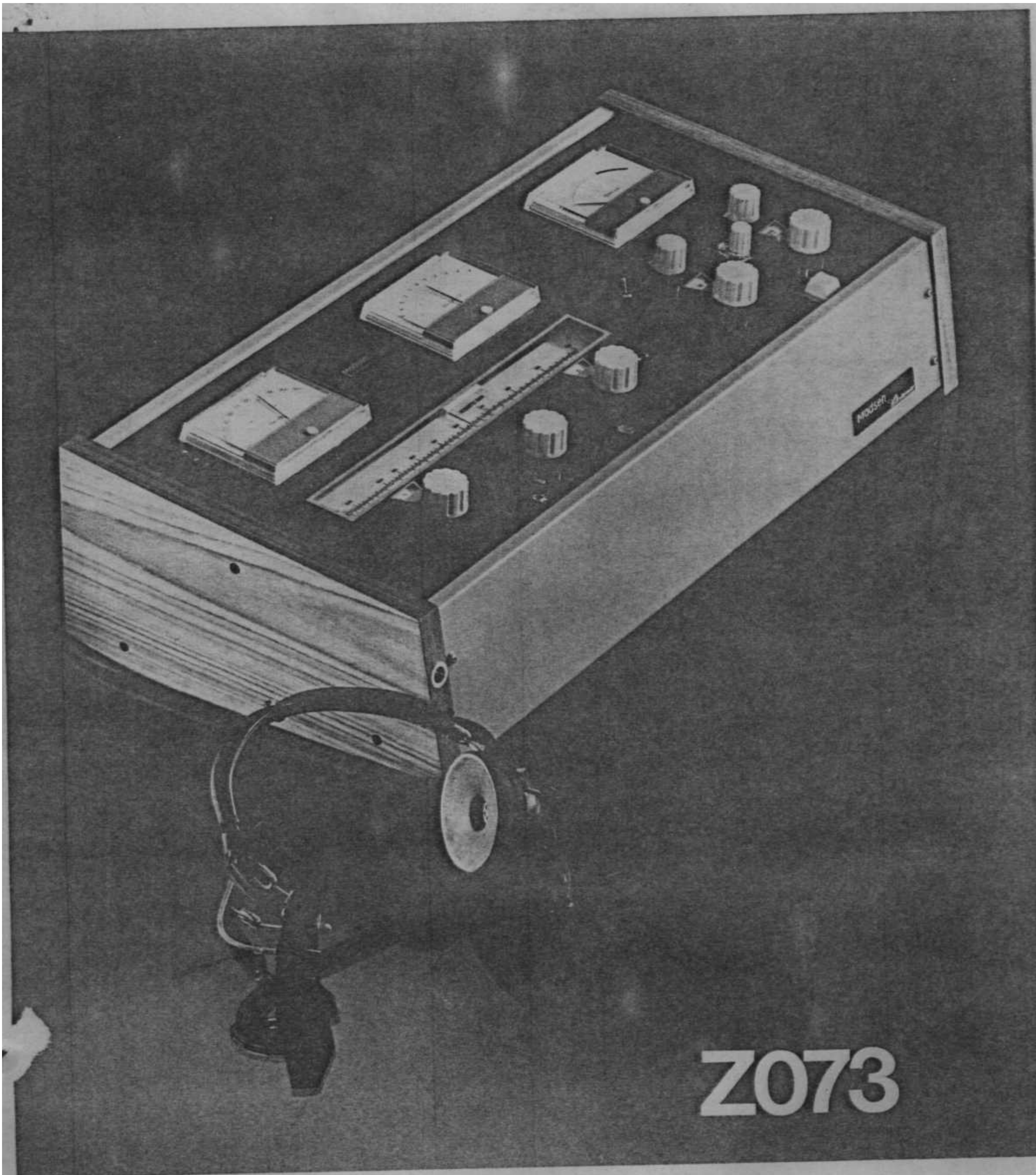
Thirty-six children served as subjects (19 males and 17 females). All had normal hearing thresholds 20 dB HL at octave frequencies 250 Hz to 8000 Hz (ANSI, 1969). The subjects were in the age range of 6 to 10 years. Three subjects with moderate sensori-neural hearing loss were also tested to check whether they could be distinguished from the normal hearing group. The subjects were selected if they met the following criteria.

1. A-type tympanogram in both ears.
2. Middle ear pressure within - 50 mm. H_2O
3. Normal Acoustic Reflex Thresholds in both ears.
4. Negative history of ear infection or ear injury

Identical equipment, environment and procedure was used with each subject.

Apparatus:

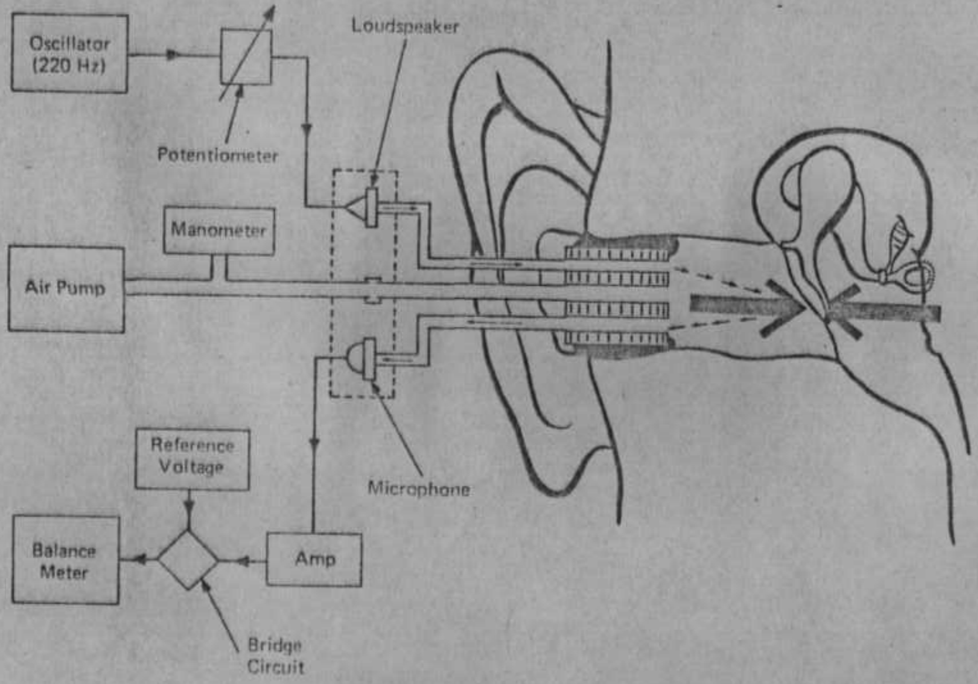
All impedance audiometric testing was done using an electro-acoustic impedance bridge. For tympanometry, the impedance bridge (Madsen Z073) was used in conjunction



Z073

Madsen
Electronics

Fig 2a.b.


Oscillator (220 Hz)
Potentiometer
Loudspeaker
Manometer
Air Pump
Microphone
Reference Voltage
Balance Meter
Amp
Bridge Circuit

with X-Y plotter (Hewlett Packard 1012). Contralateral reflexes were elicited using Telex 1470 earphone enclosed in MX 41/AR cushion. The various operational availabilities of the impedance bridge are shown in figure 2.

A portable screening audiometer Maico MA30 was used to determine the air conduction thresholds for comparison with the "Sensitivity Prediction by Acoustic Reflex" (SPAR)findings.

Calibration Procedure:

a. Calibration of Madsen Z073

The impedance bridge used in this study (Madsen Z073) was calibrated periodically. The procedure was based on the recommendations of Jerger et al (1974), Feldman and Wilber (1978) and Robinson and Brey (1978)

Specifically, it included air pressure calibration, check for air leakage, cavity equivalence, probe-tone intensity and frequency calibration, earphone intensity and frequency calibration, linearity check(after 70 dBHL) and vernier scale calibration.

Air pressure calibration was done using a commercially available manometer ('U' tube Pressure Gauge:ABC Part No.6476). Using the built-in 2 cc cavity,the air pressure leakage was checked/monitored over a 5 minute period. The probe tip was introduced into the built in

...32

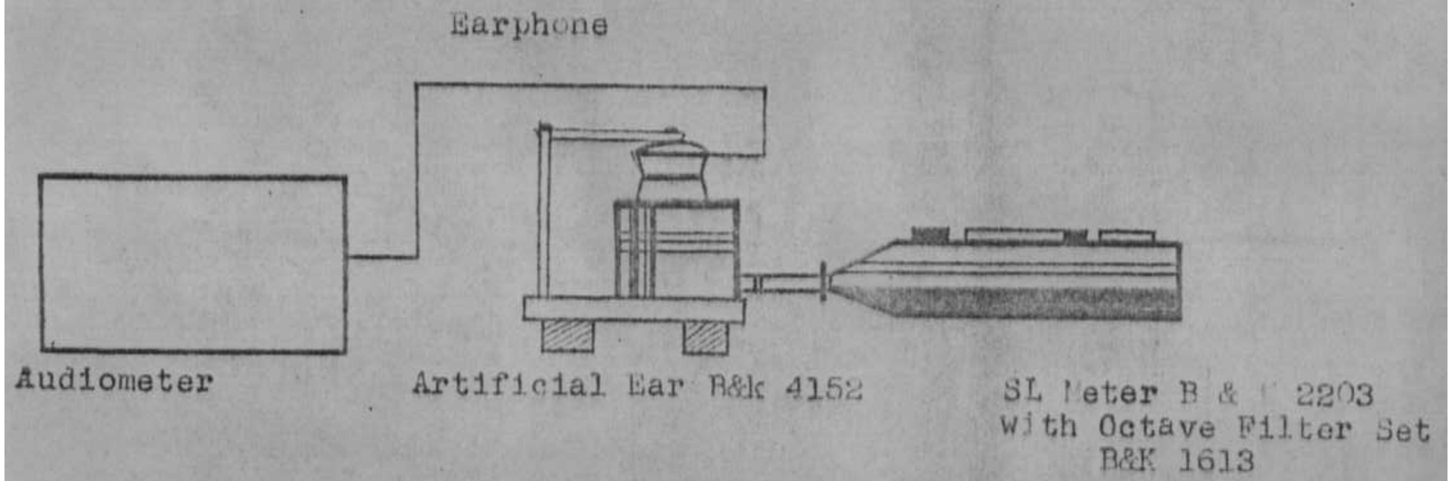


Fig 3. Set up for Calibration.

2 cc cavity. Then air pressure of 200 mm. H_2O was built. If the Manometer remained in the initial position for a 5 minute period, it was considered as an indication of absence of air leakage. A Hewlett Packard X-Y plotter was also used to check this. By disconnecting the polythene tube and closing the passage way at the rear panel, the air leakage at the passage way was assessed.

Using a Madsen Variable cavity, cavity equivalence of the instrument at all positions were calibrated.

The probe-tone of the instrument (220 Hz.) was measured for its intensity using a 2 cc. B & K coupler( ) The 2 cc. coupler was connected to a sound level meter (B & K 2209) using a condensor microphone (B & K 4+44) its associated octave filter (B & K 1613) centered at 250 Hz. An appropriate probe tip was used to connect the 2 cc. coupler. Care was taken to balance the bridge and maintain air pressure at 0 mm. H_2O. During this period, the sensitivity know was at 2 position and the compliance scale read 2 cc. The probe tone intensity was read from the sound level meter directly.

The frequency of the probe tone was checked using an electronic frequency counter (Rodart 203 timer/counter) attached to the sound level meter.

Earphone intensity calibration was done using a procedure given by Wilber (1978). Figure (3) illustrates

...33

the set up for calibration. The sound level meter (B & K 2209) was set to the following settings. The meter switch was turned to'external filter' and to 'slow'. The weighting switch was in the 'off position. The signal earphone (Telex 1470 with MX 41/AR cushion) of the impedance bridge was removed from the head band( ) and was placed over the coupler of the artificial ear (B & K 4132). The earphone was held in place by means of a tension of the artificial ear and it was adjusted to 0.5 kg. of pressure. After initial placement of the earphone on the coupler a low frequency tone (250 Hz. at 90 dBHL) was introduced and the earphone was readjusted until the sound level meter needle read the highest intensity. This is said to ensure best placement according to Wilber (1978). The frequency selector of the bridge was set to 500 Hz. and intensity at 90 dBHL and the tone was continuously 'on'. The filter was also adjusted to the respective frequency (500 Hz.). The reading on the sound level meter was noted. Similarly, other frequencies (1000 Hz., 2000 Hz. and 4000 Hz.) were checked.

The frequency was checked using an electronic frequency counter (Rodart 203 timer/counter) attached to the sound level meter.

To check linearity of the attenuator of the impedance bridge, a similar set up was used as above. The range

...34

finder was set to 120 dB. The hearing loss dial was set at maximum and the reading on the sound level meter was noted. The intensity was decreased in 5 dB steps and the reading on the sound level meter was noted for each 5 dB reduction. The linearity was checked upto 70 dB HL.

The linearity of the vernier scale was checked as described above at 1000 Hz. at 90 dB HL using 1 dB steps.

Calibration procedures indicated that the output of the instrument met the required specifications.

b. Calibration of Portable Screening Audiometer:

The audiometer used in this study was a portable screening audiometer (Maico MA 30). The audiometer was calibrated periodically during the study. The calibration specially included - earphone intensity and frequency calibration, linearity check.

The earphone intensity and frequency calibration was done in a way similar to that of Impedance bridge for frequencies, 250 through 8000 Hz.

The linearity check below 60 dB was done using the procedure used for checking linearity of hearing loss dial of impedance bridge. For intensities below 60 dB, the electrical output was measured for each 5 dB drop in readings. All this showed that the working of the audiometer was satisfactory.

*** 35

Test Environment:

Impedance testing and pure-tone testing was performed in a sound treated room of All India Institute of Speech and Hearing, Mysore. The ambient noise levels in these rooms were within the maximum allowable noise levels.

procedure:

Instruction for pure-tone audiometry:

The subjects were asked to raise their finger whenever they heard a 'pip' sound. The subjects were asked to respond even to very soft 'pip' sound. Children below 6 years were asked to drop a block or move a bead of the abacus whenever they heard a 'pip' sound and to respond even to the softest 'pip'.

Pure-tone thresholds were measured for audiometric test frequencies, 250 through 8000 Hz. using Modified Hughson-Westlake procedure of Carhart and Jerger (1959).

Instruction for Impedance measurements:

The subject was familiarized with the instrument in order to reduce fear. Then they were asked to sit still during testing till it was completed. They were asked not to swallow while testing.

The ears were examined otoscopically before inserting the probe into the ear. The probe was then inserted in the ear canal with an ear tip of suitable size and a hermetical seal was obtained. Impedance measurements were

...36

done on both ears. They included - Tympanometry (from 200 to -400 mm. H_20), static compliance measurements and determination of contralateral acoustic reflex thresholds.

To determine the acoustic reflex thresholds, pure-tone signals of 500, 1000 and 2000 Hz. of 1.5 second duration and 25 m.second rise-fall time and Broad-Band Noise was used. Inter-Stimulus-Interval for pure-tones and broad-band-noise was maintained at 3 seconds.

The above procedure was carried out on both ears using acoustic reflex data for pure-tone and broad-band-noise. Hearing loss was predicted using Jerger et al (1977) method for predicting hearing level, referred to as "Sensitivity Prediction by Acoustic Reflex" (SPAR)

The formula used was:

$$\text{Noise-tone difference} = \frac{\text{Average reflex threshold at 500Hz (HL)} + \text{Average reflex threshold at 1000 Hz (HL)} + \text{Average reflex threshold at 2000 Hz (HL)}}{3} - \text{Average reflex threshold for broad-band} + \text{Correction factor}$$

That is, the average reflex threshold (ART) for broad-band noise was subtracted from the average reflex threshold for 500, 1000 and 2000 Hz. The correction factor was determined biologically. That is, the average reflex thresholds of the thirty-seven subjects for broad-band-noise was subtracted from the average reflex threshold for the three pure-tone signals (500, 1000 and 2000 Hz.) for thirty-

... 37

seven subjects. The result was labelled as Noise-tone-difference (NTD). The obtained normal NTD was subtracted from the original norm (Jerger, 1975) of 25 dB. This was considered as the correction factor for the impedance apparatus used in the present study. The NTD values for both ears was calculated for each subject.

Chapter 4

RESULTS AND DISCUSSION

The present study attempted to predict the auditory sensitivity from acoustic reflex threshold measures.

Initially, impedance measurements were done. Subjects showing A-type tympanogram normal compliance, normal reflex thresholds and a negative history of ear infections were included in the study. Next, air conduction thresholds for pure-tones were determined. All thirty-six subjects passed the above criteria. All subjects had normal hearing for the octave frequencies (20 dB HL, ANSI, 1969).

The thirty-six subjects consisted of both males and females in the age range of 5-10 years. Four subjects with hearing loss were also tested to determine the accuracy of SPAR.

The age range, mean reflex thresholds for pure-tones and broad-band noise and the computation of correction factor as per the guidelines of Jerger et al (1974s) are illustrated in Table I for left and right ear respectively.

The Mean acoustic reflex threshold for pure+tones between ears is negligible (in the order of 0.30 dB).

Table 1

Table showing Age range, mean reflex thresholds for pure tones and broad-band noise, difference between mean acoustic reflex threshold (ART) for pure tone and noise and the computed correction factor for the instrument used in this study, for Right ear and Left ear respectively

Ear	Age Range	Mean acoustic reflex threshold for tones	Mean acoustic reflex for broad band noise	Mean difference of pure-tone acoustic reflex and broad band noise(D)	Correction factor
Left ear	5-10 years	93.27	89.94	3.33	21.67
Right ear	5-10 years	93.57	88.44	5.13	19.87

...40

Similarly, the difference between acoustic reflex threshold for noise between the ears is negligible. The acoustic reflex threshold for broad-band noise and pure-tone when compared yield a small difference of 3.33 dB and 5.13 dB for left and right ear respectively. However the broad-band noise elicits acoustic reflexes at low intensity levels than the tonal stimuli. This is in agreement with previous studies (MØller, 1962; Fisch and Schulthes, 1963; Dallos, 1964; Lilly, 1964; Djupesland et al, 1967; Deutsh, 1972; Peterson and Liden, 1972; Mythili, 1975 and Hall, 1980). Also it answers the first question of this study. That is, children also exhibit low reflex thresholds for broad-band noise than for tonal stimuli.

The computed correction factor for the instrument used in this study (Madsen Z073) were 21.67 and 19.87 for left and right ear respectively. These values are higher than the ones obtained by Sudha Murthy (1980). She had obtained 13.8 in left ear and 12.16 in right ear.

The mean acoustic reflex thresholds and standard deviations for pure-tones and broad-band noise for both the ears are illustrated in Table-2. The obtained standard deviations indicate a high variability among the reflex thresholds and a similar trend runs through all the stimuli. The mean shows the concentration of reflex threshold around 95 dB HL for 500 Hz., 91 dB HL for 1000 Hz.

...41

Table 2

Table showing Mean acoustic reflex thresholds with standard deviation for pure-tones 500, 1000, 2000 Hz. and Broad-band noise, for Left and Right ears.

	500		1000		2000		Broad Band Noise	
	Left	Right	Left	Right	Left	Right	Left	Right
Mean	95.25	94.08	90.75	92.33	94.66	94.30	89.94	88.44
Standard Deviation	7.30	6.33	7.56	5.08	9.25	7.79	9.21	8.17

...42

and 94 dB HL for 2000 Hz. The mean acoustic reflex threshold for broad-band noise is around 88 to 89 dB. However, the acoustic reflex thresholds for broad-band noise is better than acoustic reflex threshold for tonal stimuli as expected.

The test-retest acoustic reflex thresholds for 500 Hz. 1000 Hz., 2000 Hz. and broad-band noise and the values of product moment correlation for right and left ear respectively is illustrated in Tables 3a and 3b. The r values show that there is a high correlation between the test-retest scores in both ears and the values are significant at 0.01 and 0.05 levels of confidence indicating good reliability.

The acoustic reflex thresholds for pure-tones, broad-band noise, the average acoustic reflex for pure-tones, NTD and correction factor for left and right ear are shown in Table-4. The number of subjects were 36. The average acoustic reflex thresholds for pure-tones ranged from 80-116 dB HL which is comparable to that obtained by Raghunath (1977) (85 to 110 dB SPL) and also to that of Niemeyer and Sesterhenn (1974) (73 to 105dBSPL). The acoustic reflex threshold for broad-band noise varied from 70-105 dB SPL in the present study. This range is slightly wider than that of the earlier reports (Niemeyer and Sesterhenn, 1974; Raghunath, 1977). The noise-tone difference obtained in this study was 13, in normal

...43

Table 3a

Table showing Test-Retest Acoustic Reflex Thresholds for 500 Hz., 1000 Hz., 2000 Hz., and Broad-band noise and Product moment correlation, for Right Ear.

Sl. No.	Acoustic Reflex Threshold for						Acoustic Reflex Threshold for Broad-band Noise		Product Moment Correlation for			
	500Hz.		1000Hz.		2000HZ.				500Hz.	1000Hz.	2000Hz	BBN
	T	RT	T	RT	T	RT	T	RT	*	*	*	*
1	80	80	85	85	83	80	84	84	r=0.99	r=0.96	r=0.98	r=0.96
2	91	91	96	95	90	90	91	91				
3	115	115	108	105	100	100	100	190				
4	93	93	90	88	97	95	90	90				
5	103	101	95	97	110	110	100	100				
6	94	97	92	94	95	95	98	98				
7	91	93	89	90	115	115	94	95				
8	91	91	95	95	95	95	96	91				
9	89	89	90	90	85	85	85	85				
10	102	101	91	91	91	91	101	100				
11	91	91	95	95	100	105	100	100				
12	91	91	89	86	94	93	95	95				
13	100	100	100	100	90	90	98	98				

*Significpnt at 0.01 and 0.05 level of confidence

T * Test   RT = Retest

Table 3b

Table shoving Test-Retest Acoustic Reflex Thresholds for 500 Hz., 1000 Hz., 2000 Hz. and Broad-Band Noise and Product Moment Correlation, for Left ear.

SI No	Acoustic Reflex Threshold for 500Hz		1000Hz		2000Hz		Acoustic reflex threshold for Broad-band noise		Product Moment Correlation for			
	T	RT	T	RT	T	RT	T	RT	500Hz.	1000 HZ.	2000Hz	BBN
1	76	79	82	80	83	80	79	79	*	*	*	*
2	88	88	85	85	88	85	88	88	r-1	r-0.96	r-0.95	r- 1
3	102	101	96	96	88	90	90	90				
4	90	89	90	91	104	104	95	95				
5	101	101	95	91	92	91	90	90				
6	96	96	91	90	90	90	96	96				
7	90	90	85	85	91	93	91	91				
8	101	101	95	95	105	105	100	100				
9	96	94	85	85	91	90	85	85				
10	101	101	90	90	88	88	80	80				
11	88	88	95	95	100	100	100	100				
12	101	101	86	86	100	100	100	100				
13	105	105	95	95	90	90	105	105				

...45

Table 4

Table showing acoustic reflex thresholds for pure-tones, broad-band noise, average acoustic reflex threshold for pure-tones, NTD and correction factor (N = 36), for Left and Right ear

SI. No.	Ear	Acoustic Reflex thresholds(HL) for 500 Hz.	1000 Hz.	2000 Hz.	Average pure-tone acoustic reflex threshold	Acoustic reflex threshold for broad-band noise	Noise-tone difference	Correction factor
1	Left	97	93	89	93	94	20.67	21.67
	Right	96	96	88	93.33	84	29.20	19 .87
2	Left	115	115	118	116.00	94	43.67	21.67
	Right	100	100	95	98.33	94	24.20	19.87
3	Left	101	106	111	106	99	28.67	21.67
	Right	96	95	94	95	94	20.87	19.87
4	Left	76	82	83	80.33	79	23.00	21.67
	Right	80	85	83	82.66	84	20.33	19.87
5	Left	98	95	91	94.66	91	25.33	21.67
	Right	95	91	89	91.66	86	25.53	19.87
6	Left	88	85	88	87	88	20.67	21.67
	Right	91	96	90	92.33	91	21.20	19.87
7	Left	102	96	88	95.33	90	27.00	21.67
	Right	115	108	100	107.66	91	36.53	19.87
8	Left	90	90	104	94.66	95	21.3	21.67
	Right	93	90	97	93.33	90	23.20	19.87
9	Left	101	95	92	96	90	27.67	21.67
	Right	103	95	110	102.66	100	22.54	19.87

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...46

Table 4 (Contd)

Sl. No.	Ear	Acoustic Reflex Thresholds (HL) for 500 Hz.			Average pure-tone acoustic reflex threshold	Acoustic reflex threshold for broad-band noise	Noise-tone difference	Correction factor
		500 Hz.	1000 Hz.	2000 Hz.				
10	Left	96	91	90	92.33	96	18.00	21.67
	Right	94	92	95	93.66	98	15.5	19.87
11	Left	90	85	91	88.66	91	19.34	21.67
	Right	91	89	115	98.33	94	24.20	19.87
12	Left	101	95	105	100.33	100	22.00	21.67
	Right	91	95	95	93.66	96	17.53	19.87
13	Left	96	85	91	90.66	85	27.33	21.67
	Right	89	90	85	88	85	22.87	19.87
14	Left	101	90	88	93	80	34.67	21.67
	Right	102	91	91	94	101	13.53	19.87
15	Left	88	95	100	94.33	100	16.00	21.67
	Right	91	95	100	95.33	100	15.20	19.87
16.	Left	101	86	100	95.66	100	17.33	21.67
	Right	91	89	94	91.33	95	16.20	19.87
17	Left	89	86	98	91	95	17.67	21.67
	Right	88	90	93	90.33	95	15.20	19.87
18	Left	101	93	90	94.66	85	31.33	21.67
	Right	100	95	100	98	85	33.20	19.87
19	Left	86	84	88	86	90	17.67	21.67
	Right	91	85	99	88	90	18.53	19.87
20	Left	96	90	95	93	95	20.33	21.67
	Right	90	91	89	90	90	19.87	19.87

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...47

Table 4 (Contd.)

Sl. No.	Ear	Acoustic Reflex Thresholds(HL) for 500 Hz.	1000 Hz	2000 Hz.	Average pure–tone acoustic reflex threshold	Acoustlc reflex threshold for broad-band noise	Noise-tone difference	Correction factor
21	Left	96	91	100	95	100	17.33	21.67
	Right	99	94	95	96	99	16.87	19.87
22	Left	99	84	89	90.66	89	23.33	21.67
	Right	100	92	92	94.66	87	27.53	19.87
23	Left	101	101	110	104	102	23.67	21.67
	Right	94	95	116	101	95	26.53	19.87
24	Left	99	90	91	93	95	20.00	21.67
	Right	92	95	90	92.33	86	26.20	19.87
25	Left	91	82	75	82.66	70	34.33	21.67
	Right	84	84	92	86.66	78	28.53	19.87
26	Left	100	106	115	107	99	29.67	21.67
	Right	94	89	98	93.66	100	13.63	19.87
27	Left	90	89	96	91.66	82	31.33	21.67
	Right	92	89	96	92.33	87	25.20	19.87
28	Left	96	90	95	93.66	95	20.33	21.67
	Right	101	95	105	100.33	100	20.20	19.87
29	Left	82	77	88	82.33	70	34.00	21.67
	Right	90	87	83	86	86	19.P7	19.87
30	Left	102	97	100	99.66	98	23.83	21.67
	Right	98	103	96	99	100	18.87	19.87

(Contd. on next page)

Table 4 (Contd.)

Sl. No.	Ear	Acoustic Reflex Thresholds(HL) for			Average pure-tone acoustic reflex threshold	Acoustic reflex threshold for broad-band noise	Noise-tone difference	Correction factor
		500 Hz.	1000 Hz.	2000 Hz.				
31	Left	91	85	90	88.66	75	35.33	21.67
	Right	96	90	90	92	90	21.87	19.87
32	Left	98	86	102	95.33	84	33	21.67
	Right	88	90	100	92.66	80	32.53	19.87
33	Left	92	87	86	88.33	81	29.00	21.67
	Right	98	91	90	93	74	38.87	19.87
34	Left	88	82	81	83.66	71	34.35	21.67
	Right	89	85	83	85.66	82	23.53	19.87
35	Left	86	88	100	91.33	85	28.00	21.67
	Right	85	87	86	86	70	35.87	19.87
36	Left	105	95	90	96.66	105	13.33	21.67
	Right	100	100	90	96.66	98	18.53	19.87

hearing subjects. Whereas the NTD for normal hearing subjects in 1974 SPAR is 20 with any SPL of broad-band noise or NTD of 15-19 with the SPL of the broad-band noise being <d80 dB SPL. In the 1977 SPAR, criteria for normal hearing is NTD 20 and 1000 Hz. ART at 95 dB HL, and ART for broad-band noise can be any value.

SPAR criteria for prediction of hearing loss in the present study is illustrated in Table 5. The criteria for normal prediction is NTD should be greater than or equal to 13, and the ART for 1000 Hz. should be less than 100 dB HL and the ART for broad-band noise should be less than 100 dB SPL. When the NTD is less than 13, and the ART for broad-band noise is greater than or equal to ART for 1000 Hz. tone in dB HL, then a moderate sensori-neural hearing loss can be predicted. Thus the second and third questions are answered. That is, the difference between ART for broad-band noise and tonal stimuli can be used to predict hearing threshold level of children with sensori-neural hearing loss. Also a criteria can be constructed to be used for prediction of normal hearing subjects.

The ART for pure-tones and broad-band noise and the NTD for moderate sensori-neural hearing loss subjects is shown in Table 6. Here the ART for broad-band noise ART for pure-tones. The NTD of < 13 is not applicable to all subjects. Yet the criteria of ART for broad-band noise ART for pure-tones helps to differentiate bet-

...50

Table 5

SPAR criteria for prediction of hearing loss in the present study

Noise-tone difference	Broad-band noise	Prediction
13 ART for 1000 Hz. < 100 (dB HL	< 100 dB SPL (ART)	Normal
<13 or and acoustic reflex threshold for broad-band noise in dB SPL acoustic reflex threshold for 1000 Hz in dB HL (ANSI, 1969)		Moderate hearing loss

Table 6

Table showing Acoustic Reflex Thresholds for Pure Tones of 500 Hz., 1000 Hz., 2000 Hz., Acoustic Reflex Threshold for Broad Band Noise, and Noise-tone difference for moderate Sensori-neural hearing loss subjects (N = 4)

SI. No.	Ear	Acoustic Reflex Threshold for 500 Hz.			Acoustic Reflex Threshold for Broad-band Noise	Noise-tone difference
		500 Hz.	1000 Hz.	2000 Hz.		
1	Left	95	100	105	100	21.67
	Right	105	100	110	105	19.87
2	Left	95	90	95	100	15.04
	Right	90	95	100	105	9.87
3	Left	80	85	91	94	13.00
	Right	83	100	124	103	19.14
4	Left	105	105	105	105	21.67
	Right	105	105	115	110	18.17

...52

ween normal and moderate sensori-neural hearing loss subjects.

From this it is concluded that sensitivity prediction using acoustic reflex is encouraging in normal population and the limited subjects with moderate sensori-neural hearing loss used in this study. More clinical data is required.

Chapter 5

SUMMARY AND CONCLUSIONS

Assessment of hearing in children is more interesting and meaningful to-day. The arrival of immittance testing and brainstem evoked response audiometry(BERA) has revolutionised the previously less exciting measurement of hearing in children. One such revolution is prediction of hearing loss using acoustic reflex.

Prediction of hearing loss using acoustic reflex is based on the concept of noise-tone difference, i.e., the acoustic reflex is more sensitive for noise than tonal stimuli. It is reduced in subjects with sensorineural hearing loss. Based on this concept, several prediction methods have come into existence. And SPAR is one of them.

SPAR's usefulness in early diagnosis of hearing loss is well known. The accuracy of prediction is better in children and such a prediction is essential for early diagnosis and management. Also no study has paid attention to predict hearing loss in young children. Hence this attempt.

Thirty-six normally hearing young children in the age group of 5 to 10 years were chosen for this study. After ensuring that they had normal middle ear system

...54

using impedance audiometry, they were subjected to SPAR. Testing included tympanometry, compliance measurement and reflex determination using tones (500, 1000 and 2000 Hz.) and broad bund noise stimuli. And this followed a hearing assessment using pure-tones.

The obtained hearing thresholds and acoustic reflex thresholds w for noise and tonal stimuli were used to compute the correction factor for the impedance equipment (Madsen Z073). This correction factor was applied to the unweighted formula of Jerger et al (1974). Retesting was done on thirteen subjects to ensure test-retest reliability. Statistical treatment of test-retest reflex thresholds indicated high reliability.

Conclusions:

1. Children exhibited low reflex thresholds for broad band noise than tonal stimuli.
2. NTD obtained in children can be used to predict hearing loss.

Recommendations:

1. More number of children with hearing loss have to be tested to arrive at a suitable criteria for predicting hearing loss in children.

2. It would be better if a criteria baaed on average reflex threshold of three pure-tones, namely, 500, 1000

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and 2000 Hz. is used in addition to reflex thresholds for broad-band noise and noise-tone difference. Recent studies reported in the literature have used NTD, acoustic reflex threshold for broad-band noise and acoustic reflex threshold for 1000 Hz. for deciding degree of hearing loss.

3. More data are required on children with uniform hearing loss of different degrees. Hope that this information would help establish validity of SPAR.

Collecting data on children with different audiogram configuration may not be useful for establishing the validity of the test. Hence it is desirable to test more number of children with uniform sensori-neural hearing loss of different degrees.

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