THRESHOLD OF HEARING AND MAGNITUDE OF ACOUSTIC REFLEX
IN
CHILDREN

KAMINI. R

REG. NO. 7

A DISSERTATION SUBMITTED IN PART FULFILMENT
FOR THE DEGREE OF MASTER OF SCIENCE
(SPEECH AND HEARING)
UNIVERSITY OF MYSORE
1982

TO

DEAREST

APPA & AMMA

CERTIFICATE

This is to certify that the Dissertation entitled "Threshold of Hearing and Magnitude of Acoustic Reflex in Children" is the bonafide work in part fulfilment for M.Sc, Speech and Hearing of the student with the Reg. No. 7

Dr.N.Rathna,
Director,
All India Institute
of Speech & Hearing
Mysore-6

CERTIFICATE

This is to certify that this Dissertation entitled "Threshold of Hearing and Magnitude of Acoustic Reflex in Children" has been prepared under my supervision and guidance.

LectRr3r^3n Audioldgy,
All India Institute of
Speech and Hearing
Mysore-6.

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: Reg. No:7

Date: 17.5.1982

ACKNOWLEDGEMENTS

My sincere thanks are due to

- Mr. M.N.Vyasamurthy, Lecturer in Audiology,A.I.I.S.H. Mysore, for his valuable guidance.
- All my 'young' subjects who participated in the testing sessions most willingly and cheerfully.
- Dr.(Miss.)S.Nikam, Head of the Department of Audiology, A.I.I.S.H., for allowing me to use the necessary instrumentation for the study.
- Mr. T.G. Satyanarayana, Head Master, Demonstration multipurpose School, Mysore for permitting me to take children from his school for the study.
- Mr. P.Balachandra and other school teachers, Demonstration Multipurpose School, for their kind co-operation.
- Miss. Indi and Miss.Falgun for their patient listening and understanding.
- Miss. Pushpa for the neat typing.
- Mr.Srikanth and Mrs. Mythili for all their help.

CONTENTS

LIST OF FIGURES

FIG.NO. **PAGE**

LIST OF TABLES

TABLE NO. **PAGE**

CHAPTER I

INTRODUCTION

"Audiology has two major areas to control. Stimulus and response. The stimulus has come quickly under the control of instrumentation. Client response control however has eluded the examiner and his instrumentation." (Fulton and Lloyd, 1975).

Accurate assessment of hearing according to Lamb (1975) is often hindered by the inability or unwillingness of the subject to respond to sound in a prescribed manner. Fuiton and Lloyd (1975) refer to such subjects as "the difficult to test" and report that the Audiology with the difficult to test has arrived at a new era after progressing through 'three phases'.

In phase - 1, an individual, not responding to standard puretone technique was diagnosed as hearing impaired and hence assessment was incomplete or inappropriate.

To overcome the short comings of Standard puretone audiometry, classical and instrumental conditioning procedures were developed in phase - 2.

In phase - 3 it was made clear by reliability and validity studies that reliable assessment is possible in many individuals when stringent control over variables is applied in the conditioning procedure.

The foremost concern of the new contemporary era is the development of improved methods for applying advanced electronic instrumentation and human engineering principles to audiologic procedures.

The first three phases correspond to the subjective tests and the new phase to the objective tests in audiometry. "The test is objective if the patients responses can be evoked without any form of voluntary response from the patient" (Coles, 1977).

"Modern audiologic assessment is based on puretone audiometry, which is a reliable procedure for assessing auditory sensitivity in humans" (Lloyd, 1975). Puretone data provide an ordered set of threshold responses indicating auditory sensitivity in low, middle and high frequencies and possible differential between sensitivity to air conducted and bone conducted sounds. Skillful interpretation of puretone thresholds can provide gross differential diagnosis of the site of auditory impairment and communication disorders.

Children constitute a major portion of the 'difficult to test' group. As Brewster and Morrison (1978) observe, when a child comes for audiological testing, "One is dealing with an extremely complex little human being who is doing much more than responding (or not responding) to the clicks, bangs, warble tones, filtered speech, filtered music and narrow band noises we present to him." So each child is individualistic and selection of appropriate test procedure to suit his needs is absolutely essential.

In puretone audiometry, in order to elicit 'subjective' response from the child audiologists have designed special techniques.'Conditioned Orientation Reflex Audiometry' (CORA) by Suzuki and Ogiba (1960),'Peep Show technique'by Dix and Hollpike (1947), 'Food Audiometry' by Ewertson and Nielson (1970),'Ear choice technique'by Curry and Kentzrock (1951) are some of the specially designed techniques for assessment of the difficult to test children. These procedures have been successful in assessment of hearing in many difficult to test children. But responses in the subjective tests, sometimes may be influenced by certain variables. Lloyd (1975) outlines these variables as follows - 1) Linguistic variables - vocabulary and other language limitations can influence the instructions, training and conditioning aspects of puretone audiometry. 2) Motivation, cooperation and attention variables differ from child to child depending on physical, psychological and emotional problems the child might have. The immaturity of children may impose limitations on accuracy of their judgements leading to supra threshold responses rather than a valid index of auditory sensitivity. A negative attitude in the child might result in earphone rejection by him.

3) Response mode variables - Neurologic or physiologic disabilities such as cerebral palsy make the child unable to give motor responses like hand raising, block dropping or button pressing.

4) Stimulus variables - when puretones are used, low frequencies (250Hz and below) tend to be easily masked by environmental and body noises. The higher frequency tones (2000 Hz, and above) are occasionally confused by tinnitus. Narrow band masking noise might be confused with test signals, especially at low frequencies.

Thus, in some children, it might not be possible to elicit reliable responses by subjective audiometry. It is necessary that hearing loss must be identified as early as possible so that its effects on the child may be diminished. This is where objective audiometry comes in to picture. Objective tests may also be used to cross check the results obtained by subjective audiometry.

Through sophisticated instrumentation and more precise evaluation procedures, new objective tests are being developed to make direct physiological measures of body reactions to auditory stimuli. While objective techniques like Electroencephalic response audiometry (especially early and late response audiometry), Electro cochleography, Impedance audiometry have already become popular. New methods such as Respiration audiometry, Heart rate response audiometry, vasomotor response audiometry are developing rapidly. Electro dermal or psychogalvanic reflex audiometry has been reported to be successful with some children. Visual response audiometry, although has a long way to go, is quite promissing.

In the area of impedance audiometry, the acoustic reflex, because of its several characteristics, has been used by audiologists to estimate integrity of peripheral auditory system (Himelfarb etal, 1978). Acoustic reflex in humans results from a contraction of stapedius muscle in response to auditory stimulation. It is involuntary and not affected by the state of the subject, various drugs, or by other factors which usually influence behavioural or subjective auditory assessment. Acoustic reflex can be quantified by measuring the acoustic impedance of the ear by means of a quick, simple, non-invasive procedure.

In the early stages, presence or absence of Acoustic reflex threshold was used to infer presence of hearing loss Popelka, 1981). The difference between acoustic reflex threshold for puretones and acoustic reflex threshold for broad band noise called "Noise tone difference" (NTD), was used by Niemeyer and Sesterhenn (1972, 1974) to predict hearing sensitivity since then many pridictive methods have been reported-

i) Differential loudness summation test(Jerger,1973)
ii) Sensitivity prediction by the Acoustic Reflex-SPAR (Jerger et al, 1974)
iii) 1977 SPAR (Hall,1978)
iv) Prediction of hearing for single frequencies(Sesterhem and Breuninger,1977)

Few investigators (Baker and Lilly, 1976; Lilly, 1977; Rizzo and Greenberg, 1979) have given hearing prediction formulae based on regression equations.

Using the ratio of acoustic reflex thresholds for noise to tone called, 'Noise tone ratio', bivariate plot coordinate systems were developed for prediction of hearing (Popelka, Margolis and Wiley, 1976; Handler, and Margolie, 1977; Margolis and Fox, 1977; Silman and Gelfand, 1979).

Jerger etal (1978) attempted to predict hearing by
1) supra threshold amplitude ratio - ratio of the reflex amplitude of 1000 Hz tone and broad band noise stimuli.
2) Supra threshold noise tone difference - difference in reflex amplitude between 1000 Hz and broad band noise.
Three groups of adult subjects were used - normal hearing, flat sensorineural loss and sloping sensorineural loss.

The two supra threshold amplitude indices were not found to be as effective as noise tone difference in reflex threshold for hearing prediction.

Need for the present study:-

In children, who form a large segment of 'difficult to test' population, objective prediction of hearing is very useful.

Jerger et al (1978) reported that the predictive accuracy of 1977 SPAR was extremely good in children (2 to 12 years old). Predictive accuracy was 100% in normal hearing, 85% in severe hearing loss and 54% in moderate hearing loss children.

So far predictive efficiency of 'NTD'in reflex magnitude (amplitude) has not been investigated in children.

Purpose of the present study:-

It was sought to investigate NTD (reflex magnitude) in children and to explore any possibility of its use in the prediction of hearing sensitivity.

Null hvpothesis-

"There exists no difference between the reflex magnitude for puretones and the reflex magnitude for broad band noise".

The study was designed to find answers for the following questions:-

a) Does the magnitude of reflex increase as intensity of the stimulus increases?

b) Is there a difference in NTD (reflex magnitude) between right and left ears?

c) Does NTD (reflex magnitude)differ with respect to sensation level(reference:ART) of the stimulus?

d) Does NTD(reflex magnitude) of normal ears differ from that of sensorineural loss ears?

Brief plan of the study

Thirty three normal hearing children (age range of 5 to 10 years) and two (age 13 years) with sensorineural hearing loss were taken as subjects for the study.

Puretone thresholds were established at frequencies, 250Hz to 8000Hz using the 'up 5-down 10' method with principles of Hughson-Westlake ascending technique (Green, 1978).

Tympanometric and static compliance measurements were made to ensure absence of middle ear pathology. Acoustic reflex thresholds were established for the puretones (500Hz,1000Hz and 2000Hz) and broad band noise. Reflex magnitude measurements were carried out at the reflex threshold level, at 10 dB sensation level(reference:ART) and 20dB sensation level (reference:ART).

Noise tone difference (reflex magnitude), For right and left ears at 10dB sensation level and 20dB sensation level was computed. Data were statistically analyzed.

Definitions of the terms used:

Pure tone: Periodic sound wave of the sinusoidal type which has no partial or overtone (Scottwood, 1971).

Broad band noise(White noise): a sound in which energy is present over a wide range of frequencies with equal energy per cycle (Glorig,1968; Martin,1975).

Puretone 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 times.(Martin,1975)

Acoustic reflex threshold: Is the intensity in dBSPLS 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,1966).

Acoustic reflex magnitude: in the present study is the number of units of deflection of balance meter needle, in response to sound stimulation.

CHAPTER - II

REVIEW OF LITERATURE

"An objective hearing test is one which defines a patient's hearing ability without the patient's active participation or co-operation" (Northern & Downs, 1978).

Schimizu (1981) outlines ideal requirements of objective audiometry as follows:-

1. Patient's co-operation is not required.
2. Subjective judgement of the examiner is not needed.
3. Results of the test are highly reproducible.
4. Response threshold can be obtained at least within 20 dBSL.
5. Response is frequency specific so that audiogram can be predicted.
6. The technique used is non-surgical.
7. The procedure is not risky.
8. Instrumentation is simple enough for daily clinical use.

In practice, an objective test should satisfy at least some of these ideal conditions.

Objective tests that try to establish auditory sensitivity in children are:-

1. Electro encephalic Response Audiometry.
2. Electro Cochleography.
3. Electro-dermal or psycho galvanic response audiometry.

4+ Respiration Response Audiometry.
5. Heart rate response audiometry.
6. Vasomotor response audiometry.
7. Visual response audiometry.
8. The Acoustic Reflex battery.

A review of literature in these topics is as follows:-

1. ELECTRO ENCEPHALIC RESPONSE AUDIOMETRY:

Davis (1939) noted that the electrical activity of the brain as indicated by electro encephalographic recordings showed a change because of auditory stimulation. They were reported to be most prominent from vertex of the scalp and hence referred to as "V potentials".

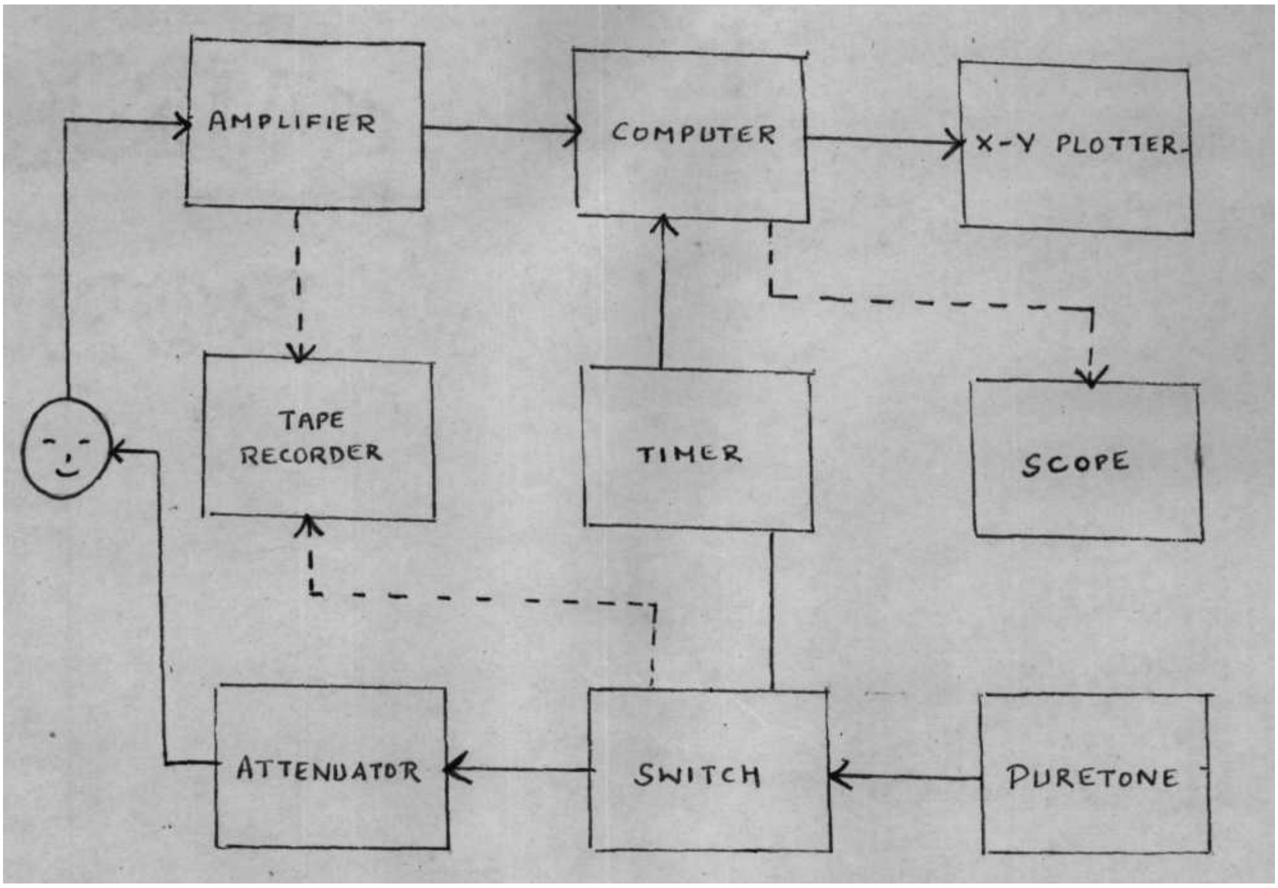
Electro encephalogram or EEG was used to determine hearing sensitivity in pre-school and hard of hearing children by Derbyshire et al (1956) and Derbyshire and McDermott (1958). Thresholds obtained by them were within ± 18 dB of routine audiometric thresholds. Witharow and Goldstein (1958) reported EEG threshold to be + 10 dB of Standard Audiometric threshold on testing hard of hearing children.

In order to reveal relatively small V potential from the on going EEG potentials, Dawson (1954) developed a photographic superimposition technique.

Clark(1958) and Clark etal(1961) developed a computer which averaged the consistent changes in the electric potentials related in time to the onset of the stimulus. Meanwhile, random noise in the background consisting theoretically of an equal number of positive and negative electrical potentials was averaged out to be of zero value so that only the wanted response activity summated in the computer.

Instrumentation for ERA, as specified by Price (1975) consists of a puretone oscillator; Audio signal generated is controlled by timer; switch and attenuator and delivered to the subject by ear phone. With the onset of the stimulus a pulse is sent by the timer to trigger the average response computer - The low voltage potentials from the scalp are picked up by electrodes attached, amplified by the amplifier system and made available to the computer. At the end of a predetermined number of sweeps, averaged data stored in the computer are traced on a graph by X - Y plotter with time on X - axis and voltage on Y - axis. In order to allow for greater flexibility of analysis, stimulus and response can be recorded during test session on a tape magnetic system. Accumulation of data can be monitored by means of visual display on oscilloscope. A camera attachment to photograph the response from the oscilloscope helps in maintaining a permanent record of the averaged response. An Oscillograph recording EE6 activity gives information concerning state of subject, effect of sedation, artifacts such as heart beats, etc. (see Fig.1).

Figure-1



Block Diagram of instrumentation used in ERA

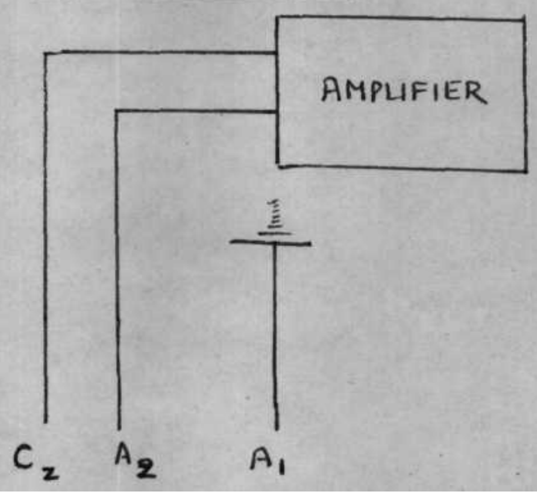
Surface of the scalp is cleaned chemically (eg.by acetone) in the areas where electrodes have to be attached.

An electrolyte is used between scalp and electrode to conduct potentials. Electrodes are securely attached to scalp by tape or glue to prevent artifacts from physical displacement

Price(1975) gives two types of electrode arrangement.
(i) Differential inputs- where voltage differences between electrodes C_z and A_2 are amplified while electrode A_1 not attached to input of amplifier connects the subject to the ground. (See fig. 2)

Figure-2

Differential Inputs



(ii) Inputs referred to the ground in which potentials at electrode C_2 are recorded as they relate to electrode A_1 which is grounded. Potentials amplified are voltage differences between C_z and earth (See fig. 3).

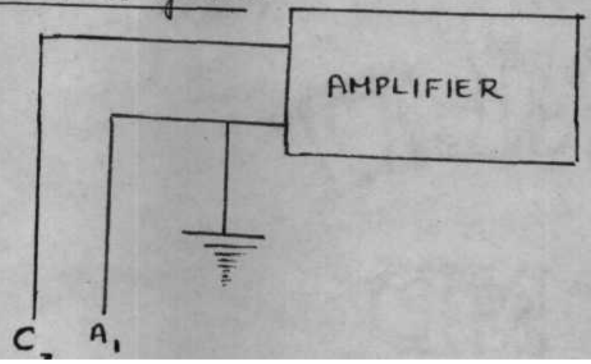


Figure-3

Inputs referred to ground

Gibbs and Gibbs(1950) find the 'differential inputs' arrangement more advantageous because "disturbances between earth and inputs are not amplified".

Placement of Electrodes may be bipolar or monopolar. In monopolar recording an electrode on an active area is referred to one on an inactive or indifferent area, where as in bipolar recording, both the electrodes are on active areas. A monopolar technique is most commonly used to record the auditory evoked potentials (Skinner, 1978). Magerison, St.John Loe and Binne (1967) find bipolar recording technique to be useful in comparing electrical activity of the scalp in one region with the activity of another region.

Subject should be comfortably seated or reclined in a quiet test room adjacent to control room. An assistant should stay with the child in the test room. A sound treated room with electrical shielding and provision for visual and auditory monitoring is an ideal testing environment.

The determination of threshold is a special problem in ERA. As aignal intensity decreases the amplitude of response also decreases. As a result, near psychophysical threshold it is difficult to distinguish the evoked response from background activity.

A preliminary step is to present moderate to high intensity signals to evoke a clear averaged response using ascending or descending procedure.

There are two general techniques followed in ERA (Price, 1975):- 1) Predetermined schedule of stimulus frequencies and intensities with interpretation of each series postponed until all series are completed.
2) Threshold searching procedure where intensity and frequency of each series is determined on the basis of judgement of information from preceeding one.

Skinner (1978) divides auditory electro encephalic response (AER) arbitrarily in to four classes of responses on the bases of latency, different properties and presumably different automical origins. They are-

a) The early or brain-stem response.
b) The middle response.
c) The late response.
d) Very late response.

(a) The early or brainstem response

The brainstem component or early response which was reported by Jewett and his associates in 1970, is a moderately large(1 to 10μ-VDH) polyphasic wave,occuring from 1 to 8 mac after the onset of an auditory stimulus (Hood,1971; Jewett and Williston, 1971; Jewett etal, 1970).

The early response is composed of a series of very fast waves(100 to 2000Hz) with seven peaks originating from different regions of brain stem (Jewett and Williston 1971).

Starr and Hamilton(1976) using patients with confirmed brain stem lesions attributed various peaks of brainstem response to the following components; auditory nerve(J_i), cochlear nuclei, trapezoid body and superior olivary nuclei (J_i and J_{iii}) and lateral leminiscus and inferior colliculus (J_{IV} and J_v). Largest amplitude occurs at peak v which also is the most stable of various peaks.

A click stimulus is used in evoking a brainstem response because it creates an abrupt pressure change within the peripheral hearing apparatus and auditory pathways producing synchronous neural firings. Which can be detected by surface electrodes. (Weber,Seitz and McCutcheon, 1981).

Tone pips or bursts with rise times slower than 2.5msec do not elicit the early response (Cobb, Skinner and Burns, 1977).

Suzuki and Horiuchi(l98l) recommend rise times of 3,2,1.5 and 1 msec for puretone pipe of 0.5, 1,2 and 4 KHz respectively. A 5 msec rise time is best for frequency specificity and response recognizability(Stapells & Picton, 1981). BER is primarily on onset response (Hecox, Squires and Galambos, 1976) produced by the onset of the signal and unrelated to signal duration (Skinner,1978).

Jewett and Williston(1971) have found good brainstem responses with click sensation levels at 60 and 75 dB and rate of presentation 2 per sec. Hood(l97l) recommends 3 per sec.

Brainstem response consists of seven waves when stimuli are applied at slow repetition rates (1 to 10/Sec) and at faster repetition rates (33.3/Sec) wave V is the most prominent (Mokotoff et al,1977). Rowe(l98l) recommends a stimulus rate of 30 to 50/Sec for acuity testing. The early response (4 to 8 msec) may be obtained with very high stimulus repetition rates but optimally with 5 to 10 per second and requires 1000 or more stimulus samples(C}lattke,1975).

An analysis band pass of 1.6 to 2500Hz gives clearest early response (Jewett and Williston.,1971). Motokoff etal (1977) recommend a band pass of 100 to 3000Hz Laukli & Mair(198l)find a wide band pass of 2-5000Hz suitable.

Berlin(1978) and Rowe(198l) finds monaural stimulation to be more sensitive than binaural.

Mean behavioral click threshold obtained from a group of normal listeners can be used as the OdB reference intensity for Brainstem Response Audiometry(Weber,Seitz and McCutcheon,1981).

The abrupt signal risetimes required to elicit the brainstem response produce wide energy, dispersion across frequency (Skinner,1978). In order to overcome this, Picton etal(l979)proposed the use of 'notched noise' masking to limit the tone response to a specific region of cochlea. This yields more accurate threshold information.

Brainstem response may be measured using surface electrodes on the scalp(vertex) and on the earlobe or mastoid(Hood, 1975)

Terkildsen and Osterhammel (1981) found a pair of electrically linked electrodes one on each side of the neck to be useful as reference electrodes for active vertex electrode.

Stapells and Picton(198l) recommend that reference electrode should be lower down the mastoid to avoid distortion of early response by post auricular reflexes.

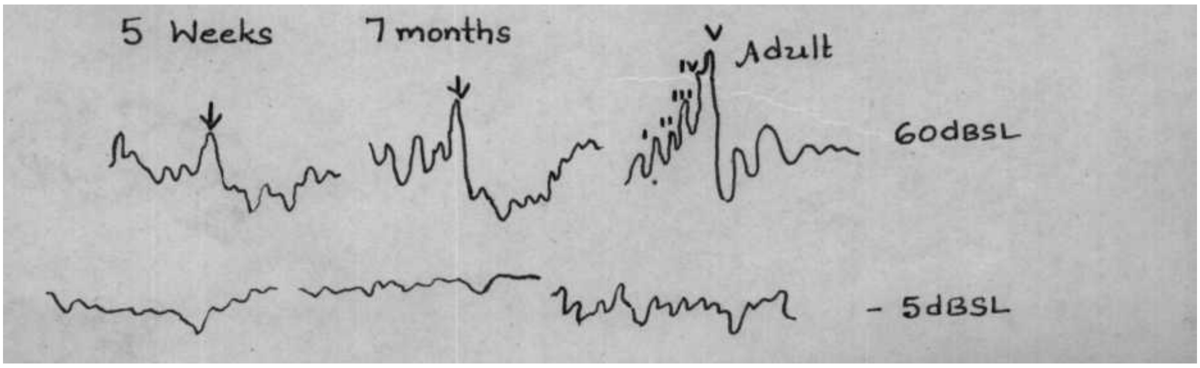
Brainstem response is not dependent upon subject arousal levels and therefore a mild sedative, natural sleep or even general anasthesia can be used to aid Brainstem response audiometry when necessary. (Fujikawa and Weber,1977). Early response can be recorded more reliably in relaxed or sleeping subjects as they are of very low voltage and may be observed easily by myogenic potentials (Skinner,1978).

Researches agree that fifth wave, the so called Jewett (J_v) is the most useful one for audiometric purposes (Sohmer and Feinmesser, 1970; Hood,1975; Davis,1976; Galambos, 1976; Meunier and May, 1976).

The latency of J_v peak has been found to be inversely proportional to the intensity of the stimulus with mean normal adult latency of 4.6 to 5.1 msec. During infancy, J_v latency progressively shortens to attain adult value between 12 to 18 months. (Hecox and Galambos,1974; Salarny etal,1976. (See fig.4)

Figure-4

Brainstem evoked responses at three age levels: Each tracing represents sum of 1000 to 2000 responses to 1 msec monaural click delivered 30 times per sec.



This latency shift has been attributed to receding conductive hearing loss due to progressive resorption of middle ear mesenchyme with gestational age by Hecox and Galambos(l974) and Berlin(1978).

Rowe(l981) recommends absolute peak latencies to be taken in to consideration for measurement of hearing accuity.

Brainstem evoked response audiometry is gaining wide acceptance for evaluating hearing in children.

Jerger and Hayes(1976) recommended the procedure as a useful cross check in determining hearing levels of young difficult-to-test patients.

Motokoff et al (1977) tested children from 6 week old to 15 years and defined following criteria to identify hearing loss-

i) No response to a 60 dBHL stimulus

ii) a wave V latency, in response to 60 dB stimulus, that is prolonged for the age of the patient and

(3) absence of response or an abnormally prolonged wave latency at one or more stimulus intensities below 60 dB.

Jerger and Mauldin(1978) by carrying out correlational analysis between BER threshold, BER latency and other audiometric indices in ears with different configuration and degree of sensorineural hearing loss, concluded that - "Average puretone threshold for 1,2 and 4KHz is most accurately predicted by multiplying BER threshold by 0.6". But standard error of estimate of predictions was relatively large (15-16 dB).

Jerger, Hayes and Jordan(l980) gave three categories of auditory sensitivity depending on results of BER audiometry on children as follows-

i) Normal sensitivity/mild sensitivity loss
 -presence of Auditory Brainstem response(ABR) in either or both ears at 40 dBHL.
ii) Moderate-Severe sensitivity loss
 -ABR in either ear to signals of 50 to 90 dBHL
iii) Profound sensitivity loss
 -Absence of an ABR in both ears to signals at 90dBHL.

Stein, Ozdamar and Schnabel(1981)used BER audiometry with 82 developmentally delayed infants and children suspected of being deaf and blind. Their criteria for interpretation of responses is given in table 1.

Thresholds obtained by BER audiometry on 24 infants were lower than those obtained by recording heart rate change as a response measure (Galambos & Galambos, 1975).

Criteria for interpretation of Brainstem evoked response

Table-1

Category	Interpretation	Criteria
A	Audiologically and Neurologically normal.	(1) Detectable wave V at an intensity level of 30 dBHL (2) Latency intensity curve for wave V within the range established for normals by age.
B	Audiologically abnormal, neurologically normal.	(1) Detectable wave V at an intensity level of 30dBHL (2) Latency intensity curve that deviates either in a parallel or falling manner from the normal curve for age. (3) Presence of a 1-v wave interval within established normal range or latency of wave v at high intensity within the normal range for age.
C	Neurologically abnormal, audiologically normal	(1) Detectable wave v at an intensity level of 30 dBHL (2) Prolongation of 1-v, 1-111 or 111-v wave interval (3) Distortion of component waves.
D	Audiologically abnormal and/or neurologically abnormal	(1) No Auditory brainstem response at maximum intensities. (2) Wave 1 but no component waves (3) Detectable wave V prolonged in latency, no detectable wave 1.

Fujikawa and Weber(1977) found that increasing the rate of click presentation and thereby increasing the stress on the system helps in the earlier detection of brainstem disorders. This was shown as greater latency shifts in infants, geriatric adults and multisclerotic patient than young adults. They altribute this shift to loss of myelization and loss of cell count.

Davis(i976) summarizes clinical importance of Brainstem Response audiometry to include wave form consistency,easy recordability and optimal latency-slow enough to avoid confusion with cochlear microphonic yet fast enough to avoid being masked by the earliest muscle reflexes.

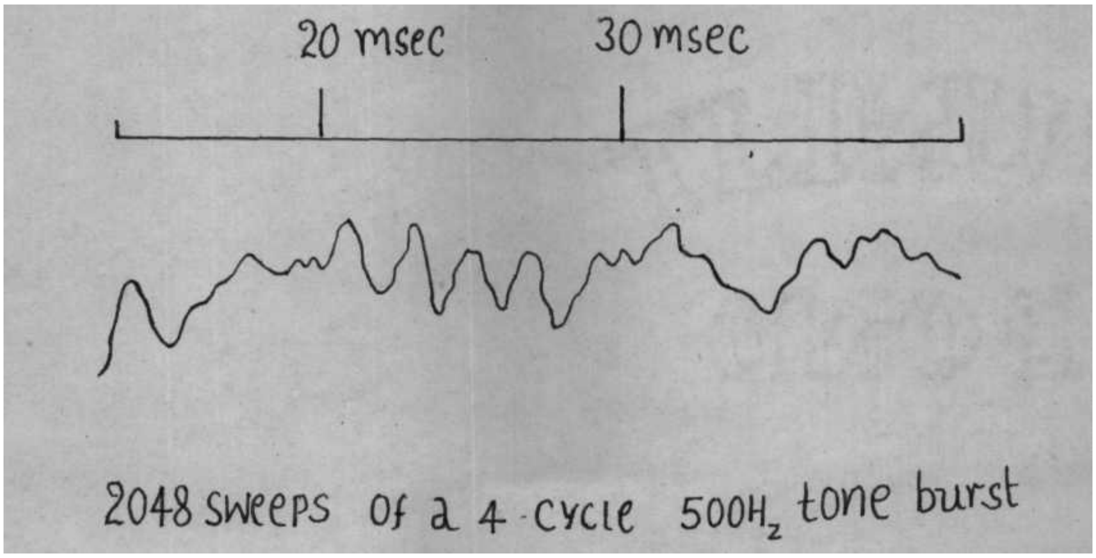
Berlin(i978) warns against exclusive use of BER audiometry with children because at high intensity levels, transcranial transmission may take place at the level of Jv making it unsure as to which ear has yielded response. He recommends BER audiometry to be included in test battery.

BER audiometry involves signals with short rise time and hence responses reflect predominantly the basal turn of the Cochlea(Davis, 1976).

Rose et al(l967) reported that synchronous firings of units of auditory nervous system to low frequency tones can be recorded.

Based on this principle, Worden and Marsh(1969) described 'Frequency following response'(FFR). It is a microphonic like response which follows the driving frequency of the stimulus.(See fig.5)

Figure-5



Sample FFR to 500H$_2$ tone burst

For recording this response, Stillman, Moushegian and Rupert(1976) use a vertex target electrode, a reference, right earlobe electrode and a ground electrode placed on opposite ear lobe.

A high gain high frequency preamplifier is used with low frequency limit set in the preamplifier to allow low frequency synchronous discharges.

Response is clearly observed for tones 500Hz & below. Rise time of tone is 4 to 5 msec. If a stimulus of frequency 250Hz is presented to cochlea, a group of firings from units of cochlea in synchrony with phase angle of 2$0Hz tone is elicited.

Davis and Hirsh(1979) reported a slow negative response at 10 msec post stimulus (SN_{10}). It seems to terminate the brainstem sequence. Source is thought to be dendritic material.

It can be elicited by tone pips of 500, 1000 and 2000Hz at low intensity levels and clicks.

SN_{10} can be recorded with active electrode on forehead, reference on right mastoid and ground on left mastoid.

Latency in newborn is longer than adults. SN_{10} provided more information than Jv in newborn subjects. SN_{10} can be useful as a threshold indicator for low frequencies.

(b) The middle response:

The middle response is comprised of a series of fast waves(5 to 100Hz) (Goldstein,1969). There is much controversy regarding the origin of middle response.

While Geisler, Frishkopf and Rosenblith(1958) believed that the component was of neural origin, Bickford,Jacobson and cody(1964) indicated it to be myogenic because response amplitude changed systematically with variation in tonus of neckmuscles. Geisler(1964) proposed that the middle response was neurologically generated with amplitude dependent on muscle tension.

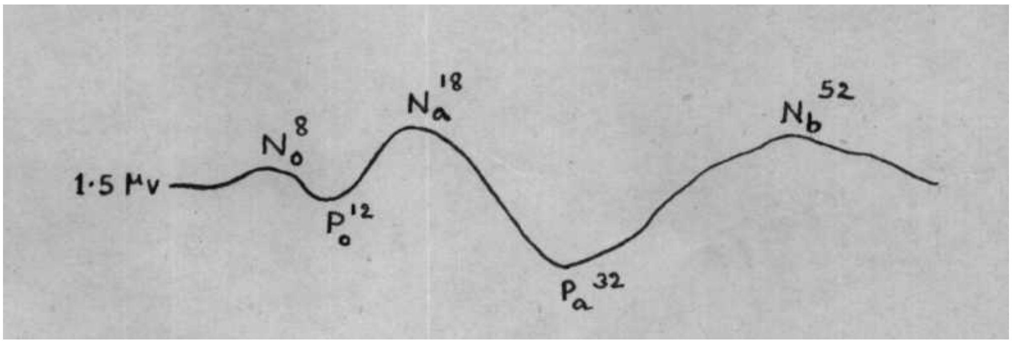
The middle Response when recorded from postauricular location is myogenic. (Kiang et al, 1963, Cody et al, 1964) Mast (1963,1965) reported that the middle response comprised of both neurogenic and myogenic components as the response recorded from vertex was consistent with muscle contraction.

Neurogenic origin of the response has been supported by several investigators,(Borsanyi and Blanchard,1964; Lowell,1965; Goldstein, 1965; Ruhm et al ,1967).

The middle response is presumed to be arising from primary cortical projection areas(Goldstein, 1969).

Lowell(1965), Ruhm et al (1967), Goldstein(1969) have described the wave form of the middle response as comprising of two positive peaks P_o and Pa at 12 and 32 msec latencies respectively and three negative peaks N_0 ,Na and Nb at latencies of 8,18 and 52 respectively. (See fig.6)

Figure-6



Lowell et al (1960) reported that the amplitude of the middle response increases with the decrease in stimulus rate. Optimum stimulus repitition rate of 10 per sec is best for clinical measurement of the middle response (Mendel,1973).

Response amplitude increases in direct relation with stimulus intensity.

Skinner and Antinoro(1969b)found that stimuli with fast rise time (10 sec) were most effective in eliciting the middle response.

Lane and Kupperman(1969) and Skinner and Antinoro(1970) found middle response to be unaffected by signal duration.

Filtered clicks and tone pips have been used to elicit the middle response, but interpretation of frequency information is difficult with such stimuli(Hood,1975).

The response waveform characteristics of the middle response are stable and unaffected by natural sleep(Mendel and Goldstein, 1969) or Sleep because of sedation(Mendel,1973)

Karlovich and Goldstein(1969) suggest 500 or more stimulus samples to be taken for analysis of the middle response.

With the finding of close(within 5 or 10 dB usually) agreement between middle response thresholds and behavior thresholds for the same stimuli, middle response threshold can be used as an indicator of auditory sensitivity (Geisler et al, 1958; Goldstein and Rodman,1967; Lowell et al,1960; Mast,1965)

Davis et al (1974) Skinner(1973) found middle responses to be inconsistent to allow any estimate of threshold.

Mc Randle, Smith & Goldstein(1974) could elicit middle response in newborns during sleep with clicks at 55dBHL. These authors find this response to be useful in threshold audiometry for neonates.

(c) The late response-

The late response comprises of 'slow waves'(2 to 10Hz) presumably arising from primary cortical projection and sensory association areas(Appleby,1964; Scott,1965).

The late response was described in l964(Davis,1964; Davis et al, 1964; Dubyshire and Mccandless 1964; Mccandless and Best,1964; Walter,1964;)

This response is generally accepted as neurogenic in origin. It is a diffuse response that is easily recordable from nearly anywhere on the scalp, but has its largest amplitude when recorded from the vertex(Davis,1939).

While late responses can be evoked by auditory, visual and tactile signals, and recorded from many areas on the cortex the wave forms differ among sensory modalities, auditory stimuli eliciting largest amplitude. (Walter,1964).

Late response in sleeping subjects probably gives rise to "K complex" a special pattern of EEG reported by Loomis et al (1938) and Davis et al (1939).

Wave form of the late response is polyphasic with vertex positive peaks at about P 75 and P_2 200 msec and vertex negative peaks at about N 150 and N_2 275 msec.

Increase in the late response amplitude with decreased rate of signal presentation has been reported by several investigators (Keidel and spreng, 1965; Davis et al,1966; Nelson and Lassman,1968). Although one signal per 10 sec. yielded largest amplitude, it is too timeconsuming for clinical use. McCandless and Best(1966b)reported repetition rates of 1 click per 2 sec or slower to be satisfactory for eliciting late response. Irregular rather than constant interstimulus internal promotes a higher amplitude response (Barnet,1971).

Leibman and Graham(1967) and Rose and Ruhm(1966) indicated that 100 or more signals may be used without risk of inhibition. The least number of runs reported to be adequate are from 32 (Davis et al, 1966) to about 50(Cody and Bickford,1965; Leibman and Graham,1967; McCandless and Best, 1964; price and Goldstein,1966).

Many studies have demonstrated that an increase in intensity produces an increase in peak amplitude and a decrease in latency. Skinner and Antinoro (1969b)and Antinoro et al,(1969) have shown that the relationship between signal intensity in dB and late response amplitude in microvolts is linear for low and middle frequencies.

Amplitudes for fairly loud click stimgli(50 to 70dBSL) range from 10 to 20 volts and get quite small as behavioral threshold is approached (Davis,1965).

A distinctive drop in the amplitude of late response when rise time of the stimulus reached 30 msec(Onishi and Davis, 1968) was observed. Thus, a rise time of 25 to 30msec is optimal since it is gradual enough to produce a puretone and sufficiently abrupt enough to evoke a clear late response.

Onishi & Davis (1968) reported that with optimal rise time of 25 to 30 msec no effect of signal duration on late response amplitude. Skinner and Jones(1968) also did not find any consistent change in response amplitude with change in signal duration.

Barnet recommends signal duration of 100msec while price and Goldstein(1966) used signal duration of 30msec in their study.

Several authors have reported that the amplitude of late response decreases as test frequency goes above 1000Hz

(Antinoro et al, 1969; Evans and Deatherage,1969; Henderson, 1972; Rothman and Davis,1970).

Henderson(1972)reported that the late response thresholds were within 10dB of behavioral thresholds at 250 and 500Hz while at 4000 and 6000Hz, late response thresholds were 20dB poorer than behavioral thresholds.

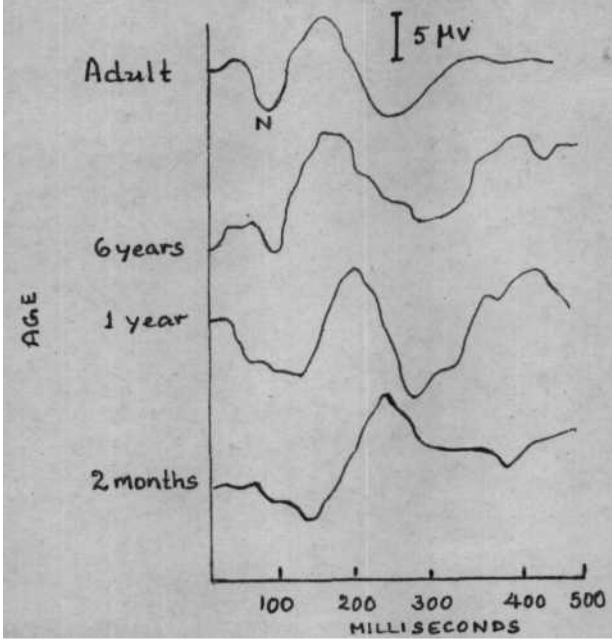
An analysis band pass of 3 to 15Hz is optimal for children and 1.5 to 30 Hz for testing adults (Hood,1975) Davis and Niemoeller(1968) suggest band pass of 3 to 35Hz for children inorder to fitter out low frequency movement artifacts and high frequency muscle potentials.

Electrode arrangement consists of an active electrode on vertex of skull on interaural plane, reference electrode on ipsilateral earlobe and ground electrode clipped to contralateral ear. Test stimulus may be presented through earphones, free field speaker or bone conduction vibrator (Mc candless, 1967).

The late response is highly influenced by the age of the subject. Price and Goldstein(1966) found decrease in latency and amplitude of the late response with increase in age. (See figure7) By the age of 7 years the late response appears much like an adult's response(See fig. 7) (Davis et al, 1967)

Figure-7

The averaged evoked response from adults & children



Mc candless and Best (1966a)and Davis and Zerlin(1966) concluded that the evoked response is highly variable at all ages, between subjects and test/retest reliability with the same subjects.

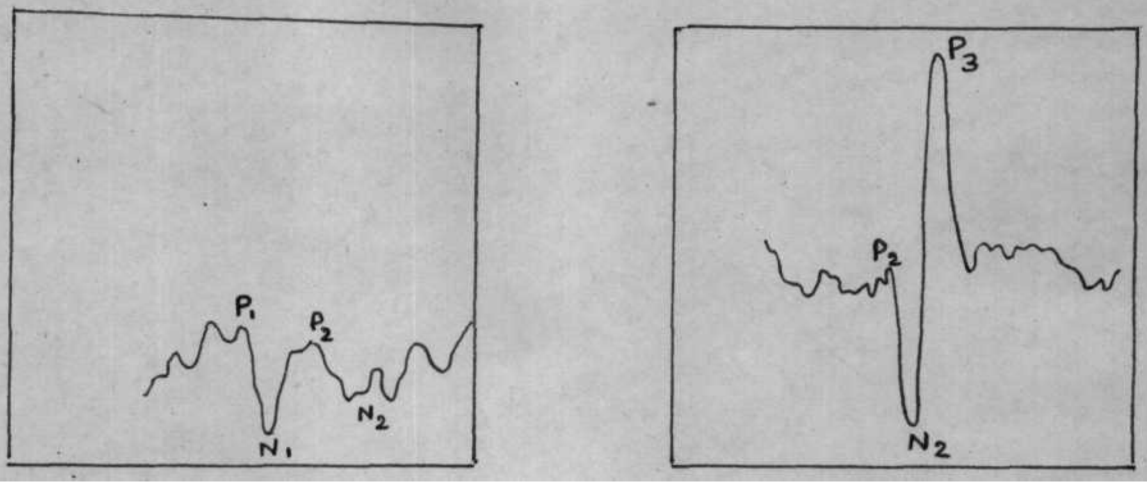
The wave form of the late response changes considerably and at times unpredictably during both natural and sedated sleep. Peak latencies tend to become longer (Skimmer and Antinoro, 1969a)as sleep gets deeper.

Rapin and Bergman(1969) found that in waking children, constant waves were $N1_{100}$ and $P2_{200}$ where as in sleeping children the constant peaks were P2,N2 350/500 msec and sometimes $P3_{500}$ & 800 msec. (see fig.8)

Figure-8

(a) AER in waking child (b) AER during stage 2 sleep

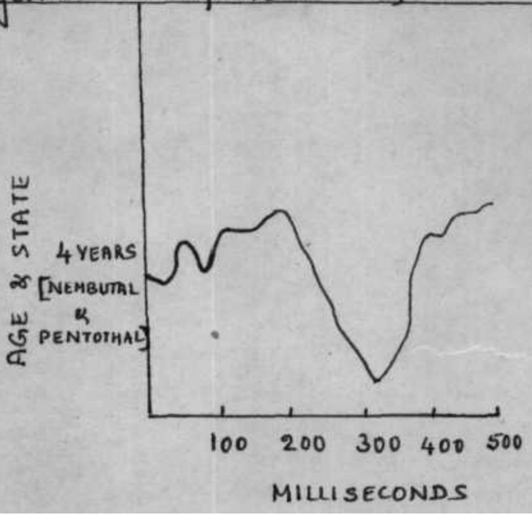
[Response to 100 presentations of 1000Hz tone at 80dBHL]



Williams,Tapas and Morloch(1962) reported that during certain stages of sleep, in the adult, a large negative peak occurs at about 300 msec which appears to be an exaggerated NL. This negative component in sleeping children is a good indicator of hearing. (Price & Goldstein,1966) (See fig. 9)

Figure-9

Negative component of AER during sleep



Peak latencies tend to become longer (Skinner & Antinoro,1969a)as sleep gets deeper.

Any medication which affects ongoing EEG activity is likely to affect evoked response. The late components of the response are observed when the patient is sedated with pentothol (Price & Goldstein, 1966; Rapin and Graziani,1967). Rapin and Graziani(1967) reported good results with children sedated with chlorpromazine. Late negative component of response at about 300 msec(N_2) is enhanced by pentobarbital sodium induced sleep.

Price(1975) recommends an analysis time of 750/1000 msec in sleeping infants inorder to insure against loss of information.

Walter(l964) reported that habituation, a progressive attenuation of a cerebral response to monotonous presentation of regular stimuli, is a prominent feature of evoked response Weber(1972) did not notice any evidence of habituation in twelve infants (14-18 week old).

In very young children for interpretation of late responses, norms are of very little value(Mc candless,1967; Lentz and Mccandless, 1971; price,1969; Price & Goldstein, 1966). A typical responses are the rule rather than exception in these populations of young children where it would be most useful.

Rose and Ruhm(1966) made a significant contribution to clinical practice with the evoked response by suggesting the use of a silent run during which time, the EEG activity is averaged but no acoustic stimulus is presented to the subject. Results from the silent run are then compared to results from a stimulus presentation run.

Price(1975) suggests combining silent run and stimulus presentation run by extending (by about 500 msecs) the computer analysis time and triggering the sweep of computer 500msec. Prior to onset of each stimulus. Then cortical activity during prestimulus period can be compared with post stimulus period activity. When the stimuli are below threshold, pre and post stimulus averages are similar. When stimuli are above threshold responses are clearly evident in post stimulus portion.

Late response has been used for auditory threshold testing in children by many investigators.

Davis et al (1967) found the difference between late response thresholds and behavior threshold obtained with same stimuli, to be 0.1dB in deaf subjects. Mccandless(l967) found that evoked response thresholds tended to be poorer by 5-10dB than thresholds obtained by play audiometry in children between ages of 3 and 7 years. Rose and Rittmanic (1968), in their study of normally hearing mentally retarded children found the difference between voluntary threshold and evoked response threshold to be 10 dB.

Suzuki and Origuchi(1969) found evoked response technique to be most sensitive in severe hearing impairments, the late response threshold differing by 0.43 dB from conditioned orientation reflex threshold.

Rapin, Graziani and Lyttle(l969) gave following criteria for interpretation of evoked response threshold- i)Threshold 40 dB or less-mild loss ii)45-70 dB threshold-moderate loss and iii) 75dB or more threshold-severe loss. They could establish normal hearing by evoked response threshold criteria in 11 children who had been diagnosed as hearing impaired by behavioral response audiometry.

Suzuki, Taguchi and Yoda(1979) found late response or slow vertex response more reliable for audiometry in children with sensorineural hearing loss, even when they are asleep.

Some investigators have directed their attention toward infants. Appleby(1964) reported that 85% of 40 neonates (2-10 days old) responded to 50 dB pips when evoked responses of vertex positive component were obtained.

Evoked responses in neonates ranged from 45dB to 60dB (Barnet and Godwin,1965; Suzuki et al, 1966; Toriyama et al, 1966)

Taguchi et al (1969) on testing 0 to 4 day old infants found better evoked response thresholds for lower frequencies and slightly better thresholds in somewhat older infants.

Evoked response thresholds for premature infants(59 dBHL) was higher than those for normal infants (43 dBHL) (Lentz and Mccandless, 1971).

Barnet(l97l) reported that nearly half of the infants suspected of having a hearing loss did have a hearing loss when examined with evoked response audiometric techniques.

Lowell, Lowell and Goodhill(l975) found considerable agreement between test and retest results in a longitudinal study on evoked response audiometry in children.

Price(1969) cautions clinicians against false positive judgements where the patient is judged to have an auditory perceptual problem, to be a malingerer, or to have a Psychogenic hearing losses or false negative errors where true organic thresholds are exaggerated. False positives may be reduced by establishing strict criteria for responses and by obtaining frequent reference series. By repeating the analysis several times for interpretation, false negatives may be minimized.

(d) Very late responses:

The 'very late' responses have been described as the 'expectancy wave' which is the last peak in the late response (Davis,1973) and the 'contingent negative variation' which is a long latency negative potential(DC shift) (Walter, 1964). Both types of responses can be related to specific conditioning stimuli to test certain cognitive or Psychological operations in children as well as in adults (Skinner, 1978). They do not come under objective hearing tests as they require active participation of the subject.

2. ELECTROCOCHLEOGRAPHY:

The term 'Electrocochleography' was coined by lempert et al (1947). Which involves recording and analysis of electrical potentials that originate within the cochlea or the auditory nerve.

There are three classes of electrical potentials, analysed in Ecoch G - 1) The cochlear Microphonic(CM) described by wever and Bray(l930) as originating from hair cells of organ of corti ii)the action potential (AP) from the auditory nerve noted initially by Derbyshire and Davis(1935) and iii) the summating potential(SP) identified by Davis (1950).

Cochlear Microphonic reflects the acoustic stimulus waveform over a considerable frequency and intensity range (Wever,1966). It is the earliest of three potentials, occuring nearly instantaneously after a stimulus reaches the cochlea. (Simmons and Glattke,1975). It is extremely risky to use cochlear Microphonic as an index of auditory thresholds or site of lesion though it has been suggested (Ruben,1967). Reason is that CM recorded from outside the cochlea indicates response from a small segment of cochlea (Misrahy et al, 1958; Simmons and Beatty,1962) corresponding to frequencies above 10KHz. For measuring CM response to lower frequencies, electrodes have to be placed within the cochlea which is not a possibility in clinical EcochG(Dallos, 1969,1973).

The SP component is a do shift in response to stimulation (Van Bekesy,1960), which is not in contention as an index of normal cochlear function in humans. (Simmons & Glattke,1975).

The AP has been thought to originate in the internal auditory meatus where the fibres from the spiral ganglion twist together to form a compact bundle (Tear et al,1962; Dallow,1973). Derbyshire and Davis(1935) suggested that the AP recorded from the roundwindow and its sorroundings originated from nerve fibres in bony spiral lamina. "The AP has proven to be the most sensitive indicator of the functional state of the peripheral auditory system yielding information about both the threshold and supra threshold characteristics of the cochlea and auditory nerve". (Glattke,1978).

The individual nerve fibres produce unitory 'spike' discharges of constant amplitude and duration. Sum of these spike potentials is the compound Action potential(Berlin,1978).

Fromm et al (1935) were the first ones to pick up cochlear potentials from the human ear. They reported good recordings of cochlear microphonic from round window niche, otic capsule promontory, mastoid process and walls of external auditory canal on testing patients with large perforations of tympanic membrane.

Lempert et al (1947) reported EcochG results conducted at the time of surgery in 11 patients. They reported that potentials recorded from roundwindow yielded largest potentials with hypodermic needle inserted in the skin of external ear as inactive electrode, Lempert et al(l950) found that it was difficult to carry out EcochG through intat tympanic membrane and hence suggested that the procedure was clinically impractical.

Ruben(l967) reported that it was not possible to obtain specific information about amount of frequency characteristics of hearing loss by recording CM and AP.

The use of an averaging computer (Clark et al 1961) was extended to human cochlear recordings by Ronis(1966). As this procedure permitted recording of very small voltage responses, it was no longer necessary to place the electrode as close as possible to the organ of Corti.

Electrodes and recording sites used in EcochG fall in to three groups: i)transtympanic needle electrodes, making contact with the promontory of cochlea ii)intrameatal surface electrodes and iii) Surface electrodes attached outside the ear canal(Glattke,1978).

Portman,Lebert and Aran(1967) and Yoshie Ohashi and Suzuki(l967) developed Transtympanic membrane technique. Electrodes are hyperdermic needles, 3-6 inches in length, insulated except at the point and outer ends. Needle point after passing through posterior/inferior quadrapt of tympanic membrane contacts the promontory. It is held in place by medical grade cement applied to tragus(Yoshie,1973) or circum aural ring held in place by a headband(Portman and Aran,197l). Reference electrode is attached to earlobe on the same side and a ground electrode placed on the forehead. General anesthesia is used in young and difficult to test children to permit electrode placement and subsequent recording (Eggermont and Odenthal,1974a j Naunton and Zerlin, 1976a).

Intrameatal surface electrodes are placed within the external meatus near the tympanic membrane(Yoshi and Ohashi, 1969; Cullen etal, 1973; Coats,1974) Local anesthesia is used to place the electrode in the skin of posterior wall of external Canal 5mm from the annulus of the tympanic membrane. Reference electrode is placed on the earlobe and ground on the forehead.

Surface electrodes outside of the ear include those which are clipped to the earlobe (Sohmer and Feinmesser, 1967) or fitted to a device which holds them in contact with the hard palate (Keidel,197l).

Transtympanic technique is appropriate when conventional behavioral and other forms of objective technique have produced equivocal results. (Schmidt and Spoor,1974; Montandon et al,1975).

The AP can be elicited only if rise time of the stimulus is faster than 1 msec. (Goldstein and Kiang, 1958). So clicks or tone bursts are used in EcochG for the purpose of providing abruptness (Portmann and Aran,1971; Yoshie, 1968,1973; Eggermont,1974; Naunton and Zerlin,1976b).

The phase of each signal can be held constant or inverted 180° during the course of gathering responses. Then the CM portion of the observed responses will mimic the phase of click or tone pip and when signal is inverted 180° and presented, CM portion gets cancelled. (Peake and Kiang; Dallos,1973). Meanwhile the summed Action potential is free of microphonic influence.

Measurement of the sound pressure level for clicks and tone pips cannot be accomplished with conventional sound level meters because the signals are too brief to be read accurately by meter. Teas,Eldredge and Davis(1962) have suggested the method of determining peak equivalent SPL. The transducer is placed in the usual position far EcochG and the microphone is placed in a position corresponding to location of patient's pinna output of the monitoring microphone is observed on an oscilloscope while clicks or tone pips are generated by the transducer. The peak amplitude and principal frequency of transducer output are noted. Then a continuous sinusoid is given instead of tone pip or clicks and is matched to the amplitude and frequency noted previously . Sound pressure level is measured for this substitute signal and it is called peak equivalent SPL.

In clinical practice, it has become common to express signal levels in dB with reference to mean click or tone pip threshold for normal listeners.

Rate of presentation of clicks or tone pips is 5 to 10 per sec. (Glattke,1978). Eggermont and odenthal,(1974 a) found that there was 50% reduction in amplitude of the AP when stimulation rate was increased to about 30 per sec.

Promontory recording requires between 50 and 500 samples for analysis where as intrameatal and surface recordings require more than 500 samples,(Glattke,1978).

Typical apparatus used for EcochG is described here. A small metal cup attached to the active electrode's outer end is connected to the preamplifier lead. The differential input amplifier concels the electrical noise, common to active and reference electrodes and enhances the AP. The fitters are set from 0.9 Hz through 10KHz (Simmons and Glattke,1975) with total gain in amplification 10,000 to 100,000 in order to provide levels adequate for computer processing. Computer must be able to sample the evoked activity from the recording amplifier and return to get next sample at a rate twice that of highest frequency passed by amplifier.

Yoshie et al(1967) describe a typical action potential response, as an initial wave N_1 followed 1 sec later by a smaller negative wave N_2 and followed occasionally later by a still smaller negative Wave N_3 latency of N_1 is defined as the time between arrival of click at the eardrum to the peak of N_1. The amplitude of the response is measured from the idealized baseline drawn through the tracing of spontaneous activity at the zero response level to the peak of the wave. (See Fig. 10).

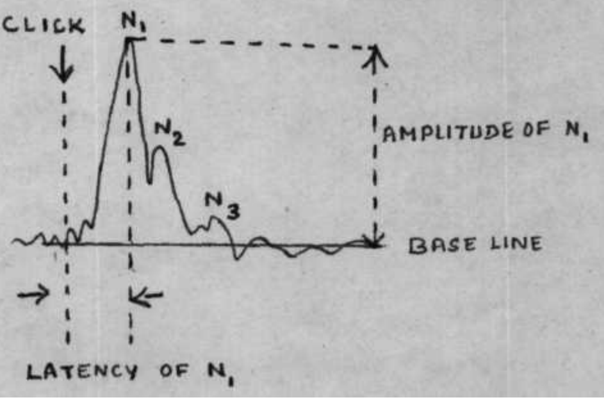


Figure-10

Electrocochleographic averaged response

(recorded from electrode in the wall of external auditory canal)

Aran(l971 is more interested in the dynamic range of variation rather than absolute amplitude of the N_1 response. He measures peak-to-peak amplitude of the response and the latency of the first negative peak N_1 . He reports that the waveform is diphasic (Negative wave positive wave) at low and medium intensities and monophasic (negative wave only) at high intensities.

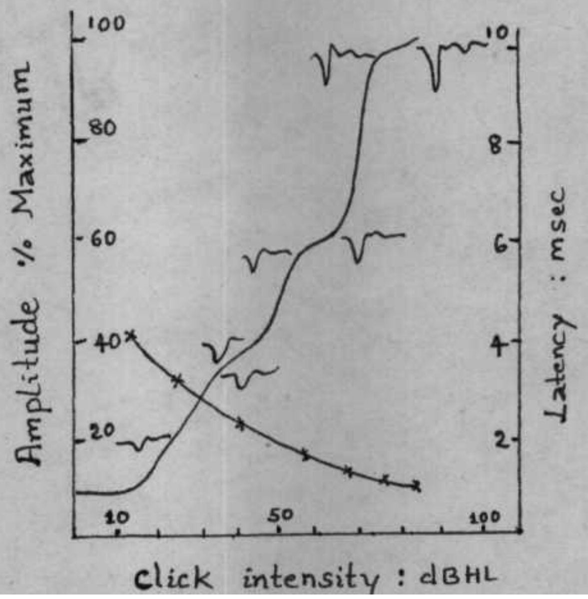
The plot of N_1 peak latency and relative amplitude against stimulus intensity is called cochleogram. (Simmons & Glattke,1978).

Yoshie(1968) examined Input/output functions which plotted click intensity against amplitude of N_1 wave in microvolts. He found that the curves rise rapidly in the begining from threshold level to an initial hump and then rise again to a second hump which is the maximal level of output. Yoshie designated the low and high intensity portions of action potential response as L and H curves respectively. At 70 to 80dB peak equivalent SPL, the curve shows the inflection point.

Aran(l97l) has an interesting technique of showing several types of results on same cochleogram including threshold of response to click, the pattern or input-output function of the click evoked response at supra threshold levels and amplitude and latency pattern of many curves. (See fig. 11)

Figure-11

Normal electrocochleogram from left ear of 3 year old



Yoshie and Ohashi(1969) have EcochG patterns for

i) Normal hearing subjects as N_1 curve showing two distinct segments of input-output function(L and H curve) which might have been generated by different population of neurons stimulated by different class of sensory cells.

ii) Conductive hearing loss as showing a latency shift for the N_1 wave and amplitude change that was proportional to the degree of loss.

iii) Sensorineural hearing loss demonstrating an overall reduction in the amplitude of N_1 which may be related to reduced number of neurons capable of firing, disappearance of L-segment of input-output function indicating specific goup of pathological hair cells and a prolonged N_1 because of neural delay from asynchrony of neural impulses.

Tone pip signals result in Ap responses with amplitude and latency characteristics which are related to the frequency region and temporal features of the individual signal.

It was reported from Eggermont and Odenthal (1974b)and Naunton and Zerlin (1976a)that EcochG thresholds may be greater than 10 dB above perceptual thresholds for 500 and 1000Hz tone pips, but that they are likely to be within 10dB of perceptual thresholds for 2000, 4000 and 8000Hz.

Portman, Aran and Lagourgue(1973) reported 'recruiting cochleogram' associated with sensorineural hearing loss. Here the response grows in amplitude very rapidly without a plateau catching upto the amplitude of a normal subject at the same level of intensity, although it is considerably closer to the threshold of recruiting patient. The latency of response will be very short failing to show the progression seen in normal cochleograms. A diphasic response pattern is seen at all sound levels. Audiogram in such a case shows sloping or flat configuration. The change in slope of response curve which usually occurs around 60dB threshold reflects transition from outer hair cells and inner hair cells. Therefore recruiting Cochleogram shows damage to outer hair cells (Yoshie,1971; and Portman et al, 1973)

Disassociated pattern of cochleogram in sensorineural hearing loss cases was reported by Aran et al (1971).

Audiogram shows normal hearing till 2000Hz, a notch of 60dB at 6000Hz and near normal threshold at 8000Hz Ap response threshold is slightly elevated with the response function growing normally till 60dB. At 60dB, a 'new' N_1 component appears which dominates the response at higher click intensities. In cochleogram, this change in wave form is reflected as abrupt disjuncture of amplitude and latency curves at 60dB. This hole in the cochleogram corresponds to loss of sensitivity between 2 and 8KHz. (Simmons & Glattke,1975).

The 'larges' (broad) responses where there is flattening or broadening of N_1 response is observed in patients with retrocochlear lesion(Portman & Aran,1972). An 'Abnormal' AP configuration with an initial positive component before N_1 component may represent a combined cochlear disorder and a more general brain pathology.

Electrocochleography is a physiological test of cochlear function in individuals who cannot be tested by conventional audiometry and whose responses to other electrophysiological tests are equivocal.(Simmons & Glattke,1975).

Aran(1971) reports results obtained from 29 children (as young as 1 month of age) on electrocochleography. He found no response to click stimulus of 100 dBSPI in 9 children, slight responses at l00dB in 3 children; in 7 of them clear responses to levels between 60 and 90dB; 6 children showing clear responses between 0 and 30 dB and 4 showing 'abnormal' response with positive peak.

Sohmer and Feinmesser(1967,1973) report good results obtained with an active earlobe clip electrode and a reference scalp vertex disc electrode in infants and childre] with suspected hearing loss or uncertain diagnosis. In 22 cases, absence of EcochG response confirmed peripheral hearing loss, normal cochleogram in 13 cases indicated that behavioral hearing loss was not peripheral in origin, in 2 children EcochG provided hearing evidence confirmed later by behavioral techniques and in 22 infants, there was abnormal responses with high thresholds, small amplitudes or long latencies. Sedation seemed to have little effect on Action potential response.

Parving, Eberling and Salomon(l981) tested 149 children with age ranging from 2 to 123 months with EcochG. There was high correlation between EcochG thresholds and puretone thresholds in 53 children. When a comparison between Behavior observation Audiometry (BOA) and EcochG thresholds was made, it Was found that BOA underestimates degree of hearingloss. EcochG gives valid estimates of hearing thresholds even in young children.

One of the advantages of EcochG is that each ear can be studied independently with masking obviously unnecessary (Berlin,1978). Northern and Downs(1978) hope that EcochG may aid in evaluating an infant's potential for hearing aid fittings or educational placement by testing his auditory sensitivity.

But EcochG gives information only about basal turn of cochlea i.e., frequencies above 1500Hz. On lowfrequency stimulation, even though corresponding neural fibres innervating cochlea respond, their contribution cannot be detected because the large amplitude basal response obscures them. (Davis, 1973).

When high pass bands of noise that progressively extend to lower cut off frequencies are used, responses evolving from progressively more apical cochlear regions are obtained (Simmons and Glattke,1975).

3. ELECTRO DERMAL OR PSYCHO GALVANIC RESPONSE AUDIOMETRY

Psychogalvanic reflex(PGSR) or electrodermal response (EDR) was observed first by Fere(l888), named by Veraguth (1909)and was reportedly used to measure hearing sensitivity by Albrecht(1918).

For the assessment of PGSR two basic methods were developed (Lindsley,1963)- i) The exosornatic approach of Fere which involves recording the degree of resistance offered by the skin in conducting an externally applied, low voltage current. Term Galvanic skin Reflex is employed to describe dermal responses detected by Fere method.

ii) Tarachnoff method of endosomatic approach where difference in electrical potentials generated by effector organs of skin are measured. This is called electrodermal response. Fere approach is more frequently used(Hogan,1975).

Bordley, Hardy and Richter(1948) utilizing modern audiometric equipment applied the technique of pairing pure tone stimuli with mild electric shock. After several presentations, tone alone was capable of eliciting the desired PGSR.

"The change in skin conductance which is the characteristic precurs or of EDR can be elicited by virtually any suprathreshold auditory or nonauditory stimulus with or without conditioning".

The recording electrodes Can be attached to inner surface of forearm or palm of the hand. Shock electrodes can be connected to one hand and response electrodes to other hand for ease of application. (Knox,1978).

Goldstein reported that latency of GSR is within a range from 1.8 to 2.9 secs. GSR tends to habituate on repeated sound stimulation(Berlin,1978). In conditioning EDR, 40% reinforcement Schedule (Chaiklin etal 1961) and presenttation of shock 0.5 sec. after the onset of tone are carried out (Bitterman et al 1952).

Crowell et al. (1965) observed GSR activity in infants as early as 20 to 67 hours. There have been many studies reporting application of PGSR technique in retarded children (Irwin et al, 1957; Kodman et al, 1959; Moss et al, 1961; Waldon,1968). Spradlin, Locke and Fulton(1969) reviewed the state of the art of EDA with mentally retarded children and found it to be essentially ineffective.

Knox (1972) suggests that uninhibited nature of children almost precludes them from being candidates for EDA.

Conditioned EDR is difficult with children as it is not objective and requires active participation from the child. Unconditioned EDR is not a threshold level assessing device (Berlin,1978).

4. RESPIRATION AUDIOMETRY

Although breathing pattern alternations had been observed following sound presentations, it was only later that measurement of these alterations were used to quantify hearing sensitivity. The procedure has been termed "Respiration audiometry" (Bradford and Rousey,1972).

Mosso, in the late nineteenth century, investigated respiratory functioning of humans and animals by recording abdominal and thoracic movements with a pneumograph. In 1878, he recorded his sleeping brother's respiration and pulsepressure changes to the sound of light taps on a table top.

Stubbs(1934) was the first person to combine pneumograph records and controlled auditory stimuli for the assessment of hearing. She examined the effects of duration, intensity and frequency 6f puretones on respiration in newborn infants while they were asleep, in awake-inactive,silent active and crying active states. Puretones in the intensity range of 30 to 85 sensation levels were given through a speaker. Respiration was recorded by pneumograph. Respiration response were increase in rate and decrease in amplitude as stimulus duration increased from 1 to 15 sec. Smaller percentage of responses occured with increase in intensity Frequency of stimulus did not have much effect on responses nor did the physical states of infants.

From this study onwards various investigators have tried respiration audiometry with different kind of stimuli and instrumentation.

Rosenau(2962,1962b)recorded respiration movements using a kymograph connected to pneumograph, The former recorded the respiratory movements of thorax and abdomen picked up by the latter. He found noise stimulus to be more effective than puretones for eliciting respiratory changes.

Wagner(1963) used a modified Psychogalvanometer and constructed a different pneumobelt to improve respiration recordings Lehnhardt(1963) introduced a cadmium sulfide photo pneumograph to record more accurately thoracic movements for air and bone conduction assessments.

Mahler and Wagner(1967) used impulse puretone stimuli where as Gerhardt et al(1967) used rhythmic white noise impulses synchronized with subject's respiration rate.

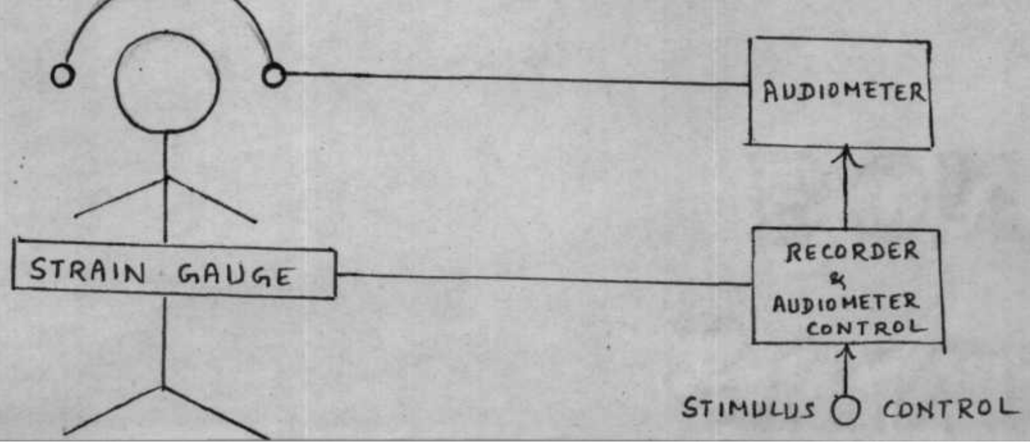
Suzuki et al(1964) used 500Hz tone and artificial sound (cow mooing) for a duration of 4 to 5 sec. in 10dB increments from 30 to 80dB. Low middle and high frequency modulated puretones were the stimuli in Heron and Jacob's study (1968, 1969).

Teel et al (1967) reported the use of a mercury in rubber strain gauge positioned around the chest of the subject to pick up respiration changes. Straingauge is attached to channel recorder through a wheat stone bridge change in balance of the bridge circuit caused by respiration movements are amplified and fed to recording pen.

Bradford (1975) describe the respiration audiometry equipment as consisting of a bellows actuated photoelectric cell strain gauge, stimulus timer and a two channel polygraph recorder with heat sensitive paper(See fig. 12)

Figure-12

Schematic drawing of the respiration audiometry equipmen



The strain guage is fitted snugly but not tightly around the chest of the person being tested. Movements of the chest during respiration lengthen or contract the bellows. The bellows, changes are recorded on the polygraph as upward deflections for inspiration and downward deflections for expiration. One channel of polygraph serves as the event marker to record the point and duration of 250 msec. stimulus tone and second channel records the respiration cycle traces. The paper speed of polygraph can be set to run at 5 and 10mm per sec. The amount of stylus deflection is adjusted by a balance control knob so that amplitude of respiration cycle recordings can Vary between 25 and 60mm in width. Stimuli can be delivered from the audiometer through bone conduction vibrator or earphones.

Kankkunen and Liden(1977) used warble and puretones of frequencies 0.25,0,5,1.0,1.5,2.0,3.0 & 40KHz, presented through earphones or loudspeakers or Bone Conductor Vibrator. Frequency modulation was ±5% 10 times per sec. Recording apparatus described by them consisted of electrodes attached on either side of chest with tapes and feel with weak current. Breathing movements change air volume of lungs resulting in alteration of impedance. This can be picked up as voltage variations by electrodes and recorded by an ink recorder operating at a speed of 0.5cm/sec. An event marker to indicate tone stimulus is connected to one of channels of recorder.

Many investigators have used Respiration audiometry in children to assess hearing.

Roseneu(1962a)in his sleep-hearing test found that normal hearing children had a mean reaction threshold by respiration from 50 to 60dB at 125,400,1250 and 4000Hz. Difference between'mean reaction threshold' by respiration and audiometric threshold was from 40 to 55dB for those with induced deafness and 34 to 39dB for organically deaf group. Rosenau found that sleep had no effect on change of respiration. Lehnhardt(l963) reported threshold by respiration to be elevated by 30dB in deep sleep and by 30 to 40dB with sedation in children.

Rosey et al(l964) found low level stimuli evoking larger changes in respiration patterns. Suzuki et al (1964) in 45 normal neonates observed three respiration alterations:- i)changes rate or deepness of respiration ii)Decrease in regularity of respiratory movements lasting 20 to 30 seconds after auditory stimulation and iii)appearance of sudden deep inspiration increasing significantly at 70 and 80 dB intensity levels. They found average of respiration responses to be 628dB.

Teel et al (1966) used respiration audiometry in subjects between ages 7 and 21 years. They considered the thresholds obtained by respiration audiometry to be in agreement if they were within 15dB of audiometric threshold 94% achieved this criteria.

Mahler and Wagner(1967) report that both the sleep and waking tests can be used with infants 6 months of age and older using respiration audiometry.

Gerhardt(1967) found increase in respiration rate with increase in rate of stimuli and change in respiration rate on termination of stimuli.

Heron and Jacops(1968,1969) report the most frequent respiration alteration in neonates to frequency modulated tone stimulation to be change of rate or depth of respiration or a 'gasp' reflex.

Kumpf and Landwehr(1970) used white noise, filtered white noise and warble tones as stimuli, presented through ear phones increasing in intensity at a rate of 1dB per sec. This was recorded on one channel of tape recorder while on the other channel, subject's breathing sound was recorded. These recorded sounds were played in to a level recorder to obtain synchronized write out called as 'pegeldiagram' by kumpf. On analysis, it was found that decrement in the amplitude of breathing sound occured near auditory threshold consisting of pauses between inspiration and expiration. Increment in amplitude of breathing sound occured when level of stimuli was above or equal to 30dB sensation level.

This technique is useful to measure air and bone conduction thresholds with children when awake and when under sedation. The procedure is not successful when subject is sleeping deeply.

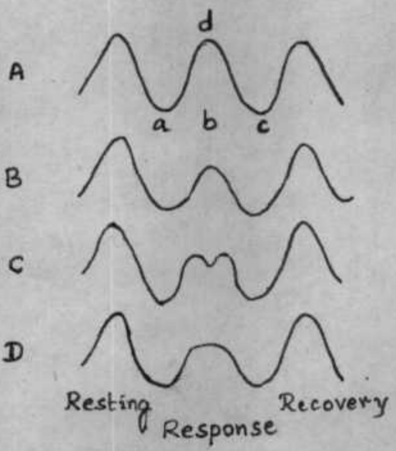
Hogan(1970) has given a measure 'the Respiration Response Index which provides a single numerical value sensitive to response activity in rate, amplitude and wave-form.

Bradford (1975) gives three respiration cycle patterns to be considered when scoring the responses /- 1) resting cycles which are regular breathing cycles immediately proceeding a tone presentation. 2) response cycle is the single cycle in which the puretone stimulus is delivered and 3) recovery cycle which is immediately following the response cycle.

Rosey (1969) reports 3 response cycle alterations related to hearing thresholds. They are: a) a reduction of amplitude, b) jamming of two cycles together or an M shaped pattern and, c) flattening of positive peak, (see Fig. 13).

Of the resting and recovery cycles, the cycle with the lesser amplitude is used for comparing a response cycle reduction. If the amplitude of the recovery cycle is leas than the amplitude of the response cycle, or if the recovery cycle is disturbed by some body movement, it is necessary to reestablish the resting cycles and to introduce the tone again at same intensity level. For considering it as a response,cycle alteration must occur immediately following the presentation of the tone. Two and preferably three of the described alterations must occur at consecutive 5dB intensity levels before the cycle alteration at the lowest intensity level can be considered the threshold.(Braford,1975).

Figure-13



Single Respiration cycle a-c recorded during quiet breathing:
[a-d] - inhalation , [d-c] - exhalation & [b-d] - amplitude.
Respiration alterations: B · amplitude reduction,
C - jamming or an M shaped pattern,
& D - flattening of respiration cycle.

Significant lengthwning of respiration cycle occurs at or near auditory thresholds for puretone stimuli and respiration thresholds determined by lengthening criteria were within ± 10dB of voluntary thresholds in 93% of subjects.

(Rousey et al, 1964; Poole et al, 1966, Rousey and Reitz, 1967; Teel et al,1967 and Brooks and Gieschen, 1968).

Rousey (1969) found that more accurate estimation of thresholds can be obtained by automation from cycle lengthening measures than amplitude change measures. Respiration thresholds obtained during second stage of natural sleep produced thresholds similar to those found during the waking state..

Rousey and Bradford (1971) reported that respiration threshold obtained during sleep, indicating normal hearing is valid but if it indicates hearing deficit, rechecking should be done.

Bradford etal (1972) found respiration threshods of preschool children to be mostly with ±, 10dB of voluntary threshold.

Bradford etal (1972) tested infants during first year of life - shortly after birth, at 4 months and at 12 months of age. Results indicated that puretones alter the new-born and infant's respiration pattern in the same way as has been observed with older children and adults.

Kankkunen and Liden (1971) obtained respiration thresholds in 92% of high risk children. Follow up investigation showed that results were very reliable.

These findings indicate that 'Respiration Audiometry may be employed for determining a neonatal and infant hearing sensitivity (Bradford, 1975) and is neither expensive, time consuming nor noxious to patients.

5. HEART RATE RESPONSE AUDIOMETEY:

According to Sokolov (1963, 1969) and Rouitenber (1968) a human being responds to stimuli in two ways- i) Defensive reflex which occurs in the presence of high intensity stimulation and limits the effects of stimulation, ii) orienting reflex which is elicited when subject attends to or recieves environmental stimuli at low or moderate intensity levels and includes changes in heart rate (HR).

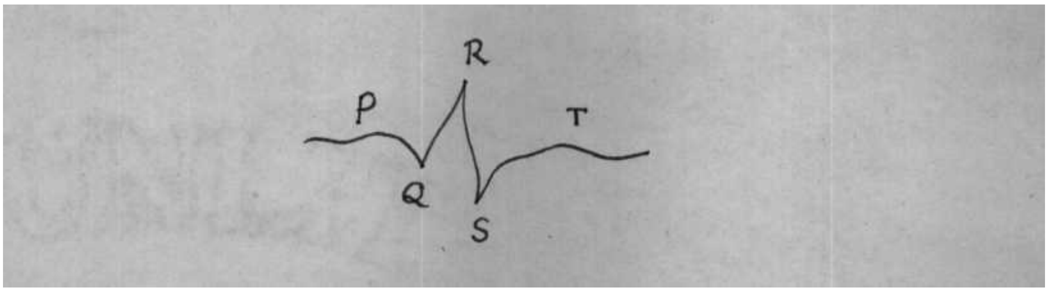
Zeaman and Wegner (1956) measured the HR response to a mild auditory stimulation in 4 normal adults and suggested the possibility of response as an index of objective test of hearing.

Smith and Borton (1980) outline the measurement procedure of HR response in audiometry.

During the cycle of its action, the heart generates electrical potentials which are conducted to skin through body fluids. Each heart beat produces characteristic wave form (see fig- 14) consisting of waves

Figure - 14

Wave form of a heart beat



P, Q, R, S and T. P wave is associated with electrical activity of atria of heart; Q, R and S waves constituting 'QRS complex' are associated with ventricular excitation where as T wave is used to indicate repolarization of ventricles. 'R' wave is used in heart rate response audiometry (Smith and Borton, 1980).

The raw cardiac activity transduced by recording electrode is amplified. Resulting signal is filtered to discorage the recording of muscle or other artifacts in the record.

R wave is detected by a circuit called 'Schmilt trigger'. This electronic circuit is simply a voltage level detector which is adjusted so that it is triggered by a relatively large voltage change (R wave) but not by smaller voltages (other cardiac waves or noise).

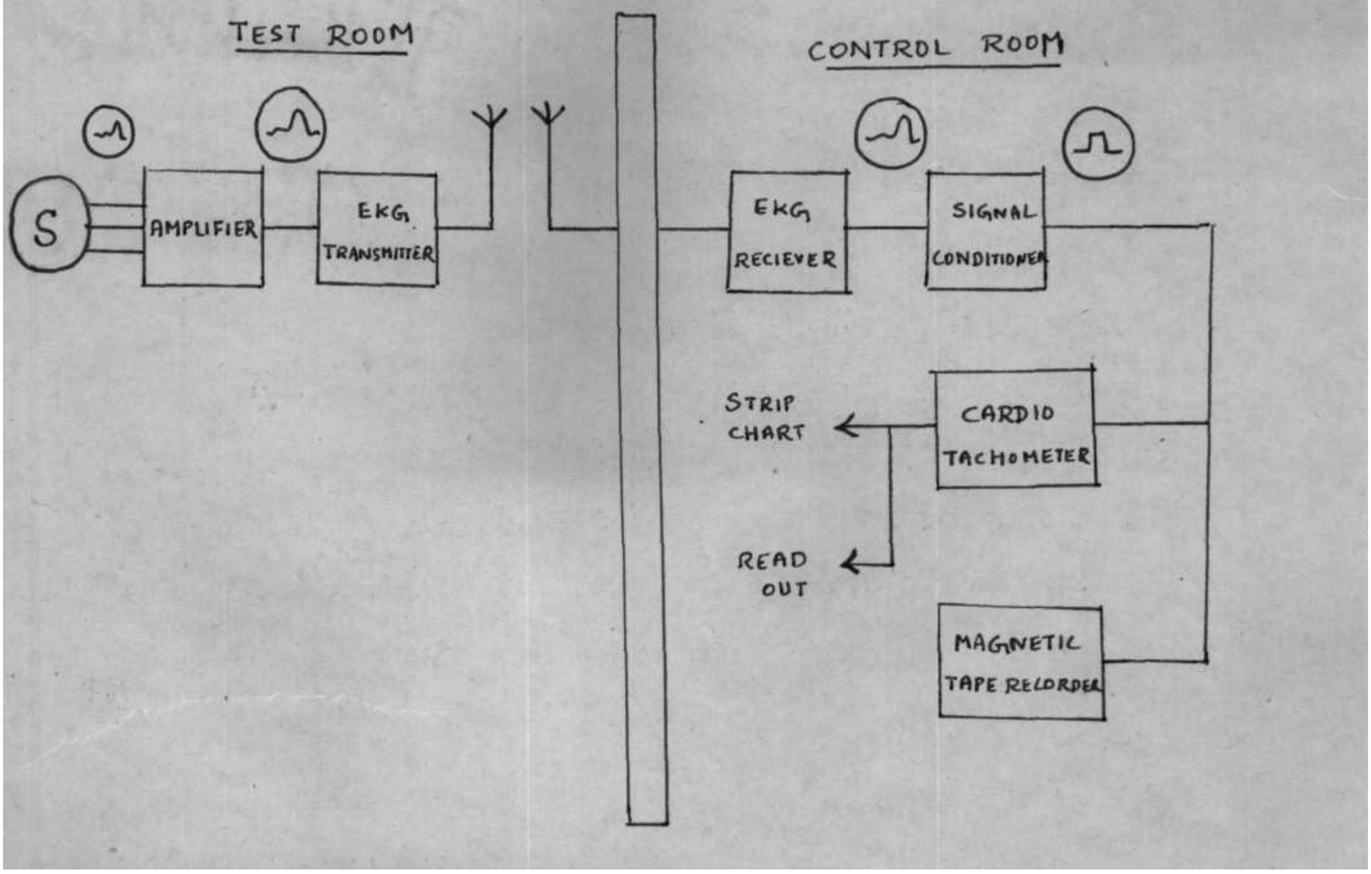
This circuit provides a pulse which triggers a one-shot multi vibrator which gives rise to a uniform square pulse for each heart beat when the uniform square pulses representing the successive R waves are fed into a cardio tachometer, it converts the time interval between successive R waves into instantaneous rates by the formula:

$$HR = \frac{60}{\text{time interval}}$$

The result is displayed as digital readouts of instantaneous HR or recorded as strip chart deflections on a calibrated scale (see fig. 15).

Figure - 15

Block diagram of Heart rate response Audiometry Equipment.



Eisenberg (1976) refers to the time interval as 'tan or T'.

Silver or gold electrodes are used. Placement of electrodes can be on inner surface of wrists (Beadle and Crowell, 1962) or left lower leg and right fore arm (Suzuki, 1978). Eisenberg (1976) recommends 2 chest electrodes, one in third interspace just to the left of the sternum and the second (ground) adjacent to the left nipple; the third back electrode is attached at the midline over the vertebral column.

Recording sites and electrodes are cleaned with 70% isopropyl alcohol. They are coated with electrolytic gel or paste. About half an hour later cardiac electrodes are applied.

Some use puretones (Beadle and Crowell, 1962, Jasienska etal, 1967, Suzuki, 1978) where as others band limited noises centered around 500Hz and 3600Hz (Schulman and Wade, 1970) as stimuli in HR response audiometry. Schulman and Kriter (1971) find band limited noise to be more effective because it contains more energy than a puretone at same sound pressure level. Turkewitz etal (1972) for the same reason found puretone to be more effective when combined with other tones than when used alone. Gerber, Mulac and Swain (1976) hence used both 3150Hz puretone and 1/3 octave band noise in their study. Eisenberg (1976) uses synthetic vowel 'ah' as stimulus.

Beadle and Crowell(1962) used stimuli of 5 sec duration where as Suzuki (1978) used duration of l00msec. Black(1964) observed that response latency increased in time as duration of signal was increased. Turkewitz etal (1972) found that durations of 1,2,4 and 8 sec did not differentially influence heart rate responses.

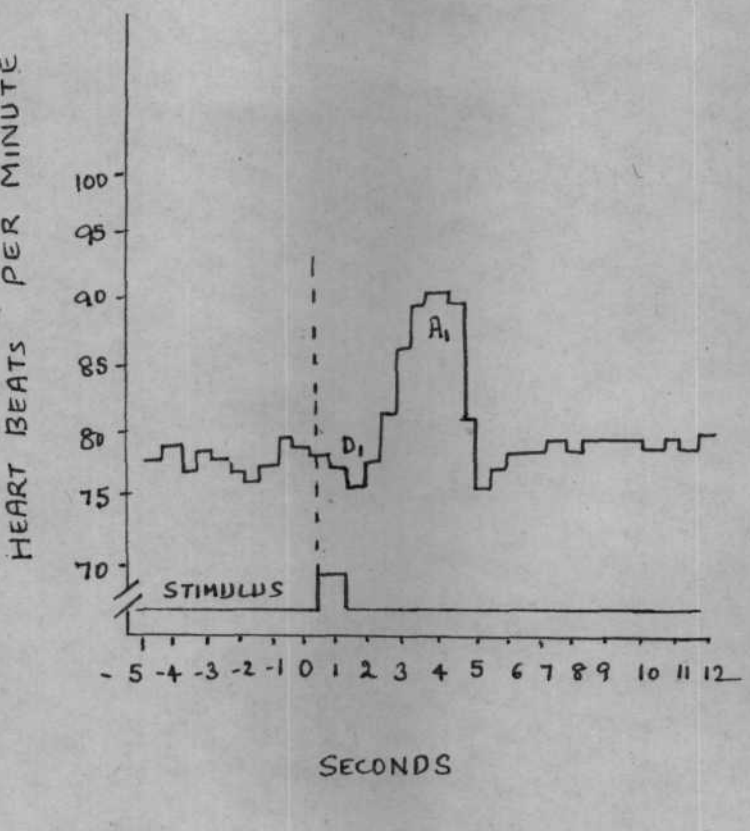
Bartoshuk (1962) noted greater response decrement associated with short interstimulus interval (6 secs) than longer one (60 secs). Gerber et al(1976) did not use a fixed interstimulus interval where as it was 30 sec in Beadle and Crowell's study (1962) and 15 sec in Suzuki's investigation(1978).

Heart rate response is usually diphasic in nature starting with a brief interval of rate deceleration(peak D_1) followed by a period of rapid acceleration (peak A_1). Some exhibit a second deceleration phase to end the response (Hogan,1975), (see fig. 16).

Figure - 16

Averaged Heart rate response of ten normal subjects:

Stimulus : pulse train [80dBSL].



D_1 Latency : 1.0

A_1 Latency : 3.2

Response duration

Beadle and Crowell (1962) on analyzing the neonatal cardiac responses to auditory stimulation found that change in cardiac rate began almost immediately and covered a time period of approximately 10 seconds following the onset of stimulus.

Butterfield (1962) finds HR response audiometry not useful in children with mental age below 3 years.

Bartoshuk (1964) reported on the basis of results obtained from 39 neonates, that the absolute threshold for neonatal HR acceleration 1KHz tone was between 38 and 48 dBSPL.

Jasienska etal (1967) tested 35 newborns (1 to 10 days old) and observed that average change in the pulse frequency to be 11 beats per minute.

Steinschneider, Lipton and Richmond (1966) demonstrated a systematic shortening of latency with increasing levels of auditory stimulation.

Magnitude of heart rate change increases with increase in stimulus intensity (Bartoshuk, 1964; Graham and Clifton, 1966; Lipton etal, 1960). But it was found by Barnet and Goodwin (1967) and Davis etal (1955) that HR response is of all or none type with no significant correlation between response magnitude and signal level.

Graham et al (1968) observed that HR response showed an acceleration within first second, reaching peak by fourth second after which there was deceleration to approximately prestimulus level.

Berg and Graham (1970) report that low intensity stimuli resulted in a HR deceleration where as moderate stimulus intensities produced a diphasic response and HR acceleration resulted for high intensity stimulation.

Schulman and Wade (1970) measured HR response in normal infants and found that most prominent response was deceleration, at 34 dBSPL, 6 secs after the stimulus onset. According to Griffiths (1975) criteria for positive HR response is deceleration of HR by 4 to 5 beats in 4 to 6 secs after the stimulus onset.

Eisenberg (1975) reported reliable HR responses to uninflected synthetic vowel of 60dB in newborns and adults. The predominant change in HR pattern was a prolonged deceleration independent of subject's level of arousal. The peak magnitude in infants was often found 6 or more seconds subsequent to stimulus onset.

Wilder (1950) reported that cardiac response follows "laws of initial values" where prestimulus HR rate influences post stimulus rate. Gerber etal (1976) in their study of 15 newborns (24 to 48 hours) controlled the influence of prestimulus heart rate upon post stimulus rate statistically by the use of analysis of covariance. Results indicated that magnitude of post stimulus rate change differed among subjects who were a significant source of variance. HR response was different in magnitude and latency for each subject. They recommend that heart rate patterns in infants must be observed in terms of absolute change for each individual subject without considering the direction of change of HR response.

Suzuki (1978) reports that the most prominent and consistent response to be an abrupt and brief deceleration with peak latency of 1 to 1.5 sec by testing children under 12 months of age. This deceleration occurred in the interval between first and second beats after the stimulus onset. As stimulus intensity increased, deceleration increased in magnitude and second acceleration became prominent.

Advantage of HR response audiometry is that it does not involve noxious stimuli (Gerber etal 1976), yields less false positive response than slow vertex audiometry (Suzuki, 1978). The main drawback is "individual variability,"

6. VASOMOTOR RESPONSE AUDIOMETRY:

In response to auditory stimulation, changes in the blood flow and hence pulse volume occur. These vasomotor responses have been used for detecting response to auditory stimulation objectively. Changes in pulse volume may be detected by rheographic or plethysmographic methods, (Mojdehi etal, 1980).

Rheography utilizes differences in conductance of electricity in tissues and blood.

Vasilev, Diskalenho and Plepis (1975) used rheography in detection of response to puretones of 10 secs duration. Responses occurred at 20dBSL in most of subjects at 125Hz 3000Hz and in half of subjects at 6000Hz. They recommend rheography as an objective technique. The principle used in rheography is that blood is a better conductor of electricity than tissues and hence changes in pulse volume are shown by changes in relative conductance of electricity. So one electrode is attached to index finger and another to palmar surface. When there is vaso constriction in response to auditory stimulation, there will be decrease in blood volume thereby increasing the total impedance of electricity.

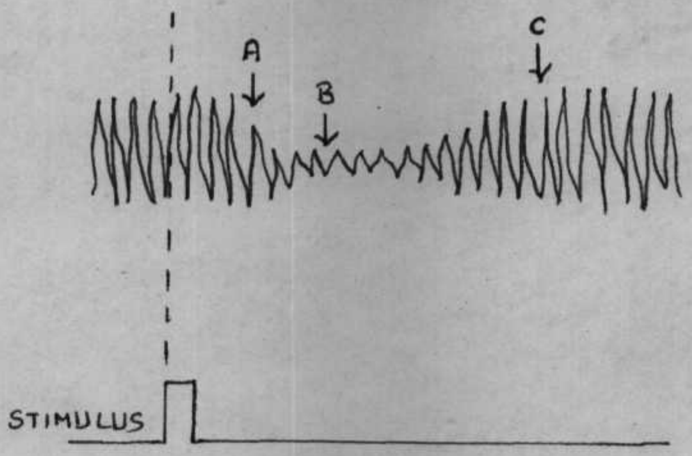
Cranley (1975) reports that although referred to as "impedance plethysmography", "rheography" is not a direct measure of volume or pressure.

Plethysmography makes use of volume changes of a body segment. Photo plethysmography uses a photo cell to detect changes in blood flow corresponding to volume changes.

Mojdehi et al (1980) outlined the procedure for Plethysmography as follows:- Subject is seated comfortably and a photocell covered by black cloth is placed on the lateral surface of the smallest digit and held in place by tapes. Room temperature is maintained at 78 to 82 F as response can be evoked from cold. An interstimulus interval of more than 30 sec is used to allow full recovery of physiological system. Vasomotor response in the form of micro circulation is detected by photocell and is charted as pulse on graph called- 'phleborheograph or PRG (see fig. 17).

Figure - 17

Finger pulse volume response ; stimulus : pulse train [80 dBSL].



Onset Latency [A] :
Peak Latency [B] :
Response duration

"Law of initial value" (Wilder, 1950) is considered by recording 10 sec period of stable pulse amplitude. Criteria for response occurence is 1) a change of 20% in digital pulse volume amplitude on comparison with pre-stimulus amplitude; 2) the first change in pulse amplitude occuring within 1.6 to 10 seconds of stimulus onset (Levander etal, 1974).

Siemaszko-zak (1976) gives another method of recording digital pulse volume called 'water plethysmography'. Here the index finger is fitted in to an aluminium capsule, it is filled with water and closed tightly. The capsule is connected through stiff plastic tube to electro manometer.

A dip in the plethysmographic curve below the base line or merely fall in amplitude of waves following acoustic stimuli evidenced a decrease in volume of finger tip blood flow ie. vasomotor response. Dip lasting at least during 2 beats of pulse and not smaller than 20% of amplitude of proceeding pulse volume was accepted as least change.

Daly (1965) obtained vaso constrictor responses in 10 sleeping subjects to thermal noise stimulation. In 80% of subjects there was response at 5 dB stimulus level.

Jansen (1969) found that among awake subjects, a white noise stimulus of 18 seconds duration evoked the response begining at an intensity of 70 dBSPL. Response was in relation with band width and intensity of the signal.

Siemaszko-zak (1976) recorded vasomotor reactions to sounds of 1024, 2048, and 4096Hz frequency at levels of 0, 10, 20, 60, and 80dB in normal hearing persons (6 - 35 years). Latency of response was found to be 2 to 5 secs not depending on intensity or frequency of stimulus.

Responses were noticed in both during waking and sleep state and % of responses increased with increase in stimulus intensity.

Mojdehi et al (1980) could record vasomotor responses in 11 out of 12 normal hearing adult subjects at 35 to 70 dB SPL.

So vasomotor response audiometry seems to be an objective technique which still has to be tried on children.

7. VISUAL RESPONSE AUDIOMETRY:

Pupil dilation as a response to auditory stimulation has been used to test hearing. Baker (1938) conditioned pupillary responses to sub threshold auditory stimulation and Unger (1939) used pupillary dilation as an indicator of hearing.

Clynes (1962) was the first person to analyze the dynamic properties of pupillary response to sound using averaging computer; objective analysis yielded following results- (a) pupillary responses could be elicited to puretone stimulation at 40dB above threshold. (b) amplitude of the response increased little with increasing signal intensity. (c) the response consists of an initial dilation reaching a peak at about 1.5 seconds after stimulus onset and a subsequent prolonged constriction phase lasting for 20 seconds. (d) a differential sensitivity to abrupt changes in either signal amplitude or frequency and (e) no fatigue or adaptation in response.

Suzuki and Kamijo (1961) evaluated pupil reaction in normal subjects (3 to 53 years). Two - third of subjects yielded positive response at stimulation level of 20 dB or less and remaining subjects at 30 to 80 dB.

Suzuki et al (1964) observed pupilary responses in sleeping children by lifting eyelids,for auditory stimulation. The threshold disparity was 50 to 80 dB in normal hearing and conductive loss children, where as in sensori neural loss children it was 30 dB.

This area of utilizing visual responses to auditory stimulation for testing hearing sensitivity is still developing.

8. THE ACOUSTIC REFLEX BATTERY:

The Acoustic Stapedial Reflex is defined as "a reflex contraction of stapedius muscle induced by sound stimulation," (Sheehy and Hughes, 1974). The reflex is consensual so that stimulation of one ear produces contraction of muscles in both the ears.

Metz (1946) demonstrated that this contraction of the muscle produces an increase in the impedance of tympanic membrane. This impedance change is monitored to measure the stapedial reflex.

The reflex testing can be done -

i) ipsilaterally where impedance change is monitored in the same ear as the stimulating ear or

ii) contralaterally in which the impedance change is monitored in the ear opposite to stimulating ear.

Acoustic Reflex Threshold (ART) is the intensity in dB hearing level at which the reflex response can first be detected (Djupesland, 1980).

The contralateral acoustic reflex can be expected to occur at 70 to 95 dB sensation level (SL) in normal ears (Jepsen, 1951, Deutsch, 1972, Peterson and Liden, 1972) and about 3 to 12 dB lower SL for ipsilateral (Moller,1962, Fria et al, 1975).

In contralateral reflex testing, if the middle ear function is being evaluated, then the test ear is the ear in which monitoring probe is fixed (probe ear). If ART or other dynamic characteristics of the reflex are being studied, then the ear being stimulated is the test ear and the ear in which impedance change is monitored the probe ear (Feldman, 1978).

After setting the balance meter of impedance instrument to maximum sensitivity and nulling it to zero, reflex stimulus (tone or noise) is introduced. Intensity of the stimulus is varied until the lowest dBHL at which there is deflection of balance meter, synchronous with onset and offset of the tone. This is ART(Jerger, 1970).

In clinical setting, the acoustic reflex battery can be used to help in the detection of -

1. Middle ear pathology,
2. Sensory pathology,
3. Neural pathology,
4. Central pathology,
5. Hearing threshold level,
6. Nonorganic hearing loss.

The present topic of concern is detection or prediction of hearing threshold level by acoustic reflex.

Early attempts at making predictive statements concerning auditory sensitivity from ART measurements revolved around two concepts -

1) If Acoustic Reflex is present, it was assumed that atleast some auditory function is present.
2) If ART was less than measured auditory threshold, it was assumed that subject had better auditory sensitivity than that behaviour thresholds indicated (Popelka, 1981).

The relation between puretone auditory sensitivity and ART had been suggested as a method of predicting the degree of SN loss in neonates, young and difficult to test by many investigators (Dedmon and Robinette, 1973; Jerger, 1970;

Robertson, Peterson and Lamb, 1968; Terkildsen, I960; Wedenberg, 1963). But auditory sensitivity predictions based on ART for puretones appeared tenuous since puretone and Acoustic reflex thresholds may occur at same intensity levels in both normal hearing and sensori neural loss ears (Dedmon and Robinette, 1973; Beedle and Harford, 1973).

Then, the Noise Tone Difference (NTD) in Acoustic Reflex Thresholds formed the basis for hearing prediction from ART. It was reported by many investigators (Moller, 1962; Dallos, 1964; Fisch and Shulthess, 1963; Lilly, 1964; Djupesland, Flottorp and Winther, 1967; Deutsch, 1972; Peterson and Liden, 1972) that ART for Broad band Noise (BBN) are 15 to 25 dB lower that that for puretones.

In 1972, Niemeyer and Sesterhenn investigated the relation between ARTs for puretones and white noise and hearing thresholds in normal and sensori neural loss subjects. The difference level (dl_2) between mean ART for tones (500 to 4000 Hz) and ART for white noise was correlated with the difference level (dl_1) between the mean ART for tones (500 to 4000 Hz) and mean hearing threshold for tones (500 to 4000 Hz). It was found to be linear function where $dl_1 = 2.5\, dl_2$

On the basis of this relation, Niemeyer and Sesterhenn proposed the formula:

$$\text{Mean Hearing Threshold} = \text{ART tones} - 2.5\, dl_2 .$$

But they found that although in flat sensori neural loss calculated hearing threshold was within 4 dB of measured threshold, in sloping hearing loss, the prediction was not that accurate.

So Niemeyer and Sesterhenn (1974) modified their formula to include ART for low pass (100 - 1600Hz) noise (LPN) and High pass (1800 - 13500Hz) noise (HPN) to be used for low (250 - l000Hz) and High (2000 - 8000Hz) frequencies in prediction. In normal ears, $d1_2$ for LPN~5 dB and for HPN~20dB. (3 : 4 ratio). In falling audiograms, dl_2- for HPN $d1_2$ for LPN. This relation was unchanged in children. Predictions as reported by them were within ± 10dB of actual hearing in 73% of cases and ± 15 dB in 90% of cases.

Miller and Davis and Gibson (1976) attempted prediction of puretone threshold on 100 ears using Niemeyer and Sesterhenn (1974) formula. There was high error rate of false positives. They suggested a higher multiplication factor in the formula for better prediction. Coles (1974) has suggested a factor of 2.7 instead of 2.5*

Margolis and Fox (1977) reported high false positive rate and poor distinction between mild - moderate and severe hearing loss when Niemeyer and Sesterhenn (1974) formula was used.

Keith (1977) on using this formula found poorer prediction accuracy than reported by Niemeyer and Sesterhenn. He found no error for 35% of predictions, 56% of predictions to be within ± 15dB 67% within ± 10dB and 82% within ± 15dB.

Ragunathan (1977) established multiplication factor 'k' for each of frequencies 500, 1000, 2000 and 4000Hz for the Indian population, k factor for the above frequencies was 2.8, 3.6, 3.8 and 3.8 respectively. With this hearing threshold could be computed for each of these frequencies, individually using Niemeyer and Sesterhenn (1972) formula.

Sesterhenn and Breuninger (1976) proposed a method for determining hearing threshold from ART in patients in whom threshold was frequency dependent. Basis was that acoustic reflex for low frequency signal can be elicited 20 to 30 dB lower than threshold level by means of preactivation with high frequency tone. Procedure involves determining ART for 8KHz tone, the preactivating stimulus. Then the intensity of the continuous 8kHz tone is adjusted to be at threshold barely eliciting reflex and an interrupted lower frequency (0.125 - 4kHz) tone is introduced simultaneously. Level of this interrupted tone is reduced from threshold level downwards until any reflex activity disappears. The difference between normal and reduced ART is dl_2 and difference between hearing threshold and normal ART is dl_1 $dl_1 = dl_2$. Because of different values for dl_2 at different frequencies in normal

hearing subjects K factor has different valu

-0.5 KHz), 3(1KHz), 3.5 (2KHz) and 4(4KHz). He

for each frequency can be determined. Predic

this method was best in normal hearing profo

subjects and least in moderate loss cases.

Jerger (1973) suggested a formula for the prediction of

It is called "Differential loudness summation test" or unweighted formula.

$$\text{Here NTD} = \frac{\text{500Hz ART} + \text{1000Hz ART} + \text{200 Hz ART}}{3} - \text{BBN ART (SPL)} + \text{2000Hz ART}.$$

In 1971, Flottorp, Djupesland and Winther demonstrated critical band phenomenon operating on ART. They observed that ART in dB remained essentially the sane up to a specific band width value (critical band width) beyo.nd which ART decreased approximately 3 to 6 dB per octave. These findings were used by Jerger, Burney, Maudlin and Crump (1974) to explain NTD in normal hearing and sensorineural loss ears and to develop another formula for hearing prediction. This is referred to as 'SPAR' the 'Sensitivity prediction by the Acoustic Reflex'.

Jerger et al (1974) hypothesize that in normal ears, ART is reached when a stimulus exceeds a critical loudness (L).

Here the loudness is referred to that neural activity which is in one to one correspondence with human listener's loudness experience. L_T and L_{BBN} are the loudness experienced when puretone and Broad band noise are the stimuli respectively. L_{BBN} is taken as the sum of loudness contributed by critical bands C_{Bn} . Because the puretone is confined to a single critical band and noise derives loudness from n critical bands noise takes less intensity to produce reflex than the tone and hence NTD is observed in normal ears.

In sensori neural hearing loss ears, there is widening of critical band width (Scharf and Hellman, 1966; Deboer and Bourmester, 1974; Martin,1974). As a result of this, the number of critical bands available for loudness summation is reduced. Then, sloping loss in these cases, reduces the relative loudness contributions from critical bands in high frequency region (see fig. 18).

Figure - 18

Hypothetical Explaination of Noise Tone Difference [Jerger et al

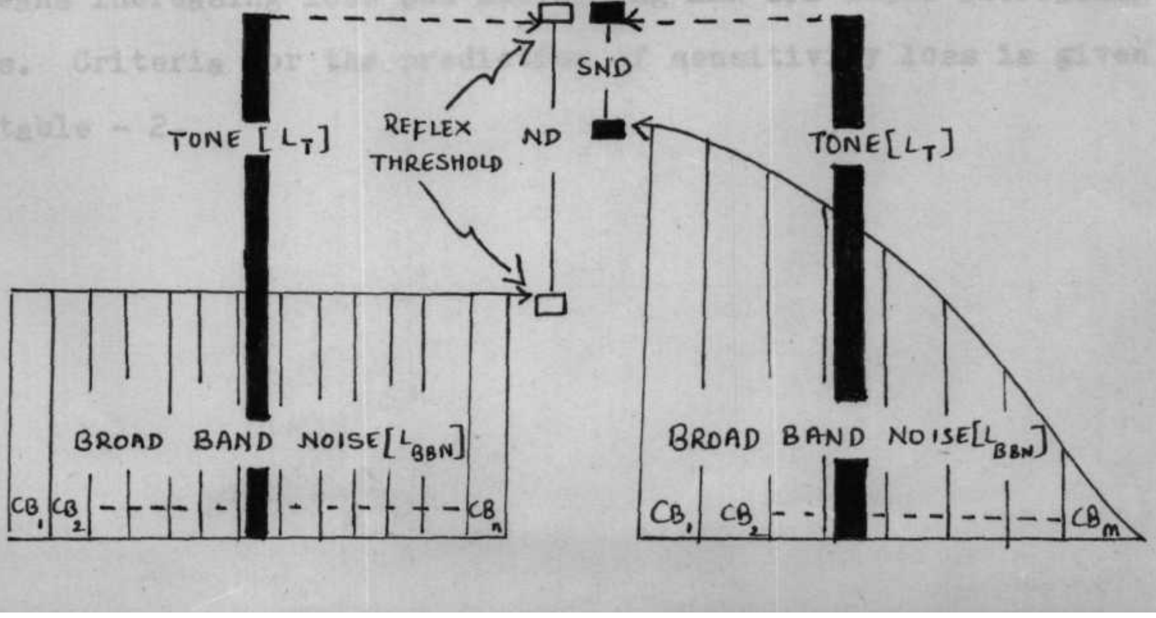


Table-2

Showing criteria for prediction of sensitivity of hearing

D	BBN SPL	Prediction
20 or larger	Anywhere	normal
15 - 19	80dB or less	normal
15 - 19	81dB or more	mild-moderate
10 - 14	anywhere	mild-moderate
less than 10	80dB or less	mild-moderate
less than 10	90dB or more	Severe
Reflex not observed		Profound

For prediction of slope of hearing loss, difference in ARTs for lowpass filtered (below 2600Hz) noise-LPFN and High pass filtered(above26OOHz) noise-HPFN was used. Criteria for prediction was as given in Table-3.

Table - 3

Showing criteria for prediction of slope of hearing loss

Difference (LPFN - HPFN)	Prediction
0 or positive	Flat configuration
-1 to -5 inclusive	Gradual slope
> - 5	Steep slope

Predictions were made for 1156 patients in the age range 3 to 91 years. To evaluate predictive accuracy of the method, audiograms (according to the degree and configuration of hearing loss) were categorized as given in table - 4 and table - 5 respectively.

Table - 4

Showing criteria for categorization of audiograms (degree of Hearing loss)

Category	Criteria
Normal	PTA less than 20 DBKL
Mild - Moderate	PTA 20 to 49 dBHL inclusive
Severe	PTA 50 to 84 dBHL inclusive
Profound	PTA 85 dBHL or more

Table - 5

Showing criteria fpr categorization of audiograms (configuration of hearing loss)

Difference in threshold between 1000 & 4000Hz	Configuration
Less than 5 dB	Flat
From 6 to 40dB	gradual
greater than 40dB	Steep

Prediction accuracy was found to be best for either normal hearing or profound loss and least successful for mild to moderate or severe loss categories. Prediction was perfect in 60% of cases. Errors were moderate (prediction and average result diverging by one category) in 36% of cases and serious (divergence by 2 or more categories in 4% of cases.

In order to facilitate for uniform clinical SPAR predictions among various testers and impedance audiometers, Jerger etal recommended a 'physiological calibration rather than physical calibration.' It is carried out by subtracting the average reflex threshold for 10 normal hearing subjects (10 to 30 years) for BBN from average reflex threshold for 3 puretones 500, 1000 and 2000Hz. Result is normal NTD for that impedance apparatus. This is subtgacted from the original norm reported by Jerger etal (25 dB) to get a correction factor for that instrument. This is added to D obtained for a particular patient and result is interpreted according to the table -2.

On using Jerger's weighted formula, Stelmachowicz etal (1974) found 72% of normal predictions, 10% of mild to moderate and 33% of severe hearing loss predictions to be correct.

Jerger (1975) and Keith (1977) find unweighted formula to be more accurate for hearing prediction than the weighted formula. The weithted formula is characterized by high rate of false positives (Johnsen etal 1976; Margolis and Fox, 1977) with prediction accuracy decreasing directly with decrease in hearing sensitivity (Schwartz and Sanders, 1976; Vanwagoner and Goodwine, 1977; Hall 1978).

In both weighted and unweighted formulae, false negative is uncommon (Keith, 1977).

Slope of hearing loss was predicted according to configuration categories of Jerger etal. Predictions were correct in 52% of flat ioss, 30% of gradual loss and 100% of steep loss ears (Keith,1977). Vanwagoner and Goodwine (1977) found error rates for prediction of slope of hearing loss to be much higher than that for prediction of magnitude of loss.

Jerger, Hayes and Anthony (1978b) gave a revised set of SPAR criteria called the 1977 SPAR as it was found by previous studies that NTD was not precisely sensitive to degree of loss (in moderate to severe range). Here absolute ART for 1000Hz puretone was taken into consideration (see Table - 6). They suggest that this criteria eliminates false negative results in children.

Table - 6

1977 SPAR criteria

NTD	1000Hz ART	BBN ART	Prediction
20	95dBHL	Anywhere	Normal
< 20	>95dBHL	95dBSPL	Mild-moderate
<20	>95dBHL	>95dBSPL	Severe

1974 SPAR method has predictive accuracy rate of 60-75% and SPAR 1977 virtually eliminates serious under estimation of hearing loss(Hall, 1978).

In 1977, Keith considered ART for BBN stimulus for separating normal hearing and hearing impaired ears. ART of 85dBSPL or less for BBN stimulus signified nromal hearing where as ART greater than 85dBSPL indicated hearing loss. When this criteria was used on a group of 52 normals and 92 hearing impaired persons, Keith observed a false positive rate of 13% and a miss rate of 3%.

In 1976, Baker and lilly introduced statistical regression for predicting hearing level using ART data on adult hearing impaired population of 125 subjects. Here noise and tone signals are weighted differentially according to their contribution to hearing threshold level(HTL) prediction. The equation predicts HTL for 4 frequencies (500, 1000, 2000 & 4000Hz).

$$\text{dBHTL} = 1.11\ \text{ART BBN(SPL)} - 0.81\ \text{ART 500Hz(HL)} + 0.85\ \text{ART 1000Hz(HL)} - 0.43\ \text{ART 2000Hz(HL)} + 0.25\ \text{ART 4000Hz (HL)} + 64.7$$

With this formula, in cases where ART is absent for one or more frequencies, HTL cannot be predicted. So Lilly(1977) introduced another equation which permitted HTL prediction from ART for BBN or combinations of BBN and 500Hz or 500 & 1000Hz or 500, 1000 and 2000Hz.

$$\text{dBHTL} = 1.07\ \text{ART BBN(SPL)} - 0.82\ \text{ART 500Hz(HL)} + 1.11\ \text{ART 1000Hz (HL)} - 0.45\ \text{ART 2000Hz (HL)} + 0.06\ \text{ART 4000Hz (HL)} - 67$$

Baker and Lilly (1976) reported that the median error of prediction to be 0 dB where as Hall (1978) found to be 3dB.

Other set of regression equations developed by Rizzo and Greenberg (1979) use ART for a single puretone signal 500Hz and a high pass Noise band. These equations also predict HTL for 4 frequencies or 3 frequencies depending on the equation used.

$$\text{dBHTL (4frequency)} = (0.2\ 6\ \text{ART HPN(SPL)} - 0.078\text{ART 500Hz (HC)} - 7.515)^2$$

$$\text{dBHTL (3 frequency)} = (0.197\ \text{ART HPN(SPL)} - 0.080\text{ART 500Hz (HC)} - 7.986)^2$$

These regression equations have an advantage that they predict threshold in dB. But they are also characterized by false positive errors and with increased hearing loss, they underestimate hearing loss (Hall, 1978, Hall and Bleakney 1981b). The regression equations pose 2 fundamental problems. 1) They are developed on the assumption that there is linear relationship between hearing threshold levels for noise and tone signals. On the contrary, effect of sensorineural loss on acoustic reflexes is not linear and varies as a function of degree of loss and the signal (Jerger etal, 1978a; Hall and Weaver, 1979). On the average BBN ART increase 3 to 5 dB for every 70 dB loss and puretone ART decrease slightly with increasing loss of up to 45 or 55 dBHTL.

2) Regression equations developed by a population homogenous in degree of loss and age will not hold good for a population that is heterogenous in these respects.

Because of clinical need for a method that would permit prediction of hearing sensitivity in different frequency regions, 'Bivariate plot coordinate system' was developed by Popelka, Margolis and Wiley in 1976.

This method is based upon two important relationships
(i) As hearing loss increases reflex threshold for tonal stimuli remain constant for mild losses, then begin to increase for more severe losses.
(ii) Difference between reflex threshold for tonal and noise stimuli is large for normal subjects and patients with severe losses and small for cases with mild to moderate losses.

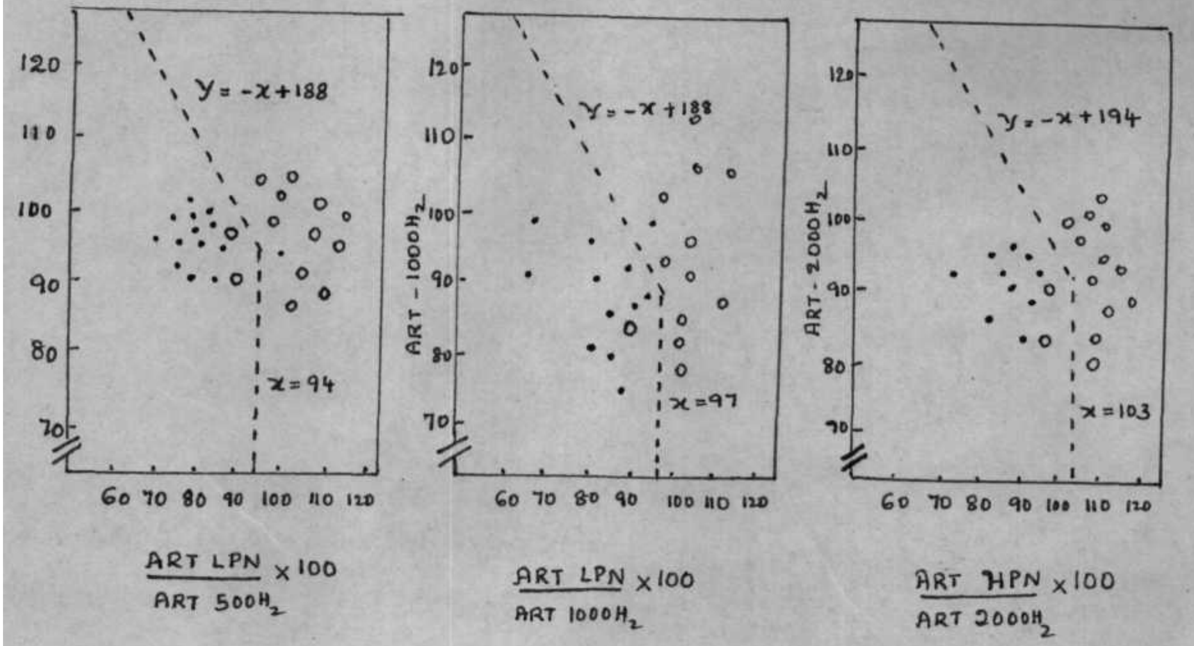
Therefore two measures - ART for puretone stimulus on Y axis and $\frac{\text{ART WBN}}{\text{ART tone}} \times 100$ on X axis were used. These two measures tend to increase with magnitude of sensorineural loss and hence when they were plotted, a scatter plot was obtained, in which normal hearing and hearing impaired subjects - segregated in to separate regions. Normal region was defined by 2 line segments in such a way that false positive and miss rate type of errors were kept at a reasonable level. The scatter plot showed normal hearing clustered towards lower left portion and sensorineural loss cases towards upper right portion.

Handler and Margolis (1977) found that ARTs for elderly group and young adults were same for 500Hz, 1000Hz and 2000Hz and LPN but higher for 4000Hz, HPN and WBN in elderly group. So they introduced LPN instead of WBN inoorder to increase the predictive accuracy in elderly subjects. They report that use of LPN yielded 0% false positive rate where as WBN gives 38% false positive results.

Margolis and Fox (1977) gave a bivariate plot system in which on the abscissa, LPN ART was used for 500Hz and 1000Hz ART and HPN ART for 2000Hz ART. In each plot normal region was defined by line segments - $x=k_1$ and $y= -x+k_2$. Values of k_1 and k_2 for each frequency plot were chosen to include as many as normal ears and yet to exclude as many as hearing impaired ears possible (see fig - 19).

Figure - 19

Bivariate plots: [Filled circles - normal ears
open circles - average sensorineural loss ≥ 32 dB]

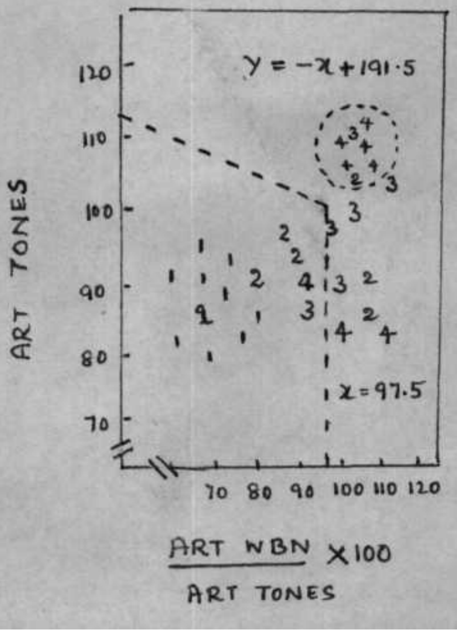


A bivariate plot for 4000Hz was not reported because ART data for 4000Hz signal was variable and did not contribute to the predictive accuracy of the technique. Criteria for predicting an individual to have normal hearing or sensori neural loss was that he should fall in the appropriate region for 2 of 3 frequencies. By this procedure, false positives were minimized and subjects with average puretone loss greater than 32 dB were correctly identified as impaired with high accuracy (93 %) .

Silman and Gelfand (1979) report that the criteria on used by earlier investigators in bivariate plot analysis, for hearing loss was an average loss of 32 dBHL for speech frequencies without regard to audiometric contour or to threshold at higher frequencies. so the method cannot be applied to cases with sloping and high frequency losses. So Silman and Gelfand suggested a new procedure. They classify the subjects in to 4 categories (l) normal hearing, (2) ears with PTA 30 dB but with high frequency sensorineural loss (40 dBHL) begining at 4kHz or above. (3) ears with loss of 33 - 40 dB for 2 poorest of 500, 1000 and 2000Hz or a loss of 35 - 55dB for one of these frequencies. (4) Ears with average loss of 45 dB for 2 poorest of these frequencies or loss of 60 dB for one; These categories fall on different regions of graph as shown in figure 20.

Figure - 20

Bivariate plot with new classification [Silman &Gelfand, 197



If average ART is not elevated, then results should be plotted on the bivariate graph. If plotted results fall in to category 1 area then one may predict normal hearing or hearing loss above 500-2000Hz. If results fall in to category 4, significant loss is predicted. If bivariate plot is located elaewhere, the patient has atleast high frequency hearing loss.

In a series of experiments reported by Margolis and associates (1981) simplified bivariate plotting (where WBN was used instead of filtered noise band) was found to be as effective in predicting hearing loss in difficult to test children as adults.

False positive rate is minimized in bivariate plot method compared to SPAR. This may be because i) bivariate plot region for normal hearing has an upper average hearing threshold limit of 32 dB while in SPAR it is 20 dBHL. ii)of difference in noise signals: SPAR uses BBN where as bivariate system uses LPN and HPN (Hall, 1980).

Johnsen and Colleages (1976) suggested that isolated high frequency sensorineural loss elevates ART for WBN even in patients with relatively normal hearing in 500 - 2000Hz region. According to SPAR criteria for hearing loss, these Pases would have normal hearing but elevated BBN ART give rise to lower D predicting a hearing loss. This results in false positive prediction. In bivariate plot method, ART for 2000Hz and HPN would be affected by high frequency loss but not ART for 500Hz, l000Hz and LPN and since criteria for normal hearing is normal categorization in 2 of 3 bivariate plots, normal prediction is got not false positive.

Hall and Bleakney(1981b) found false positive errors to be more common than false negative in bivariate plot analysis.

Since all of the predictive methods rely on relations between reflex thresholds and hearing loss, any variable that differentially influences these relationships is a potential source of error (Margolis et al; 1981). So factors influencing hearing prediction should be considered.

Static compliance changes as a function of age in adults (Jerger et al, 1972, Hall, 1979) and children(Hall & Weaver,1979) and children (Hall & weaver,1979),Even ART is reported to be influenced by chronological age.

Reflex thresholds for tone signals improve slightly with increasing age from infancy through adulthood (Margolis and Popelka,1975,Robertson Peterson & Lamb, 1968; Abahazi and Greenberg,1977)

Himelfarb et al (1978) observed reflexes in most of their neonatal subjects (8 to 96 hours) by monitoring acoustic conductance output on a stripchart recorder. Weatherby and Bennett(1980) could observe reflexes at lower levels in neonates (10 to 169 hours) using high frequency probetones. Absence of reflex with 220Hz probetone in these subjects was probably because of low impedance eardrum acting as a shunt element at low frequencies and obscuring impedance change caused by the reflex.

It appears then that there is no lower age limit restricting the use of predictive procedures provided that appropriate consideration is given to frequency of probe signal (Margolis et al 1981).

Handler and Margolis(1977) found that ARTs for 4000Hz, HPN and BBN was higher in elderly group than young adults.

Jerger et al(1978) reported that with the exception of 4000Hz, all puretones show same decline of about 7dB with increase in age. But reflex thresholds for BBN activators are not affected with increase in age.

Jerger et al(l978 a) hypothesize that there is elevation in ART for puretones because intense reflex activating signals result in the production of increased distortion products in elderly individuals even though there is no concomittant hearing loss. But BBN ART is not affected because the distortion products due to BBN add very little to energy already existing with in the band of noise.

Silman(1979a)found that young adult and elderly normal hearing subjects had similar ARTs for tonal stimuli where as elderly group had higher reflex thresholds for wide band noise.

Jerger (1979) attributed Silman's findings (which were contradicting the distortion hypothesis) to presence of mild high frequency loss in the elderly group of Silman's study. This might have resulted in Silman's younger group having subjects with better threshold than elderly group even though they were normal according to selection.

Silman (l979b)in reply to Jerger, reported that post hoc inspection of his data reveals no differences in BBN ARTs between subjects with puretone thresholds above and below 20dBHL at 8000Hz.

Gelfand and Piper (1981) duplicated Silman's study with 20dBHL threshold criteria extending for 8000Hz for both young and old subjects with younger group's threshold matched as closely as possible to elderly subjects. Results supported Silman's findings.

Net result of differential effect of age on reflex thresholds for tone and noise is a reduction in NTD. Hence accuracy of hearing prediction methods based on NTD such as SPAR tends to diminish as a function of age (Hall 1978; Jerger etal, 1978).

Predictive accuracy of SPAR 1977 as reported by Jerger etal(l978) was extremely good in children (2 to 12 years) with predictions of severe loss being correct in 85% of children and for moderate loss in 54% of children, predictive accuracy was poorer in elderly group (60 to 90 years) than young adult group (20 to 40 years).

Prediction accuracy for Baker - Lilly formula decreased systematically with age with hearing loss held constant, (Hall, 1978) and this has been reported with other regression equations also (Hall and Bleakney, 1981a).

With increase in age predictive accuracy decreased for 1974 SPAR but increased for 1977 SPAR (Hall and Bleakney, 1981b). So 1977 SPAR is preferable in older populations.

Bivariate plotting procedures can be effective with elderly subjects provided a LPN is used (Handler and Margolis, 1977).

Light, Ferrell and Sandberg (1977) found that sedation with diazepam and meperdine does not have a significant effect on SPAR testing and hence these sedatives can be used in cases of difficult to test.

Schwartz and Sanders (1976) hypothesized that if successful prediction of loss depends on an abnormal widening of critical band in sensorineural loss ears, there should be a direct relationship between degree of loss and abnormal/width of critical band for ART. They found no consistent differences in abnormal widening of critical band in subjects with mild to moderate loss or severe loss. Abnormal widening of critical band did separate those with normal hearing from those with sensorineural loss. Except bivariate plot system other predictive methods attempt to differentiate degree of hearing loss on the basis of NTD, a critical band phenomenon. Therefore findings of Schwartz and Sanders may explain inaccuracies in prediction by these methods in mild - moderate loss categories.

Accurate differentiation of those with normal hearing Vs those with sensorineural loss is primarily dependent on NTD a relative value. Above 45 dB ie. mild - moderate - severe region, accurate predictions must rely on absolute level of noise and / or tone ART. 1977 SPAR employs both NTD criteria and absolute threshold for both noise and 1000 Hz signal (Hall, 1980).

Hall and Weaver (1979) reported that reflex threshold for noise signals increase relatively systematically with the loss while reflex threshold for tone signals improve slightly through mild - moderate loss region (26 to 45dBHL). Based on this data criteria for absolute threshold for noise and 2000Hz rather than l000Hz seem to be more directly related to degree of loss (Hall, 1980).

Keith (1977) reports that with Niemeyer and Sesterhenn method also greatest portion of prediction error occurs with mild - moderate loss.

Margolis and Fox (1977) report that in bivariate plot procedure probability of a subject falling outside of normal region increases with the severity of loss.

Hall (1978) reports that Baker and Lilly regression equation most accurately predicted hearing in subjects with mild to moderate loss.

Hall and Weaver (1979) reported that relatively compliant ears elevated puretone ART from 3 to 5 dB and BBN ART by 10dB, and slight negative middle ear pressure (-50 to -100mm water) elevated puretone and noise ART by 2 to 5 dB. Hall (1978) reports that subtle middle ear abnormalities increase serious prediction errors in SPAR 1974 and SPAR 1977 versions and Baker and Lilly (1976) formula is not affected probably because it does not depend on absolute levels of Acoustic reflex.

Hall and Bleakney (1981a) found that 1977 SPAR is more affected by minor middle ear disorders than 1974 SPAR. This is because in patients with minor middle ear disorders, there is elevation of puretone ART. So they pass NTD criteria but fail in normal criteria for 1000Hz ART in 1977 SPAR, recieving a prediction of mild loss;. In 1974 SPAR, these subjects recieve normal prediction NTD based Niemeyer and Sesterhenn method will be seriously affected by minor middle ear abnormalities where as bivariate plot would be unaffected.

Prediction methods based in part on absolute reflex threshold level may tend to produce false positive results in central auditory disorder (Margolis and Fox, 1977). This is because of elevated acoustic reflex threshold for puretones. Hall (1980) hypothesises that reflex threshold for complex auditory signals such as noise will be more sensitive to central auditory disorder than simpler puretones. This may elevate noise reflex thresholds comparatively more than puretone reflex thresholds resulting in reduced noise tone difference. The net result is false positive prediction. This elevation of acoustic reflex threshold in central auditory disorder has obvious clinical importance for hearing prediction.

It has been reported by many investigators that the magnitude of acoustic reflex increases within limits as the intensity of the stimulus increases (Metz, 1951; Moller, 1958; 1962; Dallos, 1964; Hung and Dallos, 1972; Peterson and Liden, 1972; Beedle and Harford, 1973; Kaplan et al, 1977).

Moller (1962) demonstrated that the largest reflex magnitude was elicited by binaural stimulation followed in order by ipsilateral and then contralateral signal presentation. He reported acoustic reflex growth functions at selected stimulus frequencies from 200 to 4000Hz. As the stimulus frequency increased, slope of the growth function decreased.

Ravishankar Shukla(1980) found increase in reflex amptitude with increase in sensation levels to be not linear on both ipsilateral and contralateral stimulation.

The intensity range over which the acoustic reflex demonstrates growth(between threshold and saturation) is called 'Dynomic range of acoustic reflex'. With puretone stimuli, the range varies from 15 to 17dB(Djupesland et al, 1967) and for broadband noise stimulus, range is 30dB (Dallow,1964).

As probe tone frequency is increased, the magnitude of reflex measured in terms of impedance(Ω) decreased (Dallow,1964).

Jerger,Mauldin & Lewis(1977)found that reflex magnitude or amplitude increases with increase in intensity. Growth of reflex is rapid for longer duration stimulus(500 msec) and gradual for shorter duration (10 msec)stimulus. Duration at which maximum summation is reached is same (100 msec) for both 1000Hz and BBN signal. They also found that at lower intensity levels, slope of BBN function is more gradual than slope for tone duration, whereas at high intensity levels, the slopes are parallel.

Wilson & McBride(1978) measured magnitude as change in acoustic admittance in mmho. BBN & 1000Hz stimuli produced largest reflex magnitudes while smallest were observed for

250 & 4000Hz puretones. Dynamic ranges for puretones were frequency dependent. For puretones, the rate of growth of reflex increased in the begining and decreased later where as for BBN, growth is gradual through out the intensity range.

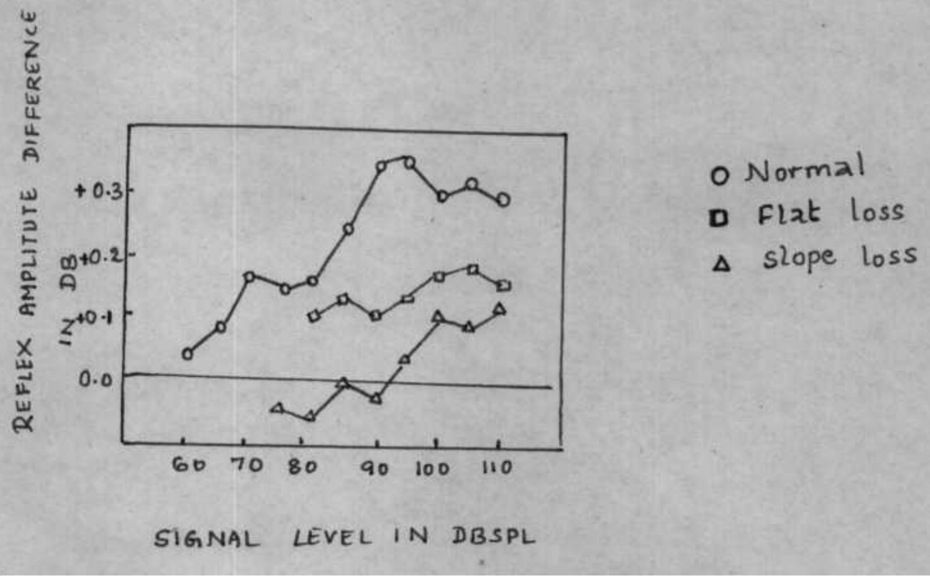
Jerger et al (1978) computed reflex amplitude as equivalent change in SPL in dB of probe signal (250Hz) in a 2cc cavity,subjects were normal hearing adults(age range: 20 to 52 years). Results were as follows- i)ipsilateral reflex amplitude was slightly larger than the contralateral reflex amplitude for both 1000Hz & BBN stimuli, ii)the reflex amplitude for BBN stimulus was consistently larger than the reflex amplitude for 1000Hz tone. iii)Reflex amplitude growth was a monotonic function of signal level. iv)In presumably normal hearing subjects, probably because of minor middle ear disorders, reflex amplitude functions were deviant.

On studying 51 ears of 31 sensorineural loss patients, Jerger et al (1978) came to following conclusions regarding the reflex amplitude functions: a) sensorineural loss patients with flat configuration showed linear functions in reflex amplitude for both tone and noise stimuli. b) Sensorineural sloping loss cases showed gradual amplitude functions. c)There was little relation between degree of loss and amplitude functions. d) As the degree of slope of sensorineural loss increased, reflex amplitude decreased.

The amplitude difference between BBN and 1KHz reflexes as a function of signal level was calculated for 3 groups, i) normal hearing, ii)Flat sensorineural loss and iii) Sloping loss. Results indicated that in normal group, the amplitude difference increases rapidly with signal level to 90dBSPL, then plateaus at about 0.30dB; in the flat loss group, the difference increases slightly and never exceeds 0.19dB and in sloping loss group the difference is even smaller, never exceeding 0.13dB (See fig. 21)

Figure-21

Effect of signal level on the noise tone reflex amplitude difference in normal hearing, flat sensorineural loss & sloping loss groups.



These large amplitude difference effects among three groups encouraged the authors to explore the possibility that some index of suprathreshold reflex amplitude might prove to be a predictor of hearing.

Two indices were computed - (1)Suprathreshold amplitude ratio:- Ratio of amplitude of 1KHz tone and BBN functions at the signal SPL showing largest amplitude for BBN functions. (2) Supra threshold noise tone differences: Average of differences of 1KHz and BBN functions at 100%, 75% and 25% points along 1KHz amplitude function where 100% is defined as the maximum amplitude function.

Results showed that amplitude ratio as expected, decreased with hearing loss. But effect was small. Suprathreshold noise tone difference decreased as expected with hearing loss and effect seesoned substantial. Mean values for amplitude indices for three groups are given below: (Table 7)

Table-7 showing values of 2 suprathreshold indices for normal hearing, flat loss and sloping loss groups.

Group	Supra threshold amplitude ratio	Supra threshold Noise tone difference
Normal	1.60	4.24
Flat S/N	1.38	2.84
Sloping S/N	1.40	2.22

Jerger et al (1978) concluded that "neither supra threshold amplitude ratio nor supra threshold noise tone difference works as well as the noise-tone threshold separation in differentiating normal from sensorineural hearing loss".

The present study was an attempt to investigate, noise tone difference (reflex magnitude) in children, to explore any possibility of its use in the prediction of hearing sensitivity.

CHAPTER - III

METHODOLOGY

The experiment comprised of the following steps:-

1. Obtaining puretone thresholds of frequencies 250Hz to 8000Hz in normal hearing children through behavioural audiometry.

2. Establishing Acoustic Reflex thresholds in both the ears for puretones 500Hz, 1000Hz and 2000Hz and broad band noise.

3. Determining the acoustic reflex magnitude for each of the above stimuli at Acoustic reflex threshold level, 10 dB above acoustic reflex threshold and then 20 dB above Acoustic Reflex Threshold.

4. Collecting similar data from children with sensorineural hearing loss.

Subjects:-

Normal hearing subjects in the study were thirty three (17 males and 16 females) in the age range of 5 to 10 years. None of them had ear aches or ear discharge previously or at the time of testing. All of them had normal hearing according to Godman's (1965) classification of hearing impairment (reference: ANSI, 1969). All the subjects had A type tympanogram static compliance within normal range of 0.30 to 1.60cd(Jerger,l970) and middle ear pressure within normal limits of ± 50 mm H_2O(Porter,1972). Some ears with elevated or absence of Acoustic Reflex Threshold had to be discarded as it was not possible to measure reflex magnitude at and above Acoustic Reflex Threshold in these ears.

In the sensorineural loss children (of age range 5 to 10 years) whom the experimenter tested, Acoustic Reflex Thresholds(ARTs) were either absent or elevated. So they could not be included in the study.

Two subjects having sensorineural loss (age 13 years) in whom it was possible to carry out reflex magnitude measurements were considered for the study.

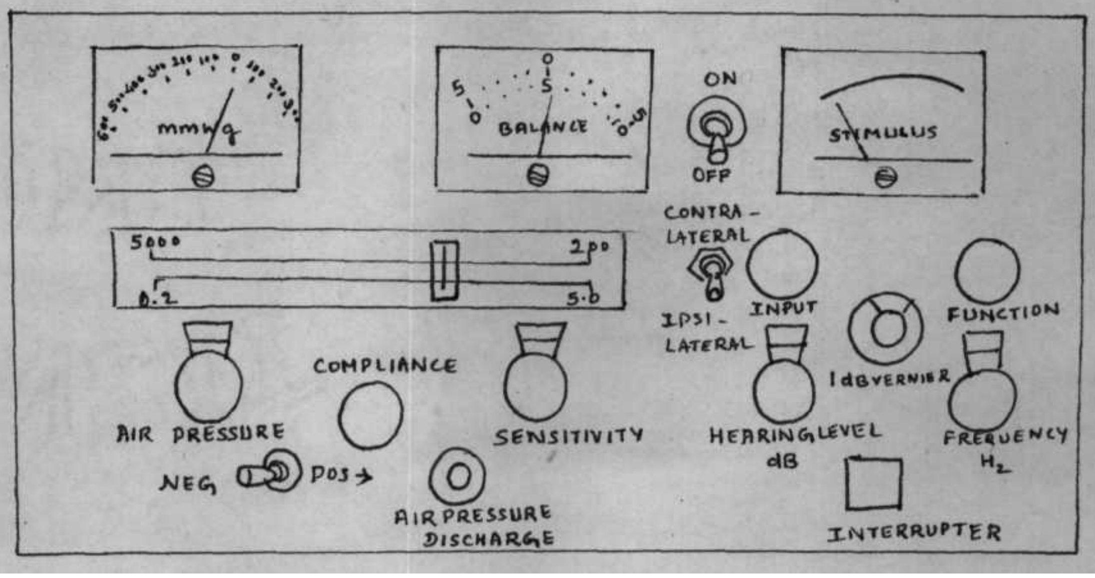
The instrumentation and environment:-

For establishing, puretone thresholds, a clinical audiometer (MA - 30) with TDH - 39 earphones and MX - 41/AR cushions was used.

Impedance(Tympanometry, static compliance and acoustic reflex) measurements were carried out using an electro acoustic impedance bridge (Madsen ZO 73) with Type E head set and Telex 1470 earphone housed in MX - 41/AR ear cushion (see fig. 22), the probe tone frequency being 220 Hz.

Figure-22

ELECTRO ACOUSTIC IMPEDANCE BRIDGE -2073



All the testings were done in sound treated rooms of All India Institute of Speech and Hearing, Mysore.

Calibration of instruments:—

Audiometer MA - 30 was calibrated to ANSI (1969) standards using the instruments, artificial ear assembly (Bruel and Kjaer Type 4152), condenser microphone (Bruel and Kjaer Type 4144), Precision sound level meter (Bruel and Kjaer Type 2209) with 1/3 octave filter set (Bruel and Kjaer Type 1616) and adapter (Bruel and Kjaer Type 0962).

Calibration procedure with this involved the following ateps:-

1) Artificial ear with the microphone was connected to the sound level meter .

2) Earphone from the audiometer was placed on the artificial ear and the weight over it was adjusted to 550 grams.
3) Sound level meter was set to 'external filter' position.
4) 250Hz puretone was delivered at 90 dBHL from the audiometer. The octave filter set was set at 250Hz and attenuator of sound level meter at 100 dBSPL.
5) Earphone was readjusted till maximum reading on soundleveL meter was obtained. This output level was compared with the expected output at 250Hz (ANSI-69) to get correction factor.
6) Procedure was repeated with other frequency signals (500 to 8000Hz) and a correction chart was prepared.

Linearity of the audiometer attenuator was checked directly from the audiometer by measuring electrical output in voltage and converting it to dB. Linearity was satisfactory, (ANSI Standard; output within ± 1.5 dB of dial reading).

Calibration of puretones of the impedance bridge was checked using the procedure as described above.

Broad band noise from the impedance bridge was calibrated as follows:-
i. The same equipment as mentioned above were used,
ii. Sound level meter was set at 'linear' position and attenuator at 90 dBSPL.

iii. Broad band noise was presented from the impedance bridge through the earphone at 90dBHL.

iv. If the output was not within ± 1dB of 90 dB, then corresponding potentiometer was adjusted to bring the output within the required limits.

Linearity of attenuator of impedance bridge was checked and was found to be satisfactory.

The acoustic impedance section of the bridge was calibrated by inserting the probe into built in 2 cc cavity of the bridge turning the compliance control to get zero on balance meter and checking whether the compliance scale balanced at 2.0 cc . If not,corresponding potentiometer was adjusted till proper reading was obtained.

To check for air pressure leakage, the probe was inserted to built in 2cc cavity, air pressure control was adjusted to +200mm on pressure meter. The pressure meter needle was observed for any leakage.

In the present study, lower red scale of balance meter from zero to ten with zero at left hand side was considered. As a result, maximum possible deflection of needle could be read on the meter. If the deflection was beyond 'ten' on the meter, measurement was carried out at sensitivity '2'.

Everytime, before inserting the probe for testing the subject, the pressure meter was set to zero to ensure that full airpressure range was available.

Test procedure

Puretone thresholds for frequencies 250 to 8000Hz were established using "up 5 down 10" method with principles of Hughson-Westlake ascending technique (Green,1978). Each subject was instructed verbally as follows.

"Now you are going to hear a series of sounds, first in the tight ear and then in the left through this telephone like instrument (earphones of the audiometer were shown). When you hear the sound, whether it is soft or loud, raise your finger. Keep the finger raised as long as you hear the sound and put it down when you stop hearing. Remember to raise your finger every time you hear the sound".

The instructions and type of response varied depending on child's age and interest. The earphones were placed on subject's ears and puretone thresholds were obtained.

Before starting the impedance testing the subject was given followinginstructions.

"In this test also, you are going to hear sounds. Unlike the previous test, you need not indicate that you are hearing the sound. Just relax completely. Sit quietly without much movements."

Sometimes, these instructions were varied depending on the child's co-operation. Further testing involved the following steps:-

(1) Earphone was adjusted over one ear and with the appropriate ear tip, probe was inserted in to contralateral ear. Absolute air tight seal was ensured for each subject.

(2) Tympanogram, static compliance and middle ear pressure were obtained using the standard procedure, at sensitivity '1'.

(3) Acoustic Reflex Thresholds for 500Hz, l000Hz, 2000Hz and broad band noise: Pressure meter was set to middle ear pressure. Sensitivity knob was turned to '3' position. Balance meter needle was adjusted to be at zero of lower scale. Reflex eliciting stimuli were delivered to test ear through the Telex 1470 earphone stimulus duration was constantly maintained at 1.5 seconds. The intensity of the stimulus was increased in 5dB steps. The level at which there was balance meter needle deflection by 1.5 units was considered as Acoustic Reflex Thresholds.

(4) For each stimulus, acoustic reflex magnitude interns of balance meter needle deflection was noted at the following levels.

(a) At Acoustic Reflex Threshold level

(b) l0dB above Acoustic Reflex Threshold (10 dB SL)

(c) 20dB above Acoustic Reflex Threshold (20 dB SL)

The impedance bridge settings for reflex magnitude measurements were same as mentioned for Acoustic Reflex Threshold determination.

The data for each subject was recorded as follows:-

TEST EAR: PROBE EAR :

INTENSITY LEVEL OF THE STIMULUS	ACOUSTIC REFLEX MAGNITUDE AT			STIMULI
	500 Hz	1000 Hz	2000 Hz	BBN
Acoustic Reflex Threshold				
10 dB SL				
20 dB SL				

(5) Five minutes later, acoustic reflex magnitude measurements were repeated to check for reliability.

CHAPTER IV

RESULTS AND DISCUSSIONS

In this study, noise tone difference (reflex magnitude was investigated in the normal hearing and sensorineural loss ears.

Of the thirty three normal hearing subjects (66 ears), 55 ears (20 right + 29 left) were included in the study. 11 ears had to be discarded because of elevation or absence of acoustic reflex threshold. Two subjects with sensorineural loss (4 ears) were taken.

Data was collected on reflex magnitude values for puretones (500Hz, lOOOHz and 2000Hz) and broadband noise stimuli at reflex threshold level, 10 dBSL and 20dBSL. In order to check for reliability, retesting was done on nineteen ears.

Computation of noise tone difference (reflex magnitude):

According to Jerger (1973) unweighted formula,

Noise tone difference (Acoustic reflex threshold)

$$\frac{\text{500HzART+1000Hz ART+2000HzART}}{3} - \text{BBN ART + Correction factor.}$$

It was reported by peterson and Liden(1972) that the maximum reflex magnitude was attained at 20dBSL(Ref:ART) and further increase in signal intensity level did not bring about further increase in reflex magnitude.

So, in the present study, for computing noise tone difference (reflex magnitude), amount of increase in reflex magnitude from reflex threshold level to 10dBSL and 20dBSL were taken into consideration.

Formula used for computation of noise tone difference (reflex magnitude) is as follows.

i) AT 10dBSL

NTD (reflex magnitude) = N - P

where $P_1 = \frac{a_1+b_1+c_1}{3}$

$a_1 = Ya - Xa$

$b_1 = Yb - Xb$

$c_1 = Yc - Xc$

& $N_1 = Y_N - x_N$

ii) AT 20dBSL

NTD (reflex magnitude) = $N_2 - P_2$

where $P_2 = \frac{a_2+b_2+C_2}{3}$

$a_2 = Za - Xa$

$b_2 = Zb - Xb$

$C_2 = Zc - Xc$

& $N_2 = Z_N - X_N$

Expansions of symbols used in the formula is given in the following Table(8)

INTENSITY LEVEL OF THE STIMULUS	ACOUSTIC REFLEX MAGNITUDE AT STIMULI			
	500Hz	1000Hz	2000Hz	BBN
Acoustic reflex threshold	X_a	X_b	X_c	X_N
10 dBSL	Y_a	Y_b	Y_c	Y_N
20 dBSL	Z_a	Z_b	Z_c	Z_N

Data was analyzed using parametric statistics. Mean values of N_1 ,P_1, N_2 and P_2 were computed for right and left ears (See Table-9).

Table-9 Showing Mean values of N_1,P_1,N_2 and P_2 for right and left ears.

EAR	MEAN VALUES			
	N_1	P_1	N_2	P_2
RIGHT	2.48	1.97	4.07	3.67
LEFT	2.34	2.03	3.75	3.63

From the above table, it is clear that a difference exists between average reflex magnitude for puretones (500Hz, 1000Hz & 2000Hz) and reflex magnitude for broad band noise. Significance of difference between Mean values of N_1 and P_1

and N_2 and P_2 were calculated. The difference was not found to be significant. So null hypothesis was accepted.

Mean values of a_1, b_1 ,c_1 & N_1 and a_2,b_2, c_2 and N_2 were determined for right and left ears (See Table 10).

Table-10 showing Mean values of a_1, b_1 ,c_1 & N_1 and a_2, b_2 ,c_2 & N_2 for right and left ears

EAR	MEAN VALUES							
	a_1	b_1	c_1	N_1	a_2	b_2	c_2	N_2
RIGHT	2.42	1.92	1.53	2.48	4.15	3.92	2.80	4.07
LEFT	2.43	2.25	1.44	2.34	4.41	3.87	2.62	3.75

Comparison of values a_1 & a_2,b_1 & b_2, c_1 & c_2 and N_1 & N_2 indicate that there is increase in reflex magnitude as sensation level(ref:ART) increases. This finding is in agreement with previous studies(Metz,1951; Moller,1958 Dollos,1964; Hung & Dallos,1972; Peterson & Liden,1972; Beedle & Harford, 1973; Kaplan et al, 1977; Jerger et al, 1977; Wilson & McBride, 1978; Jerger et al,1978).

Noise tone difference (reflex magnitude) values were computed using the formula at l0dBSL and 20dBSL for 26 right ears, 29 left ears and 19 retested ears.(See Tables 11 & 12).

Table-11 showing noise tone difference (reflex magnitude) values fop 26 right ears and 10 retested ears at 10dBSL and 20 dBSL.

Sl. No.	RIGHT EAR			
	10 dBSL		20 dBSL	
	FIRST TESTING	HETESTING	FIRST TESTING	RETESTING
1	0.5	0	0.17	0.17
2	-0.5	-0.33	-0.5	-0.5
3	0.17	-0.16	1	0.5
4	0.34	0.17	-1	-1.16
5	0.17		0.5	
6	2.67		3	
7	0.67		1.5	
8	0.67		0.67	
9	- 0.66		-0.66	
10	0	0	0	0.17
11	- 1		0.67	
12	0.84		1.34	
13	1.67		1.34	
14	0		-0.5	
15	1.84	1.47	2	1.5
16	0.67		1.34	
17	0.34		-1	
18	-0.66		-2.16	
19	-0.33		0.17	
20	-0.66		0	
21	0.67	0.67	0	-0.6
22	0.34	0	0.34	0.17
23	1.5		1.67	
24	0.17	0.34	-0.5	-0.1
25	0.84		-0.16	
26	2.5	0.84	2.84	1.17

Table-12 showing Noise tone difference (reflex magnitude) values for 29 left ears and 9 retested ears at 10dBSL & 20dBSL

SL. NO.	LEFT EAR			
	10dBSL		20dBSL	
	FIRST TESTING	RETESTING	FIRST TESTING	RETESTING
1	- 0.5	- 0.16	0	- 0.33
2	0.17		0	
3	0.5		0	
4	0.17	1.84	0.5	- 0.16
5	0.34	0	0.2	0.5
6	0.17	- 0.66	0.5	0.4
7	- 0.33		- 0.83	
8	0.5		0.84	
9	0.67		1.5	
10	0.67		- 1	
11	0.17		- 0.66	
12	- 0.66	- 0.33	- 0.83	0.17
13	1.17		1	
14	0.47		0.84	
15	- 0.33		1	
16	- 0.5		- 0.5	
17	2.17	1.84	2.5	2.47
18	0.37		0.67	
19	0.17		- 1.16	
20	- 0.16		- 2	
21	1.34		0.17	
22	0.67		0	
23	1.5	1.84	0.34	0.5
24	- 0.33	0.17	0	0.67
25	- 0.33		0.16	
26	0.67	1	0.5	0.84
27	0.84		1.67	
28	1.17		0	
29	- 1.16		- 1.5	

The statistical Mean(M) of noise tone difference (reflex magnitude) values, was determined for each ear at each level. To find individual variability within the group, the standard deviation(S.D) values were computed for right and left ears at 10dBSL and 20dBSL. The product moment co-efficient of correlation(f) was calculated to check for test-retest reliability (see Table 13).

Table-15 showing Mean(M),Standard deviation(S.D) and product moment Co-efficient of correlation( ) values of noise tone difference for right and left ears at 10dBSL and 20dBSL

STATISTICAL MEASURES OF NOISE TONE DIFFERENCE (REFLEX MAGNITUDE)	RIGHT EAR		LEFT EAR	
	10dBSL	20dBSL	lOdBSL	20dBSL
1. M	0.49	0.46	0.33	0.12
2. S.D.	0.75	0.17	0.70	0.94
3. r	0.84	0.91	0.72	0.81

From the above table, it can be observed that mean noise tone difference (reflex magnitude) is larger for right ear than left ear. So ear difference should be taken in to consideration while using the normative data on noisetone difference (reflex magnitude).

Noise tone difference (reflex magnitude) in both ears was greater at 10dBSL than 20dBSL. Hence there was decrease in noise tone difference (reflex magnitude) with increase in sensation level.

Standard deviation values indicate that for both right and left ears, variability within the group was more at 20dBSL than at 10dBSL.

Co-efficient of correlation values were significant at all conditions indicating good test-retest reliability.

Both the sensorineural loss subjects (used in this study) had moderate degree of hearing impairment. When the mean values of a_1, b_1,,c_1, and N_1 were compared with a_2 , b_2, c_2 and N_2 respectively, an increase in reflex magnitude with increase in sensation level was observed. (See Table 14).

Table-14 showing mean values of a_1, b_1,c_1, and N_1 and a_2 ,b_2, c_2 and N_2 for right andleft ears of 2 subjects with sensorineural loss.

EAR	MEAN VALUES							
	a_1	b_1	c_1	N_1	a_2	b_2	c_2	N_2
RIGHT	2.25	2.0	1.5	1.5	3.25	3.5	2.5	2.5
LEFT	4.5	2.5	3.5	3.25	6.25	5.5	5.5	5

Noise tone difference (reflex magnitude) values were computed using the same formula for 4 sensorineural loss ears(See Table 15). All the values were negative.

Table-15 showing Noise tone difference (reflex magnitude) values of 2 sensorineural loss subjects for right and left ears at 10dBSL and 20dBSL.

SUBJECTS (SENSORI NEURAL LOSS)	RIGHT EAR		LEFT EAR	
	10dBSL	20dBSL	10dBSL	20dBSL
1	-0.5	- 0.33	- 0.33	- 0.66
2	- 0.33	- 0.66	- 0.16	- 0.83

DISCUSSIONS:

In the present study, reflex magnitude for broad band noise stimulus was larger than the reflex magnitude for puretones in most of the normal hearing ears(40 out of 55 ears at 10dBSL and 38 out of 55 ears at 20dBSL). This kind of magnitude difference has been reported on adult, population by Jerger et al.,(1978). The loudness advantage enjoyed by the normal hearing ears for broad band noise might be the reason for it.

In the present study, noisetone difference (reflex magnitude) was computed by subtracting puretone reflex magnitude from noise reflex magnitude. Hence, for these [40&38 55]normal hearing ears, the noise tone difference (reflex

BIBLIOGRAPHY

Abahazi.D.A. and Greenberg.H.J., "Clinical acoustic reflex threshold measurements in infants," J.Speech Hear. Disord., 42, 1977, p.514 - 519.

Albrecht.W., "Dic. Trennung der nicht organischen von der organischen Horstorung mite Hilfe des pschogalvanischen Reflexes," Arch. Ohr. Nas. Kehlk heilk, 101, 1918, p.1 - 19 (as cited by Knox, 1978).

Antinoro.F., Skinner.P., and Jones.J. "Relation between sound intensity and amplitude of the auditory evoked response at different stimulus frequencies" J.Acoust. Soc. Am. 46, 1969, p.1433 - 1436.

Appleby.S.V., "The slow vertex maximal sound evoked response in infants," Acta. Otolaryng. Suppl. 206, 1964, p.146 - 152, (as cited by Reneau & Hnatiow, 1975).

Aran.J.M., "The electrocochleogram: Recent results in children and in some pathological cases." Arch. Klin. Exp. Ohren. Nasen. Kehlkopfheilkd 198, 1971, p.128 - 141, (as cited by Northern and Downs, 1978).

Baker.E.E. "Pupillary response conditioned to subliminal auditory stimuli," Psychological monographs, 1938, 50, p.32, (as cited by Hogan, 1975).

Baker.S.R. & Lilly.D.J. "Prediction of hearing level from acoustic reflex data." presented before the American Speech and Hearing Association Convention, Houston, Texas, November 20, 1976 (as cited by Hall & Bleakney, 1981a).

Barnet.A. & Goodwin.R.S. "Averaged evoked electroencephalo graphic responses to clicks in the human new born" Electro encephalogy. clin. Neurophysiol. 18, 1965, p.441 - 450, (as cited by Reneau & Hnatiow, 1975).

Barnet.A.B. & Goodwin.R.S., "Averaged evoked electro encephalo graphic responses to clicks in the human new born" Behaviour in Infancy & early childhood: A book of Readings.. Ed. Y.Brackbill, New York, Free press, 1967, (as cited by Gerber et al, 1976).

Barnet.A.B. "EEG Audiometry in children under three years of age" ACta Otolaryngol. 72, 1971, p.1 - 13.

Bartoshuk.A.K., "Human neonatal cardiac acceleration to sound habituation and dishabituation," Percept. Mot. Skills 15, 1962, p.15 - 27, (as cited by Smith and Borton, 1980).

Bartoshuk.A.K. "Human neonatal cardiac responses to sound: A power function" Psychonom. Sci. 1, 1964, p.151-152 (as cited by Suzuki, 1978).

Beadle.R.K. and Crowell.D.H., "Neonatal electrocardiographic responses to sound Methodology," J.Speech Hear. Res. 5, 1962, p.112 - 123.

Beadle.R.K. & Harford.E.R., "A comparison of Acoustic Reflex and loudness growth in normal and pathological ears," J.Speech Hear. Res.. 16, 1973, p.271-281.

Berg.W.K. & Graham.F.K. "Reproducible effects of stimulus intensity on heart rate response waves." Psycho physiology, 6, 1970, p.653 - 654, (as cited by Smith & Borton, 1980).

Berlin.C.I. "Electro physiological indices of auditory function" Pediatric Audiology, ed. F.N.Martin, New Jersey, Prentice Hall Inc., 1978.

Bickford.R.G., Jacobson.J.L. & Cody.D.T.R. "Nature of average evoked potential to sound and other stimuli in man" Ann. N.Y. Acad. Sci., 112, 1964, p.204 - 223 (as cited by Skinner, 1978).

Bitterman.M.L., Reed.P.C, & Kranskopf.J. "The effect of the duration of the unconditioned stimulus upon conditioning and extinction", Am. J.Psychology., 65, 1952, p.256 - 262, (as cited by Knox, 1978).

Black.R.W. "Heart rate response toauditory stimuli of varying duration" Psvchonom Sci., 1, 1964, p.171-172, (as cited by Hogan, 1975).

Bonding.P., "Critical band width in loudness summation in Sensorineural hearing loss" British Journal of Audiology 13, 1979, P.23 - 30.

Bordley.J.E., Hardy.W.G. & Richter.C.P. "Audiometry with the use of galvanic skin resistance response" Bull Johns Hopkins Hosp. 82, 1948, p.569, (as cited by Knox, 1978).

Borsanyi.S.I. & Blanchard.C.L. "Auditory evoked brain responses in man", Arch. Otolaryngol., 80, 1964 p. 149 - 154.

Bradford.L.J. & Rosey.C.L. "Respiration Audiometry" Maico Audiological Library Series^ 10, Rep.6, 1972, p.22.

Bradford.L., Rousey.C. & Bradford.M. "Respiration Audiometry with the preschool child." Laryngoscope, 82, 1972, p. 28 - 40.

Bradford.L.J. "Respiration Audiometry" Physiological measures of the Audiovestibular system, ed. L.J.Bradford, New York, Academic press Inc; 1975.

Brewster.L.C. & Morrison.M.D. "Observations of parents and child as part of the diagnostic process, The SPARC program", Early diagnosis of hearing loss, eds. S.E.Gerber & G.T.Mencher, New York, Grune & Stratton, Inc., 1978.

Brooks.R. & Gieschen.E. "Clinical utilization of Respiratory activity in Auditory Threshold determinations" J.Kansas Speech Hear. Ass. 9, 1968, p.1 (as cited by Bradford, 1975).

Butterfield.G. "A note on the use of cardiac rate in the audiometric appraisal of retarded children" J. Speech Hear. Disord. 27, 1962, p.378 - 379.

Chaiklin.J.B., Ventry.I.M. & Barnet.C.S. "Reliability of conditioned GSR puretone audiometry with adult males" J.Speech Hear. Res. 4, 1961, p.269 - 280.

Clark.W.A. Jr. "Average response computer (ARC - 1)" Q. Rep. Electronics (MIT), 1958, p.114-117, (as cited by Skinner, 1978).

Clark.W.A. et al."The average response computer (ARC); a digital device for computing averages and amplitudes and time histograms of electrophysiological responses" Trans. Int.Radio Engineers. 8, 1961, p.46 - 51, (as cited by Skinner, 1978).

Clynes.M. "The non linear biological dynamics of uni-directional rate sensitivity illustrated by analog computer analysis, pupillary reflex to light, sound and heart behavior", Ann. N.Y. Acad. Sci. 98, 1962, p.808 - 846 (as cited by Hogan, 1975).

Coats. A.C. "On electro cochleographic electrode design" J.Acoust. Soc. Am.. 56, 1974, p.708 - 711.

Cobb.J., Skinner.P. & Burns.I. "The effect of signal rise time and frequency on the BSER." presented to the American Speech and Hearing Association Convention, Chicago, 1977 (as cited by Skinner, 1978).

Cody.D.T.R. et al. "Averaged evoked myogenic and cortical potentials to sound in man." Ann. Otol. Rhinol. Laryngol., 73, 1964, p. 763 - 777, (as cited by Skinner, 1978).

Cody.D.T.R. and Bickford.R.G. "Cortical audiometry: an objective method of evaluating auditory acuity in man." Mayo clin. proc., 40, 1965, p.273 - 287 (as cited by Skinner, 1978).

Coles.R.R.A. "Personal communication". 1974, (as cited by Miller et al., 1976).

Coles.R.R.A. "Objective audiometry: A general and historical review." J.Larvngol otol.. 91, 1977, p.639 - 654.

Cranley.J.J. "Vascular surgery, volume II: Peripheral venous diseases," Hagerstown, Maryland, Harper & Row, 1975, P.76 - 77 (as cited by Mojdehi et al., 1980).

Crowell et al, "Galvanic skin reflex in new born humans", Science, 148, 1965, p. 1108 - 1111 (as cited by Hogan, 1975).

Cullen et al, "Human acoustic nerve action potential recordings from the tympanic membrane without anesthesia" Acts otolaryngol. 74, 1972,P.15-22.

Curry E,T & Kurtzrock G.H "A preliminary investigation of the ear choice technique in threshold audiometry" J.Speech Hear Disord, 16,1951,P.340-345

Dallos P.J. "Dynamics of the acoustic reflex: phenomenological aspects" J.Acoust Soc.AM, 36,1964 P.2175-2183 (as cited by Wilson & McBride, 1978)

Dallos P. "Comments on the differential electrode technique". J.Acoust Soc. Am 45, 1969 P.999-1007.

Dallos P. "The Auditory periphery", New York, Academic press, 1973-

Daly R.L. "Peripheral vaso constriction and electro encephalography as estimators of hearing threshold", paper presented at American Speech & Hearing Association convention, Chicago,November,1956 (as cited by Mojdehi et al, 1980).

Davis et al., "Electrical responses of the human brain to auditory stimulation during sleep" J.Neurophysiol 2,1939 P.500-514 (as cited by Skinner,1978).

Davis P.A. "Effects of acoustic stimuli on the waking human brain" J.Neurophvsiol. 2, 1939,P.494-499(as cited by Northern & Downs, 1978).

Davis R.C., Buchwald A.M. and Frankman R.W. "Autonomic and muscular responses and their relation to simple stimuli". Psychol Monoge, 405,1955. (as cited by Gerber et al, 1976)

Davis et al., "Evoked responses to clicks recorded from the human scalp". Am N.y.Acad Sci. 112, 1964, P. 224-225 (as cited by skinner,1978).

Davis H. "Slow cortical responses evoked by acoustic stimuli" proceedings of a conference on the young deaf child, held in Toronto, Canada, October,8-9,1964 (as cited by Skinner,1978)

Davis H. & Zeclins. "Acoustic relations of the human vertex potentials". J.Acoust.Soc Am. 39,1966,P.109-116 (as cited by Northern and Downs, 1978)

Davis et al. "The slow response of the human cortex to auditory stimuli: recovery process. Electro encephalogr. Clin. Neurophysiol. 21, 1966, p. 105 - 113 (cited by Skinner, 1978).

Davis.H. et al "Further validation of evoked response audiometry (ERA), J.Speech & Hearing Res., 10, 1967, p.717 - 732.

Davis.H. & Niemoeller.A.F. "A system for clinical evoked response audiometry" J.Speech Hear. Disord.. 33, 1968, p.33 -37.

Davis.H. "Classes of auditory evoked responses," Audiology 12, 1973, P.464 - 469.

Davis.H. et al, "Validation of clinical ERA at Central Institute for the Deaf" Rev. Laryngol., 95, 1974, p. 475 - 480, (as cited by Skinner, 1978).

Davis.H. "Principles of electric response audiometry," Ann. Otol. Rhinol. Larvngol., 85, (suppl. 28), part 3, May - June, 1976, (as cited by Skinner, 1978).

Davis.H. S Hirsh S.K. "A slow brain stem response for low frequency audiometry" Audiology, 18, 1979, P.445-461.

Dawson G. "A summation technique for the detection of small evoked potentials" Electro encephalogr clin Neurophysiol. 6, 1954, P.65-84(as cited by Skinner,1978)

Deboer E. and Bourmaster J. "Critical bands and sensorineural hearing loss" Audiology. 13,1974 P.236-259.

Dedmon D. & Robinette M. "The acoustic reflex as a tool for neonatal screening" Audecible, Fall, 202, 1973 (as cited by Tsappis, 1977).

Derbyshire.A.J. and Davis.H. "The action potentials of the auditory nerve," Am. J. Physiol., 113, 1935, p.476-504, (as cited by Glattke, 1978).

Derbyshire et al., "Audiometric measurements by electro encephalography," Electro encephalogr. clin. Neurophysiol.. 8, 1956, p.467 - 478, (as cited by Price, 1975).

Derbyshire.A.J. & Mc Dermott.M. "Further contributions to the EEG method of evaluating auditory function," Laryngoscope. 1958, 68, p.558 - 570, (as cited by Price, 1975).

Derbyshire.A.J. and McCandless.G.A. "Template for the EEG response to sound," J.Speech Hear. Res., 7, 1964 p.96 - 102.

Deutsch.L.J. "The threshold of the stapedius reflex for puretones & noise stimuli," Acta Otolaryngol, 74, 1972, p. 248 - 251.

Dix.M.R. & Hallpike, "The peep show: A new technique for puretone audiometry in young children," Br. Med. J., 2, 1947, P.719 - 723, (as cited by Lloyd, 1975).

Djupesland G., Flottorp.G. & Winther.F.O. "Size and duration of acoustical elicited impedance changes in man," Acts. Otolaryng. Suppl. 224, 1967, p.220 - 227, (as cited by Hall, 1980).

Djupesland.G. "The Acoustic Reflex," *Clinical Impedance Audiometry*, eds. J.Jerger & J.L.Northern, Massachussetts, American Electromedics, Corporation, 1980.

Eggermont.J.J. "Basic principles for electro cochleography, " *Acts Otolaryng. Suppl.*, 316, 1974, p.7 - 16.

Eggermont.J.J. & Odenthal.D.W. "Methods in electro cochleo graphy," Acta otolaryng. Suppl. 316, 1974a, p.17- 24

Eggermont.J.J. & Odenthal.D.W. "Action potentials & summating potentials in the normal human cochlea," *Acts Otolaryng. Suppl*. 316, 1974b, p. 39 - 61.

Eisenberg.R.B. "Cardio tachometry," *physiological measures of the Audiovestibular system*, ed. L.J.Bradford, New York, Academic Press, Inc, 1975.

Eisenberg.R.B. "Auditory competence in early life : The roots of communicative Behaviour," Baltimore, University park press, 1976.

Evans.T.R. & Deathrage.B.H. "The effect of frequency on the auditory evoked response," *psychonom. Sci*. 15, 1969, pp. 95 - 96 (as cited by Hood, 1975).

Ewertsen.H.W. & Nielsen.S.S. "Food Audiometry," *Acta Otolarvngol*., 69, 1970, pp. 457 - 458.

Feldman.A. "Tympanometry - procedures, interpretations and variables," Acoustic impedance and Admittance, the measurement of Middle Ear function, eds. A.Feldman & Wilber , Baltimore, The Williams & Wilkins Company, 1976.

Feldman.A.S. "Acoustic impedance - Admittance battery," Handbook or clinical Audiology, ed. J.Katz, Baltimore, The Williams & Wilkins Company, 1978.

Fere.C. "Note surdes modifications de la resistance, electrique sans 1 influence des excitations sensorilles et des emotions." C.R.Soc. Biol. 5, 1888, pp.217, (as cited by Knox, 1978).

Fisch.U. & Vonschulthess.G. "Electromyographic studies on the human stapedius muscle," Acta otolaryngol, 56, 1963, pp.287 - 297 (as cited by Hall, 1980).

Flottorp.G., Djupesland.G. & Winther.F. "The Acoustic stapedius reflex in relation to critical band width," J. Acoust. Soc. Am. 49, 1971, pp. 457 - 461.

Fria et al. "Ipsilateral acoustic reflex stimulation in normal and sensorineural impaired ears : a preliminary report," Can. J. Otolaryngol., 4, 1975, PP. 695 - 703, (as cited by Feldman, 1978).

Fromm.B., Nylen.C.O. & Zotterman.Y. "Studies in the mechanisms of the Wever and Bray effect," Acta otolaryngol., 22, 1935, PP. 477-483 (as cited by Glattke, 1978).

Fujikawa S.M. & Weber B.A. "Effects of increased stimulus rate on BER Audiometry as a function of age," J.Am. Aud. Soc. 3, 1977, pp.147 - 150.

Galambos.R. "Personal communication," 1976, (as cited by Skinner, 1978).

Geisler.C.D., Frishkopf.L.S. & Rosenblith.W.A. "Extra cranial responses to acoustic clicks in man," Science. 128, 1958, pp. 1210 - 1211, (as cited by Skinner, 1978).

Geisler.C.D. "Average responses to clicks in man recorded scalp electrodes," Technical Report, 380, Research laboratory of electronics, MIT, Nov. 4, 1960, Ann. N.Y, Acad, Sci., 112, 1964, pp.218 - 219, (as cited by Skinner, 1978).

Gelfand.S.A. & Piper.N. "Acoustic reflex thresholds in young and elderly subjects with normal hearing," J.Acoust. Soc. Am.. 69, 1981, pp.295 - 297.

Gerber.S.E., Mula C.A. & Swain.B.J. "Idio syncratic cardio vascular response of human neonates to acoustic stimuli." J. Am. Aud. Soc., 1, 1976, pp.185 - 191.

Gerhardt, et al. "Z Larvnsgol. Rhinol. Otol., 46, 1967, PP. 235, (as cited by Bradford, 1975).

Gibbs.F.A. & Gibbs.E.L. "Atlas of electroencephalography, vol.1: Methodology and Controls," Addison, Wesley, Campridge, Mass, 1951, (as cited by Price, 1975).

Glattke.T. "Personal communication," 1975, (as cited by Skinner, 1978).

Glattke.T.J. "Electro cochleography," Handbook of clinical Audiology ed. J.Katz, Baltimore, The Williams and Wilkins Company, 1978.

Glorig.A. "Audiometry - principles and practices," Baltimore, Williams & Williams Co, 1968.

Goldstein.R. "Early components of the AER" proceedings of of a conference on the young Deaf child in Toronto, Canada, October, 8 - 9, 1964, Acts. Otolaryng. Suppl., 206, 1965, pp. 127 - 128 (as cited by Skinner, 1978).

Goldstein.M.H. Jr. and Kiang.N.Y. "Synchrony of neural activity in electric responses evoked by transient acoustic stimuli," J.Acoust.Soc. Am., 30, 1958, pp. 107 - 114, (as cited by Skinner, 1978).

Goldstein.R. & Rodman.L.B. "Early components of averaged evoked responses to rapidly repeated auditory stimuli," J.Speech Hear. Res., 12, 1967, p.697-705.

Goldstein.R. "Use of averaged electro encephalic response (AER) in evaluating central auditory function" paper presented to Annual convention of the American Speech and Hearing Association, Chicago, November, 12, 1969 (as cited by Skinner, 1978).

Goodman.A. "Reference Zero levels for puretone audiometer," ASHA, 7, 1965, pp. 262 - 263.

Graham.F,K. & Cliffton.R.K. "Heart Rate change as a component of the orienting response," Psychol. Bull. 65, 1966, pp.305 - 320 (as cited by Gerber et al., 1976).

Graham.F.K., Cliffton.R.K. & Halton.H.M. "Habituation of heart rate response to repeated auditory stimulation during the first five days of life," Child Dey. 39, 1968, pp. 35 - 42 (as cited by Gerber et al., 1976).

Green.D.S. "Puretone Air Conduction testing," Handbook of Clinical Audiology. ed. J.Katz, Baltimore, The Williams & Wilkins Company, 1978.

Griffiths.C. "Instrumentation and Implementation of cardiac audiometry from 0 to 24 months," Proceedings of the International congress on Education of the Deaf, Tokyo, Japan, 1975, (as cited by Suzuki, 1981).

Hall.J.W. "Predicting hearing level from the Acoustic reflex: A comparison of 3 methods," Arch. Otolaryngol. 104, 1978, pp.601 - 605.

Hall.J.W. "Effects of age and sex on static compliance," Arch. otolaryngol. 105, 1979, pp. 153 - 156.

Hall.J.W. and Weaver.T. "Impedance audiometry in a young population : the effect of age, sex and tympanogram abnormalities," J.Otolaryngol., 8, 1979, pp.210 - 222 (as cited by Hall,1980).

Hall.J.W. "Predicting hearing loss from the Acoustic Reflex," Clinical impedance Audiometry, eds. J.Jerger & J.L.Northers, Massachussets, American Electromedics Coorporation, 1980.

Hall.J.W. & Bleakney.M.E. "The effect of minor admittance abnormalities onialse positive errors in the prediction of hearing by the acoustic reflex," The Reflex. Mrach, 1981a.

Hall.J.W. & Bleakney.M.E. "Hearing loss prediction by the Acoustic reflex : Comparison of seven methods," Ear and Hearing. 2, 1981b, p.157.

Handler.S.D. & Margolis.R.H. "Predicting hearing loss from stapedius reflex thresholds in patients with sensorineural loss," Trans. Am. Acad. Opthalmol. Otolaryngol. 84, 1977, pp. 425 - 431, (as cited by Hall, 1980).

Hawes.M. and Greenberg.H.J. "Slow responses (SN_{10}) to tone pips in normally hearing new borns and adults," Audiology, 20, 1981, pp. 113 - 122.

Hacox.K. & Galambos.R., "Brain stem auditory evoked responses in human infants and adults," Arch otolaryngol. 99, 1974, PP. 30 - 33.

Hacox.K., Squire.N. & Galambos.R., "Brain stem auditory evoked responses in man : 1. Effect of stimulus rise-fall time and duration," J. Acoust. Soc. Am., 60, 1976, pp. 1187 - 1192.

Henderson.D. "Behavioural and human evoked response thresholds as a function of frequency," J.Speech Hear. Res. 15, 1972, pp. 390 - 394.

Heron.T.G. & Jacobs.R. "A physiological response of the neonate toauditory stimulation," Int. Audiol. 7, 1968, pp. 41 - 47.

Heron.T.G. & Jacobs.R. "Respiratory curve responses of the neonate to auditory stimulation," Audiology. 8, 1969, pp. 77 - 83.

Himelfarb et al. "Acoustic Reflex Evaluation in Neonates," Early diagnosis of hearing loss, eds. S.E.Gerber & G.T.Mencher New York, Grune & Stratton Inc., 1978.

Hogan.D.D. "Autonomic correlates of Audition," Auditory Assessment of the Difficult to test, eds. R.T.Fulton & Lloyd., Baltimore, The Williams & Wilkins Company, 1975.

Hood.D.C. "Central effects on the Human peripheral Auditory mechanism," Doctoral dissertation, Northwestern university, Evanston, Illinois, 1971 (as cited by Hood, 1975).

Hood.D.C. "Evoked cortical response Audiometry," Physiological measures of Audiovestibular system, Ed. L.J.Bradford, New York, Academic press Inc., 1975.

Hung.I. & Dallos.P. "Study of the Acoustic Reflex in human beings, 1. Dynamic characteristics," J.Acoust. Soc. Am. 52, 1972, pp. 1168 - 1180.

Irwin et al., "Experience with conditioned GSR in a group of mentally retarded individuals," Training School Bulletin, 54, 1957, pp.26 - 31, (as cited by Hogan 1975

Jansen.G. "Effects of noise on the physiological state," ASHA, 4, 1969, pp. 89 - 98.

Jasienska et al. "Examination of hearing in newborns by EEG, Arch otolaryngol. 86, 1967, pp. 650 - 653.

Jespen.O. "The threshold of the reflexes of the intratympanic muscles in a normal material examined by means of the impedance method," Acta otolaryngol, 39, 1951, pp. 406 - 408, (as cited by Feldman, 1978).

Jespen.O. "Middle ear muscles reflexes in man," Modern Developments in Audiology, ed. J.Jerger, New York, Academic press, 1966.

Jerger.J. "Clinical experience with Impedance audiometry," Arch.otolaryngol., 92, 1970, pp. 314 - 324.

Jerger.J. , Jerger.S. & Mauldin.L. "Studies in Impedance Audiometry : I Normal and sensorineural loss ears," Arch otolaryngol. 96, 1972, pp. 513 - 523.

Jerger.J. "Differential loudness summation test," Presented at the second International symposium on impedance measurement, Houston, September, 13 to 14, 1973, (as cited by Keith, 1977).

Jerger.J. Burney.P., Mauldin.L. & Crump.B. "Predicting hearing loss from the acoustic reflex," J. Speech Hear. Disord. 39, 1974, PP.11 - 22.

Jerger.J. "Diagnostic use of Impedance Measures," Handbook of clinical Impedance Audiometry. ed. J.Jerger, New York, American Electromedics, Corporation, 1975.

Jerger.J. & Hayes.D. "The cross check principle in pediatric audiometry," Arch otolaryngol., 102, 1976, pp.614-620.

Jerger.J., Mauldin.L. & Lewis.N. "Temporal summation of the Acoustic reflex," Audioloav. 16, 1977, pp. 177 - 200.

Jerger.J., Hayes.D. & Anthony.L. "Effect of age on prediction of sensorineural hearing level from the acoustic reflex" Arch otolaryngol. 104, 1978, pp. 393 - 394.

Jerger.J. et al "Factors influencing the prediction of hearing level from the acoustic reflex," Monographs in contemporary Audiology. 1, 1978, pp.1 - 21.

Jerger.J. & Mauldin.L. "Prediction of sensorineural hearing level from Brain stem evoked response," Arch. Otolarngol., 104, 1978, p.456.

Jerger.J. "Comments on the effect of aging on stapedius reflex threshold," J.Acoust. Soc. Am., 66, 1979, p.908.

Jerger.J, Hayes.D. & Jordan.C. "Clinical experience with Auditory Brainstem Response Audiometry in pediatric Assessment," Ear and Hearing, 1, 1980, pp.19 - 25.

Jewett.D.L., Romana.M.N. & Williston.J.S. "Human auditory evoked potentials possible brain stem components detected on scalp" Science, 167, 1970, pp.1517 - 1518, (as cited by Hood, 1975).

Jewett.D.L. & Williston.J.S. "Auditory evoked fop fields averaged from scalp of humans" Brain.. 94, 1971, pp.681 - 696 (as cited by Skinner, 1$78).

Johnsen et al., "The white noise middle ear muscle reflex threshold in patients with sensorineural hearing impairment," Scand. Audiol. 5, 1976, pp.131-135.

Kankkunen.A. & Liden.G. "Respiration audiometry" Scand. Audiol. 6, 1977, pp.81 - 86.

Kaplan.H., Gilmans. & Dirks.D. "Properties of Acoustic reflex adaptation," Ann. Otol. Rhinol. Laryngol. 86, 1977, pp. 348 - 356.

Karlovich.R. & Goldstein.R. "The amplitude of AER as a function of stimulus rate and number" Received in a paper presented to the annual convention of the American Speech and Hearing Association, Chicago, November, 14, 1969 (as cited by Skinner, 1978).

Keidel.W.D. & Spreng.M. "Neuro physiological evidence for the stevens power function in man," J. Acoust. Soc. Am. 38, 1965, pp. 191 - 195, (as cited by Skinner, 1978).

Keidel.W.D. "The use of quick correlators in electro cochleo graphy," Rev. Larvngol.otol. Rhinol. Suppl. 92, 1971, pp. 709 - 721 (as cited by Glattke, 1978).

Keith.R.W. "An evaluation of predicting hearing loss from the Acoustic Reflex," Arch, otolaryngol. 103, 1977, pp.419 424.

Kiang. et al. "Post auricular electric response to acoustic stimuli in humans" Q. progr. Report (MIT). 2, 1963, pp.218-225, (as cited by Skinner, 1978).

Knox.A.W. "Electro dermal Audiometry" Handbook of clinical Audiology. ed. J.Katz, Baltimore, The Williams & Wilkins Company, 1978.

Kodman.et al "A psychogalvanic skin response audiometry with severe mentally retarded children," American Journal of Mental deficiency. 64, 1959, pp. 131 - 136, (as cited by Hogan, 1975).

Kumpf.W. and Landwehr.F.J., Montsschr ohrenheilkd Laryngorhinol. 104, 1970, p.535 (as cited by Bradford,1975).

Lamb.L.E. "Acoustic impedance measurement," Auditory assessment of the Difficult to Test, eds. R.T.Fulton & L.L.Lloyd, Baltimore, The Williams & Wilkins Company, 1975.

Lane.R. & Kupperman.G. "The effects of rise time and duration of puretones on the amplitude latency and general identifiability of the early components of the AER" Received in a paper presented by R.Goldstein to the Annual Convention of the American Speech and Hearing Association, Chicago, November, 14, 1969, (as cited by Skinner, 1978).

Laukli.E.& Mair.L.W.S. "Early auditory evoked response - spectral content" Audiology 20, 1981, pp.453 - 463.

Lehnhardt.E. "Arch. Klin. Exp. Ohren Nasen Kehlkopf heilkd, 182, 1963, p.623, (as cited by Bradford, 1975).

Leibman.J. & Graham.J.T. "Changes in parameters of averaged auditory evoked potentials related to number of data samples analyzed," J.Speech Hear. Res. 10, 1967, pp. 782 - 785.

Lempert J., Wever E.G. & Lawrence M. "The cochleogram and its clinical applications" a preliminary report Arch Otnlaryngol 45,1947,PP.6i-67(as cited by Northern & Downs, 1978).

Lempert J. et al."The cochleogram and its clinical applications; concluding observations". <u>Arch Otolaryngol</u> 51, 1950 PP.307-31l(as cited by Northern & Downs, 1978).

Lentz W.E. & McCandless G.A. "Averaged electro encephalic audiometry in infants". <u>J.Speech Hear Disord</u> 36, 1971, PP.19-28.

Levander S., Lindberg L. & Schalling D. "Habituation of the digital vasoconstrictive orienting response" <u>Journa</u>l of <u>experimental</u> p<u>sychology,</u> 102,1974, PP.700-705.

Light M.H., Feuel C.J. & Sandberg R.K "The effects of relation on the impedance test battery <u>Arch.Otolaryngol.</u> 103,1977 Pp.235-237.

Lilly D.J. "Some properties of the acoustic reflex in man" <u>J.Acoust.Soc.AM</u>. 36,1964,P.2007.

Lilly D.J. "Prediction of points on the audiogram from acoustic reflex data". Read before the American speech & Hearing Association convention Chicago, Illinois,November,4,1977(as cited by Hall & Bleakney 1981).

Lindsley D.B. "Emotion" Handbook of experimental psychology, ed.S.S.Steven, New York, Johnwileyand Sons,1963 (as cited by knox,1978).

Lipton E.L., Steinschneider A. & Richmond J.B.Autonomic function in the neonate". Psychosom Med.22 1960 PP.57-65 (as cited by Gerber et al., 1976)

Lloyd. L.L. "Puretone audiometry "Auditory Assessment of the Difficult-to-Test eds.R.T.Fulton and L.L.Lloyd, Baltimore,the Williams and Wilking company 1975.

Loomis A.L., Harvey P.N. & Hobart G. "Distribution of disturbance patterns in the human electroencephalogram with special reference to sleep". J.Neurophysiol. 1,1938,PP413-430(as cited by Skinner,1978).

Lowell et al "Temporal evannation. A new approach to diagnostic Audiology "J.Speech Hear Disord 25,1960,Pp.340-345.

Lowell E. "Early components of the AERin the hearing of young children" proceedings of a conference on the young deaf child in Toronto, Canada, October 8-9,1964. (as cited Skinner,1978).

Lowell M.O.,Lowell E.L. & Good hill V. "Evoked response Audiometry with infants. A longitudinal study"., Audiology & Hearing education 1,1975,PP.32-37.

Magerison J.H., St.John-Loc P. and Binne C.D. "Electro encephalography" Manual of Psycho physiological methods eds. P.A.Venables & I.Martin,New York. Johnwiley & Sons,1967(as cited by Reneau & Hnatiow,1975).

Mahler K.F. & Wagner F. "Monatsschr ohrenheilkd Laryngorhinol, 101,1967 P.512 (as cited by Bradford,1975).

Margolis R.H. & Popelka G.R. "Static and dynamic acoustic impedance measurements in infant ears" J.Speech Hear Res.. 18, 1975 P.435-443.

Margolis R.H. & Fox C.M "A comparison of three methods of predicting hearing loss from acoustic reflex thresholds" J.Speech Hear Res. 20, 1977 PP.241-253.

Margolis et al. "The effects of age on Acoustic reflex thresholds in normal hearing subjects". Hearing Assessment with the Acoustic Reflex ed. Popelka G.R., New York, Grune & Stratton, 1981.

Margolis et al. "The Bivariate plotting procedure for Hearing Assessment with Acoustic Reflex Threshold measures" Hearing Assessment with the Acoustic reflex ed. popelka G.R., New York, Grune & Stratton,1981.

Martin M.C. "Critical bands in sensorineural hearing/Loss. Scand. Audiol 3, 1974, Pp.133-140.

Mast T. "Muscular versus cerebral sources for the short latency human evoked responses to clicks" physiologist, 6, 1963 P.229 (as cited by skinner,1978).

Mast T. "Short latency human evoked responses to clicks." J.Appl. physiol. 20, 1965,Pp.725-730(as reported by Skinner,1978)

McCandless G.A. & Best L. "Evoked responses to auditory stimuli, in man using a summing computer" J.Speech Hear Res. 7,1966a PP.193-202.

McCandless G.A. & Best L. "Summed evoked responses using puretone stimuli" J.speech Hear Res 9, 1966b,Pp. 266-272.

McCandless G.A. "Clinical application of evoked response audiometry". J.Speech Hear Res.10,1967,Pp.468-478.

Mc Randle C, Smith M. & Goldstein R. "Early averaged EER to clicks in neonates" Ann Otol Rhinol Laryngol. 83, 1974, Pp.695-701.

Mendel M. & Goldstein R. "Stability of the early components of the averaged electroencephalic response". J.Speech Hear.Res. 12,1969,Pp.351-361.

Mendel M. "Personal communication', 1973 (as cited by Hood,1975)

Metz.O "The acoustic impedance measured on normal and pathological ears" Acta otolaryng Suppl. 63? 1946 (as cited by Silman & Gelfand, 1979).

Metz.O "Studies on the contraction of the tympanic muscles as indicated by changes in the impedance of the ear "Acta otolaryngol. 39,1951,Pp 397-405 (as cited by Wilson & McBride, 1978)

Meunier T.J. Jr. & May J.C. "Simultaneous Averaging of Acoustic nerve and brainstem auditory potentials in humans" ASHA 18, 1976 P.658.

Miller R., Davies C.B. & Gibson W.P.R. " using the acoustic reflex to predict the puretone threshold" British Journal of Audiology. 10,1976 Pp.51-54.

Misrahy et al. Ameri.J. Physiol. 194,1958 P.396.(as cited by simmons & Glattke, 1975).

Mojdehi. et al. "Minimum intensities of white noise which produce the vasomotor response". British Journal of Audiology. 14, 1980, P.132.

Mokotoff B., Schulman Galambos C. & Galambos R. "Brainstem auditory evoked responses in children." Arch, otolaryngol. 103,1977,Pp.38-43.

Moller A.R.,"Intra/aural muscle contraction in Man examined by measuring Acoustic impedance of the ear". Laryngoscope, 68, 1958 Pp.48-62. (as cited by Wilson & McBride 1978)

Moller A.R. "The sensitivity of contraction of the tympanic muscles in man" Ann otol Rhonol Laryngol. 71, 1962,Pp 86-92 (as cited by Feldman,1978).

Northern J.L. & Downs M.P. "Hearing in children" Baltimore, The Williams and Wilkins company,1978.

Onishi S. & Davis H. "Effects of duration and rise time on tone bursts on evoked potentials". J.Acoust Soc.Am. 44, 1968, Pp.582-591.

Parving A., Elberling C. & Salomon G. "EcochG and psychoacoustic tests compared in identification of hearing loss in young children". Audiology 20, 1981,Pp.365-38l.

Peake W.T. & Kiang N.Y.S. "Cochlear responses to condensation and rarefaction clicks" Biophys.J. 2, 1962, Pp 23-34 (as cited by Glattke,1978).

Peterson J.L. & Liden G. "Some static characterstics of the stapedial muscle reflex". Audiology 11, 1972, Pp.97-114.

Picton et al "Human auditory evoked potentials; I. evaluation of components" Electroencephalogl Clin. Neurophysiol 36, 1974, Pp.179-190 (as cited by Skinner,1978)

Poole R., Goetzinger C. & Rousey C. "A study of the effects of Auditory stimuli on Respiration". Acta Oto. laryngol. 61,1966, P.143 (as cited by Bradford, 1975)

Popelka G.R. "First attempts at hearing Assessment with Acoustic Reflex measures". Hearing Assessment with the Acoustic Reflex ed. popelka G.R., New York, Gurne & Stratton Inc., 1981.

Porter T. "Normative Otoadmittance values for three populations" J.Aud. Res 12, 1972 P.1(as cited by Feldman,1976).

Portmann M., Lebert G. and Aran J.M. "Potentials cochlearies obtenus chez 1 nomine en dehors de toute intervention chirugicale, Note preliminaire" Rev larygol otol. Rhinol, 88, 1967 Pp.157-164 (as cited by Glattke, 1978)

Portman M. & Aran J.M. "Electro cochleography" Laryngoscope, 81, 1971, Pp.899-901.

Portman M. & Aran J.M. "Relations entre pattern electro cochleographicque et pathologie retro labyrinthique". Actatolaryngol 73,1972,Pp.190-196,(as cited by Skinner,1978).

Portman M., Aran J.M. & lagourgue P. "Testing for recruitment by electrocochleography, preliminary results". Ann Otol Rhinol laryngol 82,1973,Pp.36-43.

Price L.L. & Goldstein R. "Averaged evoked responses for measuring auditory sensitivity "J.Speech Hear Disold. 31, 1966, Pp.248-256.

Price L.L. "Evoked response Audiometry "Auditory Assessment of the difficult to test eds. R.T.Fulton & L.L.Lloyel Baltimore, the Williams & Wilkins company,1975.

Price L.L "Evoked response Audiometry: Some consideration" J.Speech Hear Disord. 34, 1969 Pp.137-141.

Raghunathan M. "An objective method of validating puretone thresholds" Unpublished Master's Dissertation, University of Mysore, 1977.

Rapin I. & Bergman M. "Auditory evoked responses in concertain diagnosis" Arch.Otoloryng 90,1964, Pp. 307-314.

Rapin I & Graziani L. "Auditory evoked responses in normal brain damaged and deaf infants". Neurology. 17, 1967,Pp.881-894 (as cited by price, 1975)

Rapin I., Graziani L.J. & Lyttle M. "summated auditory evoked response for audiometry, experience in 51 children with congenital Rubells." Int.Audiol 8, 1969, Pp. 371-376.

Ravishankar shukla "A comparative study on Reflex amptitude and decay time for contralateral and ipsilateral stimulation at different frequencies and at different sensation level in normals". Unpublished Master's Dissertation University of Mysore,1980.

Reneau J.P. & Hnatiow G.Z. "Evoked response Audiometry A topical and Historical Review" Baltimore, University park press, 1975.

Rizzo S. & Greenberg H.J. "predicting hearing loss from the acoustic reflex" presented before 50th meeting of the Acoustical society of America, Boston, Massachusetts June 12, 1979.(as cited by Hall & Bleakney,1981)

Robertson E.D., Peterson J.C. & Lamb L.E. "Relative impedance measurements in young children" Arch Otolaryngol 88, 1968, Pp.162-188.

Ronis B.J. "Chdhlear Potentials in otosclerosis" Larynyoscope, 76, 1966, Pp.212-231.

Rose D.E. & Ruhm H.B. "Some characteristics of the peak latency and amplitude of acoustically evoked response". J.Speech Hear Res. 9, 1966, Pp.412-422.

Rose et al "phase locked response to low frequency tones in single auditory nerve fibres of squirrel monkey" J.Neurophysiol 30,1967, Pp.769-793, (as cited by Berlin, 1978)

Rose D.E. & Rittmanic P.A. "Evoked Response tests with mentally retarded" Arch. Otolaryngol 88, 1968, Pp.495-498.

Rosenau H. "Beitrag Zur reflexaudiometric". Arch.klin Exp. ohren Nasen Kehlkopfheikd.178. 1961. P.476(as cited by Bradford, 1975).

Rosenau H. "Sleep Hearing Test. A method of testing hearing in infants". Z.laryngol Rhinol. Otol 41, 1962a, Pp.194-208 (as cited by Bradford, 1975)

Rosenau H. "Moglichkeiten and Grenzender Horprufung im fruhen kindesalter" Paediat Grenzgeb. 1,1962b. P.27(as cited by Bradford, 1975)

Rowe J.M. "The Brainstem Auditory evoked response in neurological disease , A review" Ear and Hearing 2,1981, PP.41-50.

Ruben R.J. "Cochlear potentials as a diagnostic test in deafness "Sensorineural hearing processes and disorders ed. A.B.Graham, Boston, Little Brown & Co., 1967.(as cited by Simmons & Glattke,1975).

Ruhm H., Walker E. & Flanig in H. "Acoustically evoked potentials in man; mediation of early components" Laryngoscope, 77, 1967, Pp.806-822(as cited by Skinner,1978).

Salamy A., McKean C, & Buda F. "Maturational changes in auditory transmission as reflected in human brainstem potentials". Bran Res. 96, 1976,Pp.361-366 (as cited by Northern and Downs,1978)

Scharf B. & Hellman R.P. "Model of loudness summation applied to impaired ears" J.Acoust Soc. Am 40, 1966,Pp.71-78 (as cited by Bonding, 1979)

Schmidt P.H. and Spoor A. " The place of electrocochleography in clinical audiometry". Acta Otolaryng Suppl. 316, 1974, Pp.5-6.

Schulman Galambos C. & Galambos R. "Brainstem auditory evoked responses in premature infants" J.Speech Hear Res. 18, 1975,Pp.456-465.

Schulman C.A. & Wade G. "The use of heart rate in audiological evaluation of nonverbal children 11. clinical trials on an infant population" Neuropediatric, 2, 1970, PP.197-205 (as cited by smith & Borton,1980)

Schulman C.A. & Kreiter R. "The contribution of heart rate audiometry in the early identification of hearing impairment" paper presented to the Annual meeting of californea speech & Hearing Association, LOS Angeler, 1971.(as cited by Gerber et al 1976)

Schwartz D.M. and Sanders J.W. "critical bandwidth & sensitivity prediction in Acoustic stapedial Reflex" J.Speech Hear Disord 41, 1976, Pp.244-255.

Scott J. "Simplified instrumentation for AER" proceedings of a conference on the young deaf child held at Toronto Canada, October,8-9, 1964.(as cited by Skinner,1978)

Scottwood K. "Terminology and Nomenclature". Handbook of Speech pathology and Audiology ed. L.E.Travis, New Jersey, prenlice-Hall Inc., 1971.

Sesterhenn G. & Breuninger H. "Determination of hearing threshold for single frequencies from acoustic reflex" Audiology 16, 1977,Pp.201-214.

Sheehy J.L. & Hunghes R.L "ABC's of impedance audiometry" Laryngol scope. 84, 1974,Pp.1935-1949.

Shimizu H. "Editorial clinical use of Auditory Brainstem response: Issues and Answers" Ear and Heading 2, 1981, Pp.3-4.

Siemarzko-Zak J."Plethysmography as an objective method of audiometry" Acta Oto Laryngol 82,1976,Pp.388-393.

Silman S. "The effects of aging on the stapeding reflex threshold J.Acoust Soc. Am 66,1979a, Pp.735-738.

Silman S. "The acoustic reflex, aging and distortion product A Reply to Jerger" J.Acoust Soc Am. 66,1979b, Pp.909-910.

Silman S. & Gelfand S.A. "prediction of hearing level from Acoustic Reflex thresholds in persons with high frequency hearing losses. J.Speech Hear Res. 22, 1979, Pp.697-707.

Simmons F.B. and Beatty D.L. "The significance of round window recorded cochlear potentials in hearing". Am Oto rhinolaryngol 71, 1962, Pp. 767-801(as cited by Glattke, 1978).

Simmons F.B. & Glattke T.J. "Electrocochleography" physiological measures of the Audiovestibular system ed. L.J. Bradford, New York, Academic press Inc., 1975.

Skinner P.H. and Jones H. "Effects of signal duration and rise time on the auditory evoked potential". J.Speech Hear Res. 11,1968, Pp.301-306.

Skinner P.H. and Antinoro F. "Auditory evoked responses in normal hearing adults and children before and during sedation". J.Speech Hear Res. 12, 1969a, Pp.394-401.

Skinner P.H. and Antinoro F. "The effects of signal parameters on the auditory evoked response" paper presented to 1969 congress of Oto rhino laryngology, Mexico, Federal district, Excerpta Medica, 189, 1969b, Pp.43-44 (as cited by Skinner, 1978).

Skinner P.H. & Antinolo F. "The effects of risetime and signal duration on the early components of the auditory evoked cortical response" submitted for publication, 1970(as cited by Skinner, 1978)

Skinner P.H. "Unpublished data", 1973(as cited by Skinner, 1978).

Skinner P.H. "Electroencephalic Response Audiometry" Handbook of clinical Audiology ed. J.Katz, Baltimore, The Williams & Wilkins company, 1978.

Smith C.R. & Borton T.E. "Heart rate response Audiometry bases clinical techniques, Limitations" Ear and Hearing. 1, 1980, Pp.121-125.

Sohmer H. and Feinmesser L. "Cochlear action potentials recorded from the external ear in man" Ann.Otol rhinol laryngol 76, 1967,PP.427-435(as cited by Glattke, 1978).

Sohmer H. and Feinmesser M. "Cochlear and cortical audiometry conveniently recorded in the same subject" Israel T.Medical Sci. 6, 1970, Pp.219-223(as cited by Berlin, 1978).

Sohmer H. & Feinmesser.M. "Routine use of electrocochleography (oochlear audiometry) on human subjects" Audiology 12, 1973, PP.167 - 173.

Sokolov E.N. "Perception and the conditioned reflex" New York The MacMillan Co., 1963.(as cited by Smith & Borton, 1980)

Sokolov E.N. "The modeling properties of the nervous system". A Handbook of contempolary Soviet Psychology eds. M.Cole & I.Maltzman, New York, Basic Books,1969.

Spradlin J., Locke B. & Fulton R. "conditioning and audiological assessment". Audiometrv for the retarded eds. R.T. Fulton & L.L.Lloyd, Baltimore, The Williams & WiMng company, 1969.

Stapells D.R. and Picton T.W. "Technical aspects of brainstem evoked potential Audiometry using tones", Ear and Hearing, 2, 1981, Pp.20-29.

Starr A. and Hamilton A.E. "Correlation between confirmed sites of neurological lesions and abnormalities of far field auditory brainstem responses" Electroencephalogr. Clin. Neurophysiol 41,1976, Pp.595-608.(as cited by Northern & Downs, 1978)

Stein L.K., Ozdamar O. & Schnabel M. "Auditory brainstem responses (ABR) with suspected deafblind children" Ear and Hearing. 2, 1981, Pp.30-40.

Steinschneider A., Lipton E.L. & Richmond J.B. "Auditory sensitivity in the infant effect of intensity on cardiac and motor responsivity". Child development. 37,1966, Pp.233-252.(as cited by Hogan, 1975)

Stelmachowicz P. Taylor D. & Bowling A "comparison of two techniques for predicting hearing loss" presented at 1974 convention of the American Speech & Hearing Association, Lasvegar, November,8,1974(as cited by Keith, 1977)

Stillman R.D., Moushegian G. and Rupert A.L. "Early tone evoked responses in normal and hearing impaired subjects". Audiology. 15, 1976, Pp.10-22.

Stubbs E.M. "The effect of the factors of duration intensity and pitch of sound stimuli on the response of Newborn infants". Studies of Infant Behavior ed. G.B. Stoddard, Univ. IOWA, Stud. in child Welfare, 9, 1934, Pp.75-135(as cited by Bradford, 1975)

Suzuki T. & Ogiba Y. "Conditioned orientation reflex audiometry" Arch. Otolaryngol 74, 1961,Pp.192-198 (as cited by Lloyd,1975)

Suzuki T., Karnijo Y. "Cochleo pupillar response as a method for objective audiometry" Medical Journal of Shinshu university, 6, 1961,P 181 (as cited by Hogan,1975)

Suzuki T., Kamijo Y. & Sadaki H. "Cochleo pupillar response during sleep, An objective test for recruitment for young children" Practice Oto Rhinolaryngologica 26, 1964, Pp 248-257(as cited by Hogan,1975)

Suzuki T., Kamijo Y. & Kiruchi W. "Auditory test of newborn infants" Ann Otol Rhinol Laryngol 73, 1964,P.914 (as cited by Bradford, 1975)

Suzuki T., Tanahay and Arayama T. "Detection of hearing disorders in children under three years of age. "Int.Audiol 2, 1966, Pp.74-76 (as cited by Reneau & Hnatiow, 1975)

Suzuki T. and origuchi K. "Averaged evoked response audiometry (ERA) in young children during sleep" Acta otolaryng Suppl. 252, 1969, Pp.19-28.

Suzuki T. "Use of Heart rate response for the assessment of hearing in infants" Ann. Otol Rhinol laryngol 87, 1978, Pp. 243-247.

Suzuki T., Taguchi K. and Yoda M. "Reliability of show vertex response Audiometry in young children with sensorinaural loss". Audiology. 18, 1979, Pp.119-124.

Suzuki T. and Horiuchi K. "Rise time of puretone stimuli in brainstem response audiometry" Audiology 20, 1981, P.101.

Taguchi et al "Evoked response audiometry in newborn infants" Acta Otolaryng Suppl. 252, 1969, Pp.5-17

Teas D.C. Eldredge D. & Davis H. "Cochlear responses to acoustic transients, an interpretation of whole nerve action potentials" J.Acoust Soc. AM. 34, 1962, Pp. 1438-1459 (as cited by simmons & Glattke, 1975)

Teel et al "Thresholds of hearing by Respiration using a polygraph". Arch Otolaryngol. 86, 1967, Pp.172-174

Terkildsen K. "An evaluation of perceptive hearing loss in children based on recruitment determinations" Acts Otolaryngol 51, 1960, Pp.476-484 (as cited by Tsappis, 1977)

Terkildsen K. and Osterhammel P. "The influence of reference electrode position on recordings of the auditory brainstem responses". Ear and Hearing 2, 1981, Pp. 9-14.

Toriyama M., Matsuzaki T. & Hayaski H. "Some observations on auditory average response in man". Int. Audiol 5, 1966, Pp. 234-237(as cited by Reneau & Hnatiow,1975)

Tsappis A. "Prediction of Auditory sensitivity" Arch.Otolaryngol 103, 1977 Pp. 322-325.

Turkewitz G., Birch H.G. & Cooper K.K. "Patterns of response to different auditory stimuli in the human new born." Dev. Med. Child. Neurol. 14, 1972,Pp487-491(as cited by Gerber et al, 1976)

Unger M. "Objective measurement of hearing", Archi Otolaryngol 29, 1939, Pp.621-623(as cited by Hogan, 1975)

Vanwagoner R.S. & Goodwine S. "Clinical impressions of acoustic reflex measures in an adult population" Arch. Otolaryngol. 103,1977,Pp.582-584.

Vasilev, Diskalenko,V. & Plepis 0. "On the objective audiometry by the method of Rheography". Zh.Ushn.NOS Gorl Boleen. 1, 1975,Pp. 5-8, Mojdehi et al, 1980)

Ventry I.M. "Conditioned Galvanic Skin response audiometry physiological measures of the Audio vestibular system ed. L.J. Bradford, New York, Academic press Inc.,1975.

Veraguth I. "Das Psycho galvanische Reflex phanomen" Berlin, Karger, l960(as cited by Knox, 1978)

Von Bekesy G. "Experiments in hearing", New York, Mc.Graw-Hill 1960.

Wagner H. "Zur Methodik der schlafbeschallung" Zeitschrift fen laryngologic, Rhinoloaic, Otologic und Ihre Grezgebiete. 42, 1963 Pp. 139-146. (as cited by Bradford,1975)

Walter H. "The convergence and interaction of visual, auditory and tactile responses in human non specific cortex" Ann. N.Y.Acad. Sci.,112, 1964, Pp.320-361 (as cited

by Skinner 1978.

Wasserman et al "A versatile simultaneous multifinger photocell plethysmography system for use in clinical and occupational Medicine." Medical instrumentation, 13, 1979, Pp.393-401 (as cited by Mojdehi et al 1980).

Weatherby L.A. & Bennett M.J. "The neonatal acoustic reflex," Scand. Audiol 9, 1980,Pp.103-110.

Weber B.A. "Short term habituation; Average electro encephalic response in infants". J.Speech Hear Res. 15, 1972, Pp.757-762.

Weber B.A., Seitz M.R. & Mccutcheon "Quantifying click stimuli in Auditory Brainstem Response Audiometry" Ear and Hearing 1, 1981, Pp.15-19.

Wedenberg E. "Objective auditory tests for non Co-operative children "Acta Otolaryng Suppl. 175, 1963,Pp 1-32.

Wever E.G. and Bray C. "Action currents in the auditory nerve in response to acoustic stimulation" Proc. Natl. Acad. Sci U.S., 16, 1930, PP.344-350 (as cited by Glattke, 1978)

Wever E.G."Electrical potentials of the cochlea" physiol Rev 46, 1966 Pp.102-127(as cited by Simmons & Glattke, 1975)

Wilber L.A. "Acoustic reflex measurement procedures, interpretations and variables "Acoustic Admittance the measurement of middle ear function eds. A.S.Feldman & L.A. Wilber, Baltimore, The Williams & Wilkings company, 197

Wilder J. "The law of initial values" Psychosom Med., 12,1950, P.393.(as cited by Gerber et al)

Williams H., Tepas D. & Morlock H. "Evoked responses to clicks and electro encephalographic stages of sleep in man" Science 138, 1962 Pp.685-686. (as cited by Skinner, 1978)

Wilson R.H. & McBride L.M."Threshold and growth of the acoustic reflex" J.Acoust SOC. Am. 63, 1978, Pp.147-153.

Withrow F.B. Jr. and Goldstein R. "An electrophysiologic procedure for determination of auditory threshold in children". Laryngoscope. 68, 1958, Pp.1674-1699. 68, 1958, Pp.1674-1699(as cited by price,1975)

Wooden F. & Marsh J. "Frequency following (microphonic like) neural responses evoked by sound". Electroencephalogr Clin. Neuro physiol. 25, 1969, Pp. 42-52.

Yoshie N., Ohashi T. & Suzuki T. "Non surgical recording of auditory nerve action potentials in man". Laryngoscope, 77, 1967, Pp.76-85 (as cited by Glattke, 1978).

Yoshie N. "Auditory nerve action potential responses to clicks in man". Laryngoscope. 78, 1968, Pp.198-215.

Yoshie N. & Ohashi T. "Clinical use of cochlear nerve action potential responses in man for differential diagnosis of hearing losses "Acta Otolaryngol Suppl. 252, 1969, Pp. 71-87.

Yoshie N, "Diagnostic significance of the electrocochleogram in clinical audiometry". Audiology 12, 1973, Pp. 504-519.

Zeaman D. & Wegner N. "Cardiac reflex to tones of threshold intensity". J.Speech Hear Disord 21, 1956, Pp.71-75.