PAEDIATRIC AUDIOLOGICAL ASSESSMENT

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DEDICATED TO

. DEAREST 'AKKA'

CERTIFICATE

This is to certify that the Independent Project entitled "PAEDIATRIC AUDIOLOGICAL ASSESSMENT" is the bonafide work in part fulfillment for III Semester M.Sc Speech and Hearing, carrying 50 marks, of the student with Register No. 4

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C E R T I F I C A T E

This is to certify that the Independent Project entitled "PAEDIATRIC AUDIOLOGICAL ASSESSMENT" has been prepared under my supervision and guidance.

Guide

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DECLARATION

This independent project is ay own work done under the guidance of Dr.(Miss) Shailaja Nikam, Professor and Head of the Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier at any University for any other Diploma or Degree.

Mysore

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CHAPTER I

INTRODUCTION

The basic purpose of an audiological evaluation is to obtain information, to identify an auditory disorder, to assess the degrees of handicap and provide a plan for the management of the auditory disorders. One fails to achieve the above mentioned goals in the hearing evaluation of children because testing young children is often difficult? frustrating; and challenging to ari audiologist; most of the auditory tests are standardized primarily on an adult population. This lead to the development of a new era .in the field of audiology: 'Paediatric Audiology;'

The primary concerns of paediatrics audiology are: identifying, measuring, defining; and solving the hearing ' problems in young children. The measurement of hearing function has been the biggest problem for an audiologist as well to others, who are involved in the child health care like otolaryngologists, paediatricians, speech pathologists, neurologists and the rehabilitators.

Paediatricians are concerned with how they can identify early deafness in babies and what can be done for such children. Otolaryngologists want to learn the techniques of testing such a population and what the audiological manifestations are; the audiologists are interested In the 'how' of testing young children and the relationship of the auditory findings in different pathologies; and ultimately the rehabilitation people want to know how to relate audiological data with the expectations of hearing Impaired children with whom they work. The importance of assessment can be understood by analyzing the various consequences of an undetected and untreated hearing loss. The hearing loss will have an impact on all the aspects of growth and development of a child, if not identified and remedied.

Hearing impairment in a child impedes the attainment of his best potential language function; constricts the personality development, gives rise to aberrant emotional behaviour and culminates educational achievement.

Even a minimal loss of 25 dB in the early years of life has been reported to have a pro-found effect upon the speech and language development. This is because there exists critical periods for the development of language function and a deprivation of the auditory impact will impede the acquisition of almost all aspects of the language, that is syntactic, semantic and vocabulary (Young and Mc Conell (1957), Streng (1953) Nunnally and Bleurton (1960), Cooper (1967) and Quigley at al (1976).

Therefore, unless the hearing loss is recognized early, their attainment of future success will be in Jeopardy. To give every possible benefit for then, an accurate diagnosis of the problems is imperative.

In the recent past, a number of tests have been developed for the diagnosis of hearing loss. Initially only very gross measures were employed, which did not give information regarding the hearing function and for differential diagnosis of hearing impaired children from others' disabled children. In order to choose an appropriate remedial program differential diagnosis in children is a must.

With the advancement of computer technology, the evaluational techniques for children has improved tremendously.

The purpose of this review is to provide a synthesis of the past and current knowledge about the auditory stimuli and tests that effectively assess the hearing sensitivity and differentiates abnomal from nomal auditory function in paediatric population.

CHAPTER II

Screening is the process of applying to large number of individuals certain rapid, simple measurements that will identify these individuals with a high probability of disorders in the function tested (Northern and Downs 1974). The screening procedures can be considered as the initial step in administering broader hearing conservation programmes, especially that of providing the most efficient and earliest possible detection of all hearing losses that require medical or eductional treatment (Mencher 1974). Disagreement exists as regards the practicability and reliability of screening programme and whether there is a need to conduct them or not has been debated. But the need for screening can be established from the medical, audlological and educaltonal point of view.

Prom the medical noint of view, the detection of hearing loss at birth offers an opportunity for early medical treatment and a source of valuable information on the etiology of hearing problems. Prom the educational and audiological point of view, early detection provides the opportunity to initiate the auditory rehabilitation programme at an age which is optimal for learning/development of hearing function (Goodhill, l967). According to Goodhill (1967) the rehabilitation should be initiated before the child is 6 months old. Thus all these point to the need for screening programmes.

The goal of screening programme is to identify all children who have a significant hearing loss (Goodhill 1967). The goals of the screening programmes as enumerated by Mencher are:

1. Maintenance of an optimum state of health.
2. Conservation of human resources and optimum functioning of the individual irrespective of the type of handicap.
3. To teat large number of subjects.
4. Screening is not an end in itself, as 'follow-up' is the main thing for- - a successful screening programs.
5. To get minimum number of falsa positive and false negative responses.
6. To conduct screening programme using longitudinal approach.
7. To counsel the family, community services, to bettsr deal vith - diagnosis (Mencher 1976).

Two more precautions given by Mencher (1976) are the screening programmes should be established on the largest possible number of children. The second point is that "money spent for the prevention of hearing or early identification and treatment of a problem is money and time saved."(Mencher1976).

The screening programmes are not the province of a single professlon. The program must be a joint effort of all professions (Otology, Pediatrics, Public Health Nursing and Audiology) with appropriate referral and ultimate management predicted on the etiology, prognosis and types of treatment required.

The screening is best conducted in well baby clinics (Goodhlll and Tell, Lini and FBinraesser & others), due to mainly the availability, But Nikam and Dharmaraj ( ) observed the acoustically treated rooms to give the best results while screening infants. The time of screening should confirm to nursery routine. The optimum time is given to be 45 minutes to one hour, before the next feeding (Goodhill (1967) The child during this stage will not be indeep sleep which is usually seen after feeding or in fretful state, seen immediately preceding the next feeding.

The state of the infant prior to stimulation also has a major influence on response, judgement (which has been discussed later).

The type of stimuli and procedure used also influences the response occurrence and judgement. Pure tones and noise makers are the most commonly employed stimuli pure tone screening also, different procedures have been employed for screening. Even speech and impedance audiometry have been found to be of value in the screening programmes,
A brief review of the contribution of each of the above mentioned screening program will be discussed.

Noise makers have been used to screen babies. First the baby or the child is made to sit on its mother's laps and noise makers are presented.

Most commonly used noise makers are squeekers, horns, bells, rattlers, drum etc. along with vocal sounds. The precautions that should be taken while testing by noise makers are as follows:

1. The intensity and the duration of the stimulus parameters should be maintained for each trial.

2. The distance between the ear and the source should be maintained at a constant level.

3. Should know the frequency characteristics of all the noise makers being used.

While screening with noise makers, the clinicians should (1) cover a wide range of frequencies, (2) cover wide range of intensity and (3) not provide any visual cues.

The frequency characteristics has been established for some noise makers, which will be enumerated here:

1. Small bell gives a high frequency response around 4000 Hz at 21-35 dB at a distance of 3" when wrung loudly 45 or 50 dB HL.

2. Plastic Block or Rattle peak : 100) Hz, intensity: 45 to 55dBL.

3. A Rubber squeeker key 1000Hz peak or 2000 Hz at 45 dB SPL; when crushed: 40 to 50 dB at 1 KHz.

4. Loud squeeze toy: all frequsncies with 50-85 dB SPL

5. Tissue paper: 40-50 dB 1KHz and higher.

The noise makers should be held motion less within 3 inches of the baby's ears for atleast 10 seconds before making the sound. The waiting period is necessary to obviate any response due to the hand's location in respect to the light sources or to any air movement. Sheridan (l957) has suggested to vary the distance as age varies. She has suggested to hold the noise maker at 30" at 6 months to 39" at 9 months. She explained that differences in hearing or distance hearing as due to the incomplete experience of the infants with sounds,and to his ability to discriminate foreground from background noises. The output of the loudspeaker 3 to 4 feet from the infant's ear was not proved effective. A typical testing sequence with stimulus presentation and the intensity levels is as follows:

The noise makers should be presented for about 30 seconds and observe the child 's response. Then should wait until the child resumes his original state before presenting the next stimuli. The responses should be judged with respect to the type and intensity of stimuli being presented. (Ewing (1944).

In this technique the mother holds the baby in her lap supporting him under the arm and holding him away from her body. This position is chosen as it permits the child to move freely. The observer sits in front of the child and attracts and holds his attention. The tester standing behind the mother then attempts to distract the child's attention by presenting auditory stimuli out of the range of child's peripheral vision. Visual comnunication between the tester and child is to be avoided. The following distractions were presented at a distance of 4 to 5ft. at intensity of 30 to 40 d3 (ref, 0.0002 2 dynes/cm^2).

1. High frequency range; wherein unvoiced consonants (S, Sh, k, p, t) were presented.
2. Middle frequency range wherein rattle, china cup and metal spoon were used.
3. Low frequency range: voice rattle, xylophone were used.

The above stimuli were presented alternately to left and right ears. The procedure was as follows: If the child responded to the sound, then the stimuli and ears were changed. On the other hand if the child did not hear the sound, then the same sound was presented to the other ear. Each correct response was rewarded, the reward was allowing him to see the stimuli. The observer's task was to maintain the attention of the child as well as to observe and record the responses. The responses to be observed were (1) Turning- of eyes towards the tester. (2) Looking up at the observer, (3) Stopping activity or becoming active, (4) Looking up at the mother, (5) Widening of eyes, (6) Turning his head slightly. If the child passed the test, then the parents were informed of it. On the other hand, if the child failed then he was referred for other evaluations and followed up. The validity of the test was found to be dependent upon the (l) skill of the observer, in the interpretation of the responses, (2) ability of the tester and the knowledge and experience of the tester.

The other stimuli which has been widely used for screening is pure tones. But the question that has not been answered is, the number and the combination of pure tones to be employed in screening. A number of investigators have conducted studies regarding this aspect (House and Glorig, 1957,1958) Stevens and Davidson, 1959 ; Hanley and Gaddie 1962 ; Miller and Bella 1959)

The main controversy is regarding the use of single/more nuaber of frequency in a screening programme. Bouse and Glorig coapared the single and sweep frequency screening procedures in infants and found a sucess of 30% with single frequency audiometry. Stevens and Davidson (1959) also have compared the two procedures, that is single (4 KHz) and sweep frequency audlosetry and concluded, that single frequency as not as efficient as the sweep frequency audiometry and a combination of 500 Hz and 4 KHz was suggested as better compared to 4 KHz alone.

Miller and Bella (1959) screened children at 500, 1K, 2K, 4K and 3 KHz and found the 3 frequency average, 1K, 2K and 4KHz to give the best results. The percentage error was only 3% for the combination of 1K, 2K and 4KHz whereas for other combinations the error was as follows: Only 4KHz - 39% ; 2K-4KHz - 46.2% ; 1K-4K - 9.4%. All frequencies except 3KHz - 15.4%, Thus the data clearly indicated that a single frequency would not be of much help in any screenlng-programme.

But some investigators have recommended the use of single frequency audiometry using a 4 KHz. tone - in screening programme (Glorig and House,1957,1958; vaclan and for (1954); Hanley and Goddie (1962). The reasons enumerated by the investgators for recommending 4 KHz for screen programe.

1. the 4 KHz screening saves time as it can be accomplished within 5 to 10 Seconds.
2. This causes less disturbances in the daily routine espcially, in public school audiometry.
3. It results only in 10% error and the accuracy was observed to be 99.5% (Walkan and For 1957: Glorig and House (1957,1958)
4) this can be administerd with case, causes less fatieue and does not require much skill,
5. It can be employed for testing children younger Than 3 years of age.
6. this in minimally effected by noise, and
7. it is inexpensive.

The difference of opinion existing, can be attributed to::

1. differences in depend concerning the acceptance of false negative compared in false postive responses:
2. insufficient data, and
3. ar inability to compare one study with another due to diversity in situtations of the study.

The main drawback of pure tone screening is, it does not provide much information regarding the condition of the Middle Ear. Even in the pressure of Middle Ear pathology one can pass in the pure tone screening test.Thus while in perting the data obtained from such screening test. one should be very cautions.

CHAPTER II

SECTION 2.

BEHAVIOURAL OBSERVATION AUDIOMETRY (BOA):

BOA inlocalisation procedure which may or may not include response consequation (Fulton, 1973), It refers to the audiologist's attempt to elicit observable responses to sound. The responses may be either reflexive (respondents) or voluntary (operant) which are temporally related to the auditory stimulus. In this various stimuli are presented through speakers which are placed at an angle to the child and behavioural responses following stimulation are observed. In 30A various auditory stimuli, stimulus controls, test situations, response reliability and response criteria are used (Fulton and Lloyd (1975). For the BOA to be successful in identifying the problems, the examiner should have some prerequisite skills, which can be summarised under the following heads:

1. Control of Behaviour: The observer should have the ability to direct the child's activity in the required direction especially in the difficult to test population like hyperactive destructive children.

2. Control of environment: The examiner should be able to minimize the auditory and visual distractions in the test environment,

3. Choice of material; The examinee should have the ability to select toys which are neither too distracting nor very interesting, but which can draw the attention of the

child temporarily to a sufficient degree.

4. Stimulus presentation; The examiner/clinician should present the stimulus, without providing any non-auditory cues and should move from simple to complex stimuli, so as to maintain the motivation of the child. The same stimuli should not be presented over and over again as this will lead to adaptation and fails to hold the child's attention.

5. Choice and interpretation of responses

The task- should not be too time consuming and should be able to isolate the desired responses from the unwanted responses. The desired response should be encouraged and should facilitate generalisation. For this, reinforcement should be provided for the desired response. In the interpretation of response, one has to see whether there is a total unresponsiveness on the part of the subject. This implies a problem, other than deafness.

6. Test environment : The examiner should be able to measure the ambient noise at the time of the test.

In BOA various stimuli has been utilised, but the most commonly used are speech or complex sounds produced by noisemakers.

Unfamiliar and familiar stimuli have been used in 30A. Some of these are: Rattle, Cracker, Squeezer, Laugh, Cry, White noise, Narrowband noises, Warble-tone (Marquis, 1931; Downs and

Sterritt, 1967; Hardy, Gerber, Miller and Swain, 1976). Marquis (1931) has recommended the use of different stimuli for different age groups: For infants - birth to 4 months, noise makers have been suggested. For infants of 4 to 7 months old, Speech stimuli and for infants of older than 9 months, pure tones have been recommended. 3ut some advocate the use of warble tones (Orchik and Rintelmann, 1975; Swain and White, 1933; Hardy, 1953; Langenback, 1965; Aockune and Robinson, 1975). Various reasons have been given for the preference of warble tones to other stimuli. These are: that if provides a psychological advantage by reducing fatigue and uncertainity for the tester (Swain and White, 1933).

According to Hardy (1958) Warble tones draws the attention of the child. Langenback (1965) states that "a fluid character is added by warble tones which excites the child's attention and keeps it awake." Thus the warble tones have been said to have attention drawing, excitable and awakening characteristics. But all the above data was based on experience and observation and not on experimental basis. Owar Robinson and Vauglon(1975) studied the relative efficiency of pure tone and warble tones, in the testing of children. They did not observe any difference between the efficacy of pure tones and warble tones in young children. Bench, Collyer, Mentz and Wilson(1976) conducted a series of experiments, in studying the behavioural responses of infants of different ages to acoustic stimuli. The following parameters were taken: (1) effects of different prestimulus activity states; (2) the effectiveness of different stimuli in eliciting response; (3) any differences in the assessment when different segments of the baby's body was observed.

The above mentioned parameters were studied in Infants of 6 weeks, 6 months and older than 6 months. The results of the series of experiment conducted were as follows: the tonal stimuli was ineffective in all age groups compared to Broad band noise. The cues to judge the response to tonal stimuli differed with the body segments for younger and older children. In the 6 months old infants, human voice stimuli enhanced responses. The state of light sleep was preferred for the younger age group and for the older age group, the wakeful state was preferred. Thus pre-stimulus state has been found to have an important influence on the response determination. Large differences were noticed for the different body segment in the 6 months but not in other infants. In younger infants the response was usually a gross, pasoxysmal startling reflex but in 6 months old infant, the head turning v response was characteristic.

No concensus has been observed in the discussion about the applicability of various auditory stimuli to different age groups among children. But as has already been stated, noise makers and speech are employed most often in the clinical set ups.

The state of the infant prior to stimulation has also been found to play a significant role in the elieitation of response to auditory stimuli. In this area also, investigators have failed to give a single state which can be considered as the optimal state.

<u>Prestimulus</u> state: A number of studies have been conducted to investigate the influence of prestimlus state on the behavioural response of the child subsequent to stimulation (Eisenberg, 1964; Ashton, 1971; Ling et al, 1970; Hutt et al, 1968; Langford and Bench, 1975).

Eisenberg (1964) observed neonates in states of deep sleep, light sleep, less than full wakefmllness and full wakefulness with alertness. The response was found to occur frequently in the light sleep stage (75%) and least in the full wakefulness state(59%).

Bench and Boscak (1970) have also reported of maximum responses during the light sleep stage. But in contrast to the above two studies; Ashton (1971) Ling et al (1970) Hutt et al (1968) have reported of maximum responses in the wakeful state compared to any stage of sleep in neonates. Langford and Bench and Wilson (1975) on the other hand did not observe any significant effect of pre stimulus activity on the neonates responses judgements. The effect of state was observed to interact with the type of stimuli presented. For stimuli which elicited a high proportion of responses, the prestimulus activity had very little effect but for the sounds which elicited few responses; the prestimulus activity had a significant effect. Bench, Langford and Wilson (1976) studied the effect of pre stimulus activity in 6 week and 6 month old infants. They observed a decrease differential effect of pre stimulus activity on different age groups. This differential effect was related to the type of response manifested by these subjects. The more localized the response, the lesser is the influence of pre stimulus activity on response judgement. But in general in all 3 age groups a decrease in the false positive response occurred with a decrease in the prestiaulus activity level.

Thus while discussing the effect of prestimulus activity on the response judgement, one should take into consideration the type of stimuli being used as well as the type of response being measured.

The effect of pre stimulus duration on the response judgement has been studied by many investigators (Connolly and Strattoa, 1969 ; Ling et al , 1970 ; Butt and Butt, 1970 ; Ashton, 1971 ; Langford Bench and Wilson (1975). Each investigator has recommended different durations for measuring pre stimulus activity. Longford, Bench and Wilson (1975) did not find any effect of prestimulus duration on response Judgements in neonates as well as in infants of 6 months of age, (We are back, at where we started the discussion, that is still uncertain regarding the stimuli to be used in 30A.)

The type of responses to stinull are quite varied. The responses may be halting body movements, an increase in body movement, a localizing response, engaging in rhythmical activity, changes in the facial expression, and various reflexive actions, Like audio Oculogyric Aeropalpebral or cochleopabral and Moro reflex•

Different tests have been developed by taking different types of behaviour as an index of response. These are : (1) Awakening test; (2) Auropalpebral test ; (3) Hearometer; (A) Crib-O-Gram; (5) Reflex Inhibition Audiometry: (6) Suck test; (7) Cry testj (3) Swing & Ewing test;(9) Downs and sterrit test. A brief description about each of these tests will be given in this section.

1. <u>Ewing and Swing (1951,) Developaental Tests of hearing</u>

Swing and Ewing (1951) contend that at different stages of development of the child, specially during the first year of life, tests which measure different responses should be employed. This is because, as the child grows, the response to sound also becomes more and more specific. Thus a particular response indicates the stage of development hearing that an infant has reached.

A list of tests that are appropriate for different age groups can be foraed based on the maturation of auditory behaviour in children.

	LOUD SOUNDS	QUIET Unfamiliar	SOUNDS Familiar
I.Immediate post-natal period	Reflex startle occurs. This response is not infallible and further tests should be made atlaterstage.	nil	nil
II. 4-5 months	Variable degree of inhibition of startle re-flex.	Many sounds unfamiliar looks only once.	A few sounds familiar. Looks Rt. Lt.
III. 6-8 months.	Inhibition of startle.Usua-lly complete, may be one response	Very few sounds are unfamiliar.	Localizes many sounds.

Therefore by considering the above given data as reference, one can Judge the response accurately. For children above one year, a failure in speech acquisition will be an indication of hearing loss. Thus the knowledge about the maturation of the auditory behaviour is a must for evaluating child's responses to test stimuli.

2. Downs and Sterritt (1964) Screening Test:

They reconroend tearing screening for all newborns and infants. Three aspects of infant testing are controlled or defined as accurately as possibles (1) The stimulus; (2) The duration of response, and (3) The infant's state and condition.

1. The stimulus: Two types of stimulus were used. First a broad band noise was presented at SPL's of 70, 80, 90 and 100 dB through loud speakers. This type of stimulus elicited a generalized response.

The second was a narrow band filtered noise, peaking at 3 KHz with energy between 2500 and 3000 Hz presented at the same SPL's, The 3 KHZ tone was presentedto differentiate cases with better hearing in the low frequencies than high frequencies.

The noise was used as a signal because of the following reasons: This provides (1)greater accuracy of measurement and control in a sound field (2) problem of standing wares is minimized (3) more effective than pure tone in eliciting and sustaining the continuation of the interaural muscles activity. The use of 3KHz aided in differentiating hereditary congenital from non-hereditary congenital loss. To increase in-ter Judge agreement, rating scales and rigid definition of response categories were applied to the various parameters of the infant's responses.

2.2.9

The following table gives the complete description of Stimulus and response parameters of the Downs and Sterritt (1964) screening test:

Parameter	Description	Code
Time variables	Duration of response Latency of response	Seen from beginning of response. Seen following signal presentation.
Site of observed responses	Bye	E
	Entire body(Moro-Reflex)	M
	Cessat ion of body activity.	C
	Limb movement,	L
	Head turn, towards away from stimulus	Tor A
	Facial grimmacing	s
	Mouth Sucking.	S
Intensity of Response	No response	1
	Questionable	2
	Clear but weak	3
	Strong	4
	Paroxysmal	5

The prestimulus states of the child, the drugs administered/to the ielivery, the familial history of deafness or other problems and the prenatal history of the infant, has been given importance in this screening test.

The prestimulus states were classified as follows and were given codes:

Condition	Description	Code
Observed state	Sleeping quiet	SQ
	Sleeping Grimmcing	SG
	Sleeping moving	SM
	Awake quiet	AQ
	Awake-Grimmacing	AG
	Awake-moving	AM
	Drowsy	DR
	Fretful	FR
	Crying	CR

The authors have recommended the use of instrumental recording to measure the response accurately.

3. Awakening Test:

This was prepared by Wedenberg (1956). He suggested the presentation of tone pulses at 3KHZ at 75 dB SPL to awake from light sleep. The criteria of response are : movements of eyelids, changes in heart rate and general body movements. The rationale for using 3KB* is that, adequate hearing at 3 KHz predicts the audibility to speak normally, given normal intelligence. The stage of sleep is monitored by stroking the eyelash with a finger. If a reflex movement of the eyelid can be elicited, a negative reaction to the tone, that is failure to wake within one minute constitutes a valid result.

4. Auropalpetralble Reflex (APR):

APR was used mainly for differential diagnosis. This reflex comprises of a rapid and distinct closing of the eye-lids in response to tones of high intensity under standard conditions. The stimuli used is pure tones ranging from 500 to 4000 c/s frequencies at SPLs between 105 and 115 dB re. 0.0002µv. This aids in differential diagnosis between retrocochlear and eochlear, as in retrocochlear and conductive loss cases, the APR willoccur at levels as in the case of normals.

The APR has also been measured using different stimuli. Northern and Downs (1974) have made use of broad band noise, at levels of 50 to 70 dB SPL in a quiet room, observed this reflex, and for Speech, the APR was obtained at 55-75 d3 SPL, For warble tones it was seen around the level 55-90 d3 SPL. Thus, compared to pure tones, all the other stimuli elicited APR at almost the same level.

Other differentiation between retrocochlear and cochlear is, in retrocochlear or conductive loss cases, an audio gram can be plotted using this response but in cochlear loss cases, this has not been possible because of the irregularity intro-duced by recruitment. Thus basically this test is for differen-tial diagnosis and threshold determination is not possible.

5. Hearometer:

is an Instrument used in neonatal hearing testing by Griffiths (1965). Here a loud speaker is placed over the sleeping infant and interrupted pure tones of varied frequencies and intensities are delivered from it. The satisfactory response is the awakening of the Infant froa sleep. This again cannot be used such for the determination of threshold.

6. Crib~O-gram

This was developed by Simmons (1976). This is a machine which records the responses following the presentation of stimulus. This device consists of a motion- sensitive transducer attached to a bassinet and a graphic recorder which records the measured motion as well astiming signal generating equipment. Prior to each test a 10 seconds prestimulus recording of bassinet ability is obtained and then recording is done for 6 seconds following the presentation of stimuli. This cycle is repeated at desired intervals. It also includes control periods, where recording without the presentation of the signalwas done. The scorer of the response is to be ignorant of the events which comprises of control periods. This device was used to screen neonates in normal nurseries. Out of 7615 neonates screened, 777 failed on this test and a majority of infants gave reliable responses especially when measured during light sleep stage of sleep.

Thus, this device can be used for (1) aass screening and (2) for individual testing in intensive care unit/preventive measures.

The sound stimulus is presented at 92 dB for 1 second, for about 10 seconds and response measured for 6 seconds post stimulus. To avoid the startle response in other personnel, a prestimulus is presented at 40 dB, at 4 KHz. About 20 tests could be done in 24 hours. Scoring has been easy. Any change in the ongoing crib activity within 2 seconds after the sti- •ulus presentation is taken as positive responses. The reliability was found by presenting stimuli events and the number of responses was checked. If it is too much, then the changes are not

taken as responses but as indications of motor activity coincident with stimulus - (children who followed the up through questio- nnairs to parents and physicians) Best condition to record the responses was found to be when the child was asleep or when the ongoing activity was regular. The fit (1.) clarifies the response pattern changes with the level of consciousness.

7. Accelrometer Recording System:

This is an automated procedure of recording the response of the neonates to stimulus, developed by Altman et al (1975). This was basically developed to improve efficiency of mass screening programme. This device comprised of a sound source, cradle, vibration pick up, analyzer system and recorder. The sound source was a tape recorder with audio amplifier mounted on an adjustable stand.

The cradle was provided with a wooden pillow for head and shoulder rest. The cradle was placed on a floating floor structure, which consisted of a concrete slab, supported by a tyre-tube. The concrete slab was covered with a polyuse-thene sheet and the whole structure was placed on a table.

An accelerometer was attached to the wooden pillow. A pre amplifier amplified the voltage of the responses accelerometer passed through a narrow band filter adjusted to 0.1 to 20 Hz band width andwis given to the accelo-ymeter. The accelerometer generates a voltage proportional to the acceleration of vibrational set up in the wooden pillow.

The voltage of the signalwas registered by the recorder. The Barker of the recorder notes the sould stimulus imitation on the paper, and as it is coupled with a timer, it controls the duration of the stimulus also.

The authors using this device tested neonates of 20 to 96 hours who were in different stages of sleep and arousal- The stimuli used was an i octave noise band with center frequency of 3150 KB at 90 dB SPL.

Distinct responses were obtained in majority of the neonates tested in his study. Thus, the automated device was useful in neonatal detection of hearing loss. The advantages of this device are; this can be employed with minimal disruption of mercery routine and the scoring of response is simplified. Solid borne noise Is excluded by the place-Bent of the cradle on the floating floor structure and a better S/N ratio is obtained, because of the filters used. But still, this device has to be validated and a reduction of the False positive results is necessary. In addition, though the device is very sensitive to vibration, breathing and heartbeats do not manifest in the recording as their acceleration is very low. But this device can be reliably used in screening programs for the early detection of profound loss.

This was given by Marsh and Hoffman (1976). In this technique, the reflexive eye blink elicited by an tactile stimulis is inlubited by-stimulus which precedes the eliciting stimulus by 10 msecs.. The presence of inhibition with a given stimulus is strong evidence that the tone is above the patient's threshold.

This audiometry seems to have a high potential in testing young children, as the administration is safe, simple, comfortable and does not demand the co-operation of the subject. But still more research is desired to make any conclusive statement.

9. <u>Suck test:</u>

In this test, the functional relation that exists between novel stimulus presentation and infant orienting response characterized by momentary disruption of the ongoing activity is utilized. The measures such as non nutritive sticking suppression (a decrease in total sucking rate), sucking initiation and sucking cessation can be used (Quist and Hoecinganann, 19).

The procedure is as follows t The Bother is instructed to skip the infant's early morning feeding and to bring the food in a nursing bottle. The mother and infant are placed in a quiet testing room vith earphones held near the infant's ear by Bother,at the saae tiae, she in instructed to give the bottle,While the infant's nursing testing in the right , ear at 3 KHz at 80 dB HL is initiated and the level is gradually increased in 10 dB steps until a cessation of sucking response is observed. All other frequencies, the same procedure was used. If the infant failed to respond at two or aore frequencies at 60dB, cooing and labial sounds were used. If the Infants failed on this also, then they were retested 3-6 weeks later and again if he failed then was referred for a neurological and otological examination. The cessation of sucking was seen as a consistent pattern. The puretones were found better than complex noise and holding of earphones avoided the occurrence of standing waves. This test was found useful In Infants as young as 1 month old (Mattungle 1970). A blind nipple can also be used for testing infants. In such cases, the air trapped within the nipple Is measured. This also has been found useful by Regan and Michele (1977).

10. Bottle feeding technique (Pack 1935)

was used to maximise the detection of response Identification, by minimising the body movements. This has been claimed to be useful for three reasons:

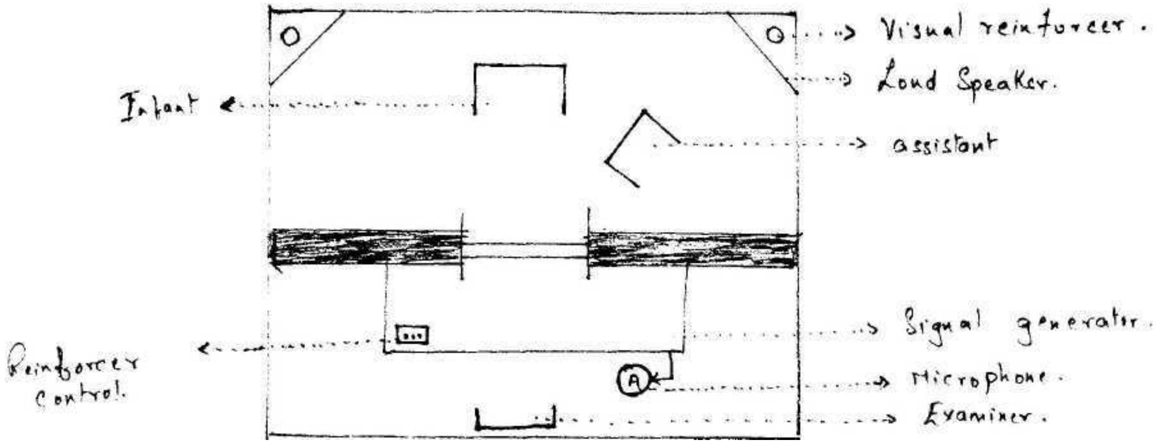
1. reduces random activity,
2. a steady sucking response,may be established,
3. crying can be eliminated as a masking noise.

Sucking is a rhythmical activity and therefore interruptions will be clearly discernible. By using warbled tones, information regarding the hearing of the child at specific frequencies can also be obtained. The response that may be observed on stimulation are: Startle, APR, initiation or cessation of sucking, observable change in respiration pattern or arousal. Only, if the same response pattern is repeated several times, then should it be judged as a response.

11. Localization Audiometry :

This is applicable to Infants of 3-4 months of age as this is based on the orientation which is developed only by 3-4 months of age.

The set up is as shown in the fig (1).



The infant is seated in between the 2 loudspeakers An assistant draws the attention of the infant,already from the source. Attractive animated toys are placed adjacent to the loudspeaker which act as reinforcement for a correct orienting response. The limitation of this audioaetry is as follows:

Information obtained is that of the better ear of the infant. Therefore a unilateral hearing loss cannot be detected and not applicable. The other drawback which has been reported is that children less than one year with profound loss do not respond at all, but this actually becomes an advantage as it makes one suspect hearing loss in the child.

CHAPTER III

PURS TONE AUDIOMETRY

Pure tone tests far hearing sensitivity are the most basic tests that are used by audiologlsts (Allen and Fernandez, 1960, cited by Price 1978).

These tests are termed as 'Routine Audiometry' as practicully every professional uses these tests in the evaluation of hearing sensitivity. A need for conducting of pure tone audlometry has been enumerated by many investigators (Barr, 1965)/ Ewing (1965},' Goldstein (1965); Price (1978).

According to Barr (1965) the puretone test results, aids in starting an educational program for the child and it also aids in the selection of hearing aids and in monitoring the results of surgery or medication. Ewing (1965) has also given that pure tone test results are very necessary for the E.N.T. surgeons, in deciding the line of treatment to be opted. Goldstein (1965) has stated that "testing of infante with pure tone tests is as useful and valid as testing with speech if one sets the goal, as the determination of auditory sensitivity and the probable effects of reduced auditory sensitivity on the under stand ing of speech." His argument is that in case of neonates and children with profound stimuli, the speech signal has no advantage over the pure tone stimuli, as both will be equally meaningless. He further says that, the use of speech as stimuli will result in misdiagnosis more often than when tested using pure tones. Example is, if a case's sensitivity to the low frequency components of speech can obscue. a high frequency loss for such cases the reaction to speech can be elicited close to normal thresholds. Thus a lack of detection of high frequency loss would later result in the failure of the normal understanding of speech and thus the particular case will be put under central auditory disorder. The pure tones are preferred for other reasons: they are easy to calibrate, control and specify. Price (1968) has given that puretones can be used without any restriction because any complex signal can be analyzed as a combination of pure tones. Price (1978) has also given emphasis to pure tone testing and his argument for preferring pure tones, is that, any complex signal can be analyzed as a combination of pure tones and therefore, pure tone tests form the basis for other tests like speech reception threshold, Speech discrimination threshold etc. The pure tones are useful as indicator of hearing sensitivity and also in predicting the pure tone testing in the clinics is justified.

Two general procedures can be employed to measure the hearing sensitivity using pure tones. In both the procedures the range of frequencies covered is held constant, that is from 125 Hz to 8 KHz. In the first procedure, the test frequencies are selected at given intervals, and the thresholds are obtained for each frequency and Plotted on a graph, with the frequencies marked on the x-axis and intensity on the Y-axis. Then all the Paints on the graph are joined by straight lines. The resultant graph is called the 'Audiogram'..

The second method involves sweeping across all the frequencies in the range selected at different intensity levels. The speech of sweeping is ai octave, during each ten minute Period. The Hind of recording gives the average threshold across the whole frequency range. Though the Procedures are different, the audio-grams obtained by these two Procedures approximate each other. (Price, 1978).

The standard Procedure of Rare tone audiometry is as follows :

The subject to be tested will be seated in a chair inside the sound treated room. Then he is given the instruction, that whenever he hears the tone, he has to indicate by raising his finger. Then the earphones are Placed on his ears. The Adiologist first tests the better ear. The first frequency tested will be 1000Hz. The alernative level is adjusted, well above the estimated threshold, and response obtained. Then the search for threshold is ensued by using Hughao n-westlake method (1944). Once threshold for 1KHz is obtained then threshold for higher frequencies are tested, then a recheck is done at 1KHz, before testing the lower frequencies. The same Procedure will be employed for testing all the frequencies in the betterear as well as In the Poorer ear. After NC testing is done, then the BC vibrator is Placed on the mastoid and the thresholds obtained, following the same Procedure as for AC. Once the AC and DC thresholds are computed, further testing is decided upon, comparing the AC and BC thresholds Thus this is the standard way in which Pure tone audiometry is conducted in clinics.

The thresholds obtained by pure tone audiometry are affected by certain Parameters like - instruction givento the Patient, duration of the stimulus, the test environment, the method of obtaining threshold, the Position of the BC vibrator, and the central masking phenomenon. Thus while interpreting the audiogram, the influence of all these factors should be taken into account.

In the evaluation of children, who are normal in all respects and are older than around 7-8 years, the standard procedure can be used. But in younger age groupe and those with some Problems like multiple handicap, mental retardation etc., the standard Procedure cannot be adopted.

The above mentioned groups will be lagging behind the adults in the development of language, speech, mental maturity, emotional stability, judgemental ability etc. The Children's attention span is very limited compared to adults and as Pure tones are not meaningful, the children will lack motivation to

Perform when these are Presented. The instructions will also be above the level of comprehension and therefore they fail to Perform the task. On the whole, the functional significance of the stimuli is not understood by the children and result in very loor Performances and thereby invalidate the test. Therefore some modifications were made to make it applicable to all infants younger/older than 2 or 3 years. Therefore, in order to evaluate such cases, a modification of the standard technique had to be made.

Conditioning Principles were adopted in the development of Pure tone tests for children. Conditioning techniques are of two types Classical and operant. In classical auditioning techniques the behaviour is elicited by a stimulus is considered as a respondent behaviour, which includes the unconditional and conditional reflexes.

The unconditional reflexes are those which are elicited without the intervening conditioning or learning, on Presentation of stimuli. The example for such reflex is the staPedius muscle reflex to a loud stimulus/ changes in cardiovascular and respiratory measures on stimulation. The disadvantage of using unconditional reflexes for the assessment of auditory sensitivity are (1) Mast of these reflexes can be elicited only for very loud stimuli. (2) The organism tends to adapt to continued Presentation of the stimulus, thus the strength of the reflex diminishes with increased Presentations.

The conditioned reflexes have been used to estimate hearing sensitivity. The commonest application of such a reflex is the Electrodermal Response Audiometry.

Electrodermal *Response* Audiometry(EDR)

The E.D.R. is based on the skin galvanic reflex or Psychogal van ic reflex. This was given by Hardy and Richterr (1958). This response is mediated through the autonomic nervous system and the electricity is generated in the skin. The E.D.R. is also knovm as skin-galvanic response, or Psychogal Vanic responses.

'TWO types of E.D.R. response to acoustic stimuli. These are seen(i) Pere effect and (2) Tarachanoff effect. The Fere effect refers to chaiges in resistance of the skin,which is recognised by applying a voltage to the skin by electrodes and observing the change in current. The Tarchawoff effect refers to changes in D.C. Potential between the two electrodes in contact with the skin. The equipment for recording remain same. Both reveal the activity of the audiomic nervous system. Both can be used with classical conditioning Procedures with mild Faradic shock as the unconditioned stimulus. Under appropriate coditions either response may be interpreted as a response to acoustic stimuli (Hardy) Goldstein (1963) Hardy and Pauls (1959), Wang (1957) (1958) claim that E.D.R. gives information regarding the CNS function and the learning processes as related to conditioning.

E ,D .R can also be used as a screening test. The E DR . is considered to be of some clinical value inspite of its many limitations. The limitations of E.D.R . has been mainly ascribed to the, difficulty in conditioning, non-specificity of response, differentiation of response from random continuity, the Probablity of chance and large individual variability.

Thus, diagnosis based on E.DR. data is very limits ed

Though it has been used with Peediatric Population, it has little support as a test for children.

Thus, on the whole, now-a-days, the classical conditioning techniques are not employed for the hearing testing of children.

ccntd. 3.6

The operant conditioning techniques have been adopted quite extensively for the evaluation of the hearing function of children of varying groups. This type of conditioning was introduced by Thorndlke. The main difference between the classical conditioning ano operant conditioning model is in the former model, the response is elicited by the conditioned stimulus, whereas in the latter model, the response is controlled by the conscenieiices. The term operant emphasizes the fact that the behaviour operates upon the environment to generate consequences depending upon the consequences generated, the behaviour gets modified. Thus the core idea of this model is that the behaviour is determined by the consequences generated when desired consequences are applied to the behaviour in the presence of an antecedent stimulus the probability of occurrence of that behaviour seems to increase. To bring out increase in the behaviour, positive reinforcements are preferred.

Using the operant paradigm, either the already present responses can be strengthened or, can generate the response. To generate response to the desired stimulus, first a non-auditory stimulus is presented. The response is elicited. Then this non-auditory stimulus and auditory stimulus are coupled together and response established. Once the respore e is eonsistent, then the response to the non-auditory stimulus is extinguished by non-reinforcements, or by time out and the response to the auditory stimulus is retained by providing positive reinforcement contingently. Thus by differential consequation of the two stimulus conditions, auditory and non-auditory stimulus conditions the response to auditory stimuli are elicited.

The tests which are based on operant conditioning paradigm use either the differential consequation of two stimuli or can just strengthen the response by directly applying positive reinforcement to the desired responses. Thus the basic steps involved in forming such tests are:

1. Select the stimulus for which one wishes to obtain measures and arrange for the control of the physical properties of that stimulus;
2. Define the response and range the integrity of that measure;
3. Differentially consequate the responses in an arrangement which strengthens the probability of obtaining the desired discrimination responding behaviour.

The success of the paradigm depends upon the control of the stimulus, response and consequential events and the interactions between them in achieving the goal of stimulus response control, (Fulton, 1978).

Based on the operant paradigm, several techniques have been developed. These can be classified, on the basis of the consequences used. The main categories are:

1. Techniques using picture consequation;
2. Techniques using Mechanical Toy consequation; and,
3. Techniques using tangible consequation;

The above categories are sub divided and the value of each of these techniques in the evaluation of the hearing function of children will be discussed individually,

I. Play Audiometrv: This technique was advocated by Barr (1965). This technique comprises of two phases, that is learning and threshold determination. This technique is based on learning principles. The procedure is as follows:

The child is placed et a small table beside the audiometer, where the tester can clearly watch the child all the time. The play instruction is given with the left hand and the right hand is used for manipulating the attenuator dial.

The play instruments are placed on the table in front of the child . These instruments are colourful, simple educational types of toys are employed in series games.

First the tone is presented to the child, at levels above the estimated thresholds. Once the tone is presented, the clinician should demonstrate with a quick, sharp motion as how to move the toy. The movement 3hould be made in a very marked way, so as to catch the child's attention. This type of demonstration is repeated until the child appears to have understood the procedure. Thus tho moving of the toy becomes a reguard for perception of the tone, while the penalty,of being prevented fromexecuting the pleasant action, points out to him that he has not followed the rules of the game. Thus the learning is based on traditional trial and error principles.

This audiometry was found to be successfully applicable to rd of the children between 2½ and 3 years. But variations in threshold measurement was more compared to adults. To counteract this, the play audiograms should always be based on two tests whose results do not diverge more than by 5 d3. The play audiograms was observed to correlate well with -"E.D.R. audiograms and follow up, audiograms. The play audiometry was found useful in children of ½ *years.* , where as Electrodermal response was found useful even in younger age groups, that is less than 2½ years. But when one is left to prefer between the two, play audiometry is preferable because the equipment necessary for this is less difficult to operate and less time consuming than that necessary for "Electrodermal audiometry. Play audion»try requires less personnel and it is based, On a pleasant experience compared to Electrodermal audiometry, which involves to an unpleasant experience.

Thus Electrodermal audiometry is Preferred to as a last resort, The reliability and validity of play audiometry was established in children of mean age of 3 yrs. 6mths. and 2 years 6 months and 3 years 4 months respectively (Lowell, 1975)

II. <u>Conditioned Orientation reflex Audiometrv (CORA)</u>

This audiometry was developed by Suzuki and Ogiba (1960) based on operant conditioning principle. In this procedure the signal is presented to the subject, through sneakers mounted at an approximately ^5° angles on both sides of the subject, These- authors advocated the use of mechanical toys as reinforce for the desired behaviours. In this procedure, the mechanical dolls were located immediately below the speakers. These dolls were activated whenever the child made a correct orienting response, that is if the child turned towards the source, every time the stimulus is presented. It was possible to estimate the thresholds during sound field testing, by using CORA.

The success rate differed for the different age groups. In children who were 1 to 2 years of age, the success was only 33.5% to compar d to 64% in children of 3 to 4 years of ago. The thresholds obtained by CORA ranged from *25.9* to 27.8 dB across the frequencies 500HZ, 1KHZ, 2KHz and 4 KHz in children of less than 1 year of age and the thresholds ranged from 11.4 to 12.5 dB across frequencies for children of 2½ to 3 years of age.

The conditioning was recieved by trials of combined tone-light stimulation and extinction was observed to occur within thre trials at 50dB and 2 trials at 10dB. This rapid was argued as an indication of inadequate achievement of conditioning in the subjects, in CORA (Pulton, 1978). CORA tecnnique was observed to have certain limitations like:

1. This did not permit bilateral threshold raeasuroments and only allowed for unilateral, that too better ear threshold measurement.
2. The stimuli as it was nresented through loudspeaker, is was not stable and was snsceptable to grosa intensity changes.

3. Th- speaker and dolls were placed in such a way that they could be by a very small angle of head or eye movement differentiation of accurate responses from random activity.

4. The localization responses were poorly defined and highly subjective.

5. No provisions were made for demonstrating discriminative responses (Fulton 1978),

6. Only *2* dolls were used which failed to maintain the child's attention and interest..

Fulton and Graham (1966) used this techninue and found it to be unsuccessful. Thus these disadvantages led to the development of Visual Reinforcement audiometry.

III. <u>Visual Reinforcement Audiometrv (VRA)</u> This technique was described by Liden and Kankkunan(1969). VRA technique developed as a result of failure of COBA in evaluating the hard of hearing population. This is n non-directional technique which takes into consideration, four types of responses to tone stimulation, that is reflexive, investigatory, orientation and spontaneous responses. The procedure for this techninue is as follows:

Picture slides which maintains the interest of the child were selected by preschool audio educators. These slides were projected on two frosted glass windows located on either side of the curved front panel of the box shaped apparatus. The switching of the slides from Rt. to left or vice Versa was arranged electronically with the help of mirrors. The switch board is placed on the audiometer. The loudspeakers were mounted on two seperate movable and nilustable arms making it possible to present the tones with an azimuth of 90° on each side. The following frequencies of steady tones were employed as stimuli: 0.25 KHz, 0.5 KHz, 1 KHz, 2 KHz,3 and 4 KHz. These test frequencies were later modulated and presented. The pre-sent it ion, levels ranged from -10 dl to 110 d3. The audiometer and the loud-speakers were calibrated by taking 10 normal subjects with thre-sholds in both ears being within + 5 dB (ISO standard).

The loud speakers were placed at a distance of 15 cms, lateral to the subject's cars and at an azimuth of 90°. The nontest ear was blocked with *nn* insert ear plug and was covered with aa external muff.. The thresholds were determined by the method of limits. A reference value for the hearing test of children was computed. This was accompllshnd by matching the attenuator settings to the attenuator settings in a minimal audible field in the absence of the subject to that of presence of the subject. The actual testing of the children was conducted in a sound treated room.

The loudspeakers were placed on the lateral side of the child's head to make use of the head shadow effect in seperating the right and left ear tone thresholds, as masking cannot be done in children most often. In normals, identical cure were obtained in both ears and therefore asymmetrical curve between the two ears was obtained, then a unilateral loss was suspected. The insertion of ear plugs increased the attenuation provided by the head shadow to the energy marking of the far ear. Thus even monoaural loss could be detected using VRA audiometry.

The child to be tested was first trained to respond to a tone coming from the same side as the subsequent picture. The subjects were not instructed to respond in any specific way and therefore this resulted in a wide variety of responses to stimulation. The children under test were also not provided with any information regarding the test procedure. The children below 3 years were provided with toys to play. For children older than 3 years, the instruction was that he was going to hear a sound in one of the speakers and then would he shown a picture. The testing was started at 600 Hz at a level of 30 to 40 dB above estimated threshold. The response noted in children less than 3 years was a stoppage in the act of play and looking up it the window or the audiologist. Same procedure was followed to obtain the threshold of both ears individually. Thus, monosural thresholds were obtained by this technique But by switching the tone from side to side, bilateral tone threshold also could be determined.

VRA technique was used to test 120 normal hearing children and 935 hearing loss children of age ranging from 3 moths to 6 yrs. All subjects could be successfully tested with VRA. Reliability was also established in hard of hearing and normal hearing children The thresholds obtaine by the technique in children was higher compared to adults threshold and the threshold approximated that of adults as they grew older.

The 4 types of responses that is reflexive, investigating, orienting and sponteneoas response was seen at different age groups

The reflexive behaviour was seen in children of loss than one year of age. This response was characterized by changes in the expre-ssion of the child's face, movement of shoulders and head. The changes in the facial expression were like wrinkling of forehead, widenine of eyes. jerking of lips or changes in rate of eye blinking.

The investigatory response was observed in younger age groups, as they were not able to immediately understand the connection between tone and Picture. The response was characterized by first looking at the loudspeaker and then associating; the tone with the and iolo gist and then facing the audiologist,

The orientation response was characterised by the child immediately looking towards the window.

The spontaneous response was the most highly developed response. Here the child used to report directly when the tone was heard. This kind of response was seen in older age groups of children.

Some differences were observed between CORA and VRA. In the younger age groups, that is less than 3 years old, the thresholds obtained from CORA and VRA were similar, but in children older than 4 years, the thresholds were better on VRA. In addition to the above, VRA had certain advantages over CORA. VRA could be performed in a shorter duration and as different slides were used, the value of reinforcement was higher and therefore maintained the child's motivation throughout the test administration. As no specific responses were demanded, it was easier to elicit the response, but difficulty *vns* in the evaluation of the true response. The validity of the technique depended upon the qualification and skill of the audiologist. Any unconscious changes in the expression on the clinician's face influences the child and therefore all these will result in erroneous interpretation of the response. But in spite of it the VRA is claimed to be a better techninue compared to CORA, because in VRA, no specific response is demanded and therefore co-operation from the child is not needed and as the practice effect is also minimal, the VRA was found applicable to children as young as 6 to 3 months of age.

Matking and Thomas (1974) used this technique in testing children of 6 to 35 months of age and they found that all children could be conditioned to one of the A trials. They recommended the use of the term minimal response level instead of threshold and reported of changes in the level with age uptil 23 months, and marking a plateau after that. Even after marking the plateau, the level was not equal to that marked by adults - thus according to the study, auditory acuity is a product of physiologic development. But Fultoni(1973) stand is that, auditory acuity is not a product of physiological development and whatever variations one observed in thresholds with variation in age is attributable to the type of task set up in different techniques of evaluation.

IV <u>Peep Show</u> : This techninue was given by Dix and Hallpike (1947). This was designed to avoid the two main limitations of conventional pure tone audiometry in its application to the evaluation of children. The two goals were:

1. to assign meaning to pure tones,and,
2. to overcome the difficulties encountered in getting the co-operation of the child for testing.

This was achieved by employing conditioned responses to a series of short pure tone stimuli delivered through the loud speaker.

The procedure of this technique is as follows:

The child is made to sit in front of the box, in which are displayed a series of attractive pictures. But in order to see the pictures, the child had to first illuminate them by pressing a button. This press-button mechanism was set up in such a way that it worked only when the synchronized light and sound stimuli were delivered,

The stimulation mechanism is controlled by the examiner. He is seated in another chamber and observes the child through a screen. The stimuli used are pure tones of frequencies 250 to 4 KHz. The intensity of the signal is varied by means of an calibrated attenuator dial. One instructor is seated in the test chamber to condition the child and to change the picture if necessary.

The tester first ensures that the child's attention is focused on viewing aperture. Then a double signal, the lamp flashes and synchronized impulses of sound through loudspeaker are presented. The instructor at once presses the button, illuminates the picture and encourages the child to inspect it. Once this has been achieved, the signal is withdrawn and simultaneously the picture is also made invisible. Thus two or three demonstrations are given to the child and then the child if encouraged/ conditioned to operate the button and illuminate the picture when and only when the double signal is given. As soon as conditioning is achieved, the light signal is slowly eliminated. This is done by using a shelter over the lamp. Thus at this stage it becomes a test of hearing.

In children who have severe hearing loss, the extinction of light signal eliminates the response completely. But if sufficient hearing is present then response continues to occur even when the light is extinguished. The intensity of the signal is then progressively reduced until a threshold is obtained. Once the threshold for one frequency is obtained, other frequencies are taken up for testing and the sarae procedure is used. In case of co-operative children, the whole procedure is claimed to take only 5 minutes.

The tone and light presentation are carried out electronically and the tones are presented in pulses to avoid artifacts due to standing waves. For successful testing by peep show, the child should be in an optimal state, the general stability should be good and he should have normal intelligence. The design of the peep show has been reported to be quite complex and its maintenance has been reported to be difficult. Therefore these factors hinder Its usage in the routine set up. But peep show has been claimed to be very useful as a rapid and efficient technique in the evaluation of children, the peep show has been found to be applicable in testing hard of hearing children as young as 2 to 3 years. Once the procedure is understood by the child, the testing can be done using earphones and 3C vibrators. In addition this technique can be employed to do hearing aid evaluation. This technique was employed to test children of 2 to 3 years of age. Successful audiograms were obtained with 3% of the children under 2 years of age and in 43% of 2 year olds and 80-93% in children 3 year or older.

V. <u>pup Show</u>: This technique is a modification of peep show, given by Green (1953). In this technique, instead of illumination of pictures, a tfry pup is activated. Consequent to a correct response by the child, here the interruptor switch of the audiometer is replaced with one having an additional set of normally open contents. The extra set of contacts are wound in series with the dog and Its battery. This ensures the non-activation of the dog, when its own switch is put on. For the activation both the switches should be closed. The battery used is of single 4½ volts instead of the conventional 2 volts battery. This is to prevent the stopping of the dog's motor at inappropriate movements when both the switches are closed simultaneously, then a series of movements are initiated in the dog. The dog takes 6 walking steps, a pause and 4 high barks. The whole cycle of walking and barking keeps repeating, until the circuit is broken either by the child releasing the button switch or by the tester interrupting the tone. To subs- titue the dog by some other toy, an auditory phone plug is installed in the rear of the audiometer which can be disconnected when not in use.

The child's fingers are placed hear the switch. The in- structions are given in pastomime or in spoken form that whenever he hears, tone be should press the button. Then the ear- phones are placed and the stimuli are presented at subrathreshold Levels initially. The child is conditioned to press the button on presentation of stimulus. Once the conditioning has been established, the test Is conducted using earphones and 30 vibrator, and thresholds are obtained for the different frequencies. If the interest in the test is lost, then a candy is to be provided. The candy is placed about a foot in front of the dog, and the individual being tested is encouraged to walk the dog toward the candy. Once this is done, the child is rewarded with the piece of the candy. The tester may hasten the child's reward by presenting sustained tones until the goal is reached. This technique is considered to be a simple, inexpensive and interesting technque especially for evaluating the hearing sensitivity of very young children.

<u>VI. Puppet in the Window Identification Test (PIWI):</u>

This technique was modeled on the principle of CORA. The difference being, in PIWI earphone are used and a 90°

localization response to the window is required. This technique was developed by Haug, Baccaro and Guilford (1967),

PWI Involves gross head turning responses to the sound source and which if correct is rewarded by an illuminating the window which contains different kinds of hand puppets. The procedure of this technique is as follows:

In the initial phase of the testing is done using free-field speakers. The child is seated on the mother's lap in front of a table on which are placed a number of gayly coloured nesting boxes or some kind of tpys. The position of the child is so arranged that ha is facing the source at an angle of 90° at a distance of 5ft. A clinician engages the child in play. In the other test chamber, the audiologist is seated at the audiometric console, with his one hand holding a bright puppet, with his other hand on the controls of the audiometer and his foot on the switch, which illuminates the window placed in the other chamber, A low frequency tone is presented in a beep-beep fashion. Once the tone is heard, the child turns towards the source. At this instant the window which is situated at the same place as the loudspeaker, is illuminated and the hand puppets in the window are made visible for the child. Gradually the intensity of the stimulus is reduced in 5 dB steps until the threshold is obtained. The reinforcement is provided in a controlled manner. If the child responds too soon or too long after the presentation of the stimulus then the window is not illuminated, depriving the chili his reinforcement and thus extinguishing the random responses of the child. Once the threshold for one frequency is obtained, similar procedure is employed to obtain thresholds for other frequencies. At the conclusion of the free field testing, earphones are placed on the child's ears. As the child has already been motivated by the reinforcement provided to them, he does not resist wearing the earphones. If the child refuses to wear the earphones then smaller and lighter headset should he used (hearing aid receivers). The stimulus is presented to the ear nearer to the loud speaker employed, as he will continue to turn towards the window. After testing the nearer ear, the opposite ear is taken up for testing. After this, as a double check, the two ears are tested, randomly to confirm the thresholds obtained earlier. After "AC" testing, the BC testing is done by placing the vibrator on the mastoid. Same procedure as for AC is employed, To hold and maintain the interest of the child, 7 different pupets are used. The total time for the completion of testing was found to be around 30-45 minutes.

To validate the PIWI technique, the author tested 54 infants, age ranging from 5 to 36 months using this technique. The results obtained from this technique was compared with the otological findings and history. The correlation between PIWI and history and otological findings was found to be high. Thus they claimed this technique to be a valid test for the evaluation of young children. But the drawback of this technique is that, the success is dependent upon the skill, training and experience of the children.

VII. Peek-A-Boo Audiometry:

This test was given by Vander Host and Kuypey (1969). Here the authors stress on the interrelationship between the observer and the child rather than the rest task, the instruments required for the administration of this test are: a specially constructed trapezoidal table, audiometer, tape recorder, sound filter set and power amplifier.

The child is seated on its mother's lap in front of the table. On the other side is placed the loudspeakers with lights. The border of the table on the chill's side is lowered, so that the child is in a position to see the examiner and thereby providing a feeling of security to the child. On the table, holes were seen near the loudspeakers. These holes were used to show the dolls from each hole respectively depending upon the loud speaker being used. Totally 5 identical dolls were utilized. Out of the 5, 4 dolls were mounted on wooden pillar, so that they could be raised to any level soundlessely. With the help of nylon cords and wheels dollsware connected in such a way that they can be replaced for any other toy.

On the tester's side of the table, are provided switches to choose one or more loud-speaker (selection switch) and cords to raise the dolls. He may choise the sound normally produced by a doll but usually this is not done so. The observer's main task is to control the situations and alter the program, and also see to the comforts of the child as well as the mother.

The observers/is placed at a distance of 2ft, away from the child which aids the observer to record not only the slightest eye movements but also other kinds of small changes in behaviour. The audiometer, the tape recorder and the filter set will be placed near the 2nd observer, such that the child is not distracted either by the apparatus or anyone manipulating it.

In this test, the pure tones are presented as a short pip or sometimes as a series of pips in a rhythm corresponding with the raising of the toy, This is partly to maintain the interest of the child. Another alternative which is used to avoid boredom setting on in the child,instead of obtaining the threshold for one particular tone scaning the audiogram by first presenting all tones at one intensity level and then at another and so on is employed.

First the mother and the child are put at ease, then to catch the child's attention a doll is shown and once the attention is captured, the doll is withdrawn and immediately a rhythmically interrupted tone is presented from the right (1000Hz) at an intensity of 60 dB. The child may react to the presentation of the stimulus in any one of the following ways:

1. he may turn his head towards the source immediately following stimulus presentation. Such a kind of response indicates that the directional hearing is present.
2. he may either start looking about the room. This indicates that he may have heard the tone, but is unable to localize. This has been explained on the basis that the prediction of direction of pure tones is very difficult especially for clicks and therefore the second response is considered to be quite normal.

3. he may not respond to sound but may do so to the doll, in such a ease, the clinician should try once again by presenting another sound.

4. he may not respond to sound as veil as doll. In such a case, one should refrain from further testing using acoustic stimuli but should test and try the effects of lights with a variety of tendercies dolls to see whether there is anyantistic in the child's behaviour.

The conditioning of the child is carried out in the following steps. First the client is shown the doll each time there is the presentation of sound, Using loudspeakers. Then the sounds are presented from various directions and the corresponding dolls are shown. 3ut this is not used in cases vith asymmetrical loss, (l) To condition the child to the character of sounds low tones to the left and high tones to the right or leud to left and soft sounds to the right is presented (2) In this condition the conditions 2nd and 3rd are combined, here. The child is conditioned to the character of the sound as in the 3rd condlton, and a sound is presented from a wrong loudspeaker, Normally in such situations also the first motion is towards the sound sourde because that is a reflex and the second reaction is in the direction of the dolls.

The results obtained with a Peek-A-Boo audiometry when compared with pure tone audiometry at a later date,revealed a high

correlation.

VIII Story Telling Audiometry:

In this technique, slide projectors are made use of, to keep up the motivation of children throughout the test administration. This technique was developed by Miller (1963),

This technique consists of two categories of slides. The first is composed of a series of pictures that are basically unrelated to each other. This series contained pictures of animals, toys, Scenary etc. The selection of a colourful and a variety of material was used to motivate the group of younger children. The second series of pictures depicted a complete story about the real or functional, images of animals and children. T e child was instructed to press a button w he never he heard the sound. This series was for oldar children, whose age ranged from 4 to 6 years. This technique was found successful in maintaining the motivation of the children under test.

IX. Fairy tale :taudiometry in children:

This audiometry has been advocated by Lesak (1970). In this technique, the child under test is shown a toy house and a fairy tale regarding the bewitched people is told to the child. He is infomed that people, animals and many other types/kinds of things are present in the house, but as they are all bewitched, they are unable to get out. Sometimes they cry out for help and only when the child presses the magic mushroom, can they be freed. In order to hear their cry, the telephone receiver hage to be worn, which are in turn connected to an audiometer.

The child is also told that if the mushroom is pressed without their cry for help, will only result in disturbance, and they will be asleep and therefore will not free them. So with this background, the pure tone stimuli are presented and the thresholds are obtained. To maintain the child's at ention, throughout the test administration, the figures in the fairy tale are chosen to represent certain frequencies. The advantages of this technique as claimed by the authors are that it is a special kind of psychological approach, it is a simple and small device which is easily operated. One major positive point of this techninue is that it most often keeps the child interested and motivated throughout the test administration. This technique was found to be useful in children of 8 months to 2 years old by the authors.

X. Tangible Relnforcement Operant Conditioning Audiometrv (TROCA)

This was developed bated on the Motion, that the intangible reinforcements are not very effective in eliciting the desired responses, especially in mentally retarded children. Therefore Spradlin and Lloyd (1965) developed a techninue using tangible reinforces like Candy, cereal, trinklet etc., which is termed as TROCA. The procedure for this technique is as follows:

Prior to testing, an appropriate reinforcer is selected. A reinforcement schedule best suited for the subject is set up. Then instruction is given to the child, that whenever the sound is heard, he has to press a button. If the response is correct, then the tangible reinforcements are provided. On the other hand if the response is incorrect then a mild punishment (time out) is given. This techninue was found to yield a success rate of 60% In infants of 5 months of age (cited in Gerber, Jone3 and Costello (1977). But when TROCA and Peep show results were compared in normal hearing children 25 to 32 months, the peep show was observed to yield better results (Stern, Cole and Gans 1980). Therefore they rejected the assumption that type of reinforcement has a significant influence on the behaviour.

XI. Reaction Time audiometrv (RTA):

"Reaction time, is tha tisse elapsed between presentation of a stimulus and the subject's response," (Rapin 1964). Reaction time can be used to as rapid responses occur only in motivated individuals. The importance of motivation is the success of any technique of evaluation has been stressed by Rapin (1964). According to him the lack of motivation accounts for children's failure to respond. In addition operant conditioning which aimsat maintaining the motivation, should provide reinforcement for rapid responses. Thus reaction time measure has an important role to play in the determination of response to a stimuli especially in children. The reaction time has been observed to increase markedly when stimulus intensity reaches threshold (Chocholle 1945). Thus this measure can be taken as index of hearing sensitivity also.

The author conducted the experiments to study the auditory and visual reaction tirae in normal children and hard of hearing children. Based on the reaction times in the tvro condition, the hearing sensitivity was estimated. If a child responds rapidly to visual stimuli and not it all to auditory stimuli,he is probably not perceiving tho auditory stimuli, thus may be a hard of hearing candidate. On the other hand, if tiv child's responses are fast to light stimuli but very slow to acoustic stimuli then it is probable that the sound is near his threshold level. If the child does not respond to both the stimuli then the inference would he, that the child has a problem other than simple auditory disorder. The threshold estimated by Auditory Reaction Time audiometry vas found to be within 10 dB of conventional puretone audiometry. The auditory RT was found to be less than visual in normal children, and RT for the stimuli was still better. In hard of hearing children visual RT was better than auditory PT.

From the experiments conducted, they concluded that the reaction time to visual and auditory stimuli interact and manifest in improvement in response. The reinforcement also increased the RT. This technique was c.tairasd to be « useful for evaluating hearing impaired population for chlldren of 5 years and above Intelligence and brain damage without any motord effects was not found to interfere with testing. But age had an effect, as younger the age of the child, the longer was the reaction time

(Teichner 1954). Bentra and Joynt (1959) found brain damage also leading to increased RT in contrast to Rapin(1964) The reinforcement was observed to have a significant effect upon RT. The use of light as well as sound was found to have two advantages Delivering of stimuli which are readily perceived and responded prevents the flagging of attention and motivation can be maintained. Secondly the latency difference in the response to the stimuli gives information regarding hearing loss, lack of motivation and distractability and or brain damage. The positive point of RT is that it/only gives an Yes or No answer but also indicates the threshold level. In addition, the equipment to measure reaction time was found to be very simple and inexpensive. The stimuli is programmed manually. A his switch starts the clock and turns on the stimulus simultaenously. The subject can have the control to switch off both the stimulus and the clock. The reaction time is read from the clock, by the experimenter,

delivers the reinforcement when necessary. The stimuli most often employed is a light torch powered by a battery and a standard audiometer with an added switching device, such that it will stay on until the subject turns it off by pressing on his key.

Thus the author concludes that the reaction time to evoked auditory and visual stimuli to be a simple and promising techninue to estimate the hearing function in children.

Advantages of operant conditioning techniques

These techniques provide for an objective assessment of the auditory function in children. This aids in sustaining the motivation of the child under test. The method of presentation can be varied to suit the behaviour and ability of the individual tester and this is a statistically reliable measure of response ability (Roberts (1972).

The disadvantages of these techniques are. these have limited application to the testing of hearing impaired children. This is because, the conditioning principles are all based on feed back from response, situation, which itself is disrupted in hearing impaired population. Therefore conditioning techniques will beefno help untill the subject is aware of the importance of sound per se to the response situation. A hearing impaired child fails to understand this relationship and will try to respond on the basis of his everyday behavioural repertoire and this will interfere with the accuisition of the correct response and prevent consistent reward. This will in turn result in frustration and the child will lose interest in the test situation.

One remedy for the above problem is the use of cross model facilitation technique. This is a two stage oparant procedure. First, conditioning is established with some other modality. Most often visual is chosen. Once the child understands the task, the auditory stimuli is introduced and gradually the conditioning for the visual stimuli is substituted for auditory stimuli. The advantages of such a procedure is (l) the tester has been taught the necessary skill for proficient response in the test situation. (2) the co-operation and interest of the subject is established, (3) a base line measure of the tester's general performance ability is obtained, which can be used to Judge response to auditory stimuli (Roberts (1972), (1976))

Thus by employing the modification mentioned above, the conditioning techniques can be used in clinics to evaluate the auditory function of children of varying age groups and also the difficult to test population.

SPEECH AUDIOMETRY IN CHI LDREN

INTRODUCT ION:

Human beings are viewed supericy- to other earth lings due to therrability to communicate *verbally*. This communiciation comprises of expression and perception of other's speech. The speech perception ability- is dependent upon one's ability to process speech through the ears. Thus a test for the assessment of communication ability should potray the specific perception problems encountered by the individual and suggest ways and means for rehabilitations.

Among the plethora of test: available for such evaluation, pure tone audiometry.has been employed moat often. But even this has certain inherent limitations in its aplicability to the assessment of speech perception processing.

The nature of the stimulus used in pure tone audiometry is abstract. It is uncommon, as pure tone are not experienced in one's communication. It does not provide information about a person's speech discrimination ability.

Hardy and Whetnall (1964) argred that pure tone are in no way related to the speech which the child develops ultimately. Therefoie pure tones should be substituted by speech for evaluation of he ring sensitivity in children. In addition learning occurs for speech as well as for pure ton s and as speech is the desired stimulus, one should promote learning for speech.

Some of the other drawbacks of pure tonrs are that it is unfamiliar, uninteresting and does not tap the speech perception ability adequately.

The disadvantages of pure tones audiometry initiated research for more refined procedures/ led to the development of speech audiometry.

- Speech audiometry can be defined as a set of procedures which allows for systematic presentation of carefully selected speech stimuli through a calibrated communication system and controlled enviornment" (Fulton and Lloyd(l975)Speech audiometry mainly deals with three dimensions of speech perception process. First is the speech detection threshold which may be defined as "the level at which a listner may just detect the presence of an ongoing speech signal and identify it as speech". (Martin 1973)

2. Speech reception threshold: defined as the lowest hearing threshold level at which atleast 50% of a list of spondiar, words can be correctly identified (Martin 1975).

3. Speech discrimination: which is a measure of an ear's ability to understand speech at supra threshold level.

History of speech audiometry:

The concept of the usage of speed in testing the hearing sensitivity was first suggested by wolf in 1874. He stated that "the human voice was the most perfect conceviable measure of hearing". He constructed a table consisting of intensity values for the various sounds of the German language. His measure of intensity was paces or distance from the speaking source rather than decibels. In his list he made use of syllables and words. Later in 1390, he recorded the words on an edison wax cylinder and presented the words to the ear of the patient through adjustable tubing which had provision ror the control of intensity of the record, d materials (0 'neill and Oyer, 1966).

The first systematic usage of speech was in the assessment of various sound transmitting and amply-fying systems.

compbell(1920) developed a method for assessing the efficiency of sound transmission of the telephone. He made use of nonsense syllables consisting of various consonants followed by a vowel/i/. Crandall modified this and formed the standard articulation test.(cited in Jerger 1973)

In 1927, Fletcher devised the 1st speech audio-meter (Western-Electronics 4-A) and employed it for group screening. But this audiometer had little clinical utility (cited in Jerger 1973).

In 1929, Fletcher and Steinberg an their associates at the bell telephone laboratory designed a method ror the assessment of various electronic comunication systems. They made use of speech for this evaluation, Main emphasis was placed on the trans-mitting system.

In the estimation of speeen perception ability one is interested in tr listened Therciore using the same speech materials, the ability of listener was evaluated keeping the speaker and the transmission: system constant.

A speech chain represented in Figure-1 gives a clearer idea about the links involved in speech audiometry.

Figure:1

(Rose, cited in 1978, P-229)

By manipilating only the listner link, one can study its functioning under different circumstances.

Fletcher(l929) also gave the concept of articulation function displaying the accuracy of speech perception as a function of signal intensity. He assigned percentages to the correctly identified, words on the standard articulation test. His work was an important milestone in the develcpmen" of speech audionjetry.(cited in Jerger 1973)

Hughson and Thompson(1942) using the materials of Fletcher(1929) developed a monitored live voice technique for the computation of the threshold for speech. They also established the relationship between pure tone and speech threshold. This work actually predated the use use of speech audioraetry as a clineal tool.(cited in Jerger 1973)

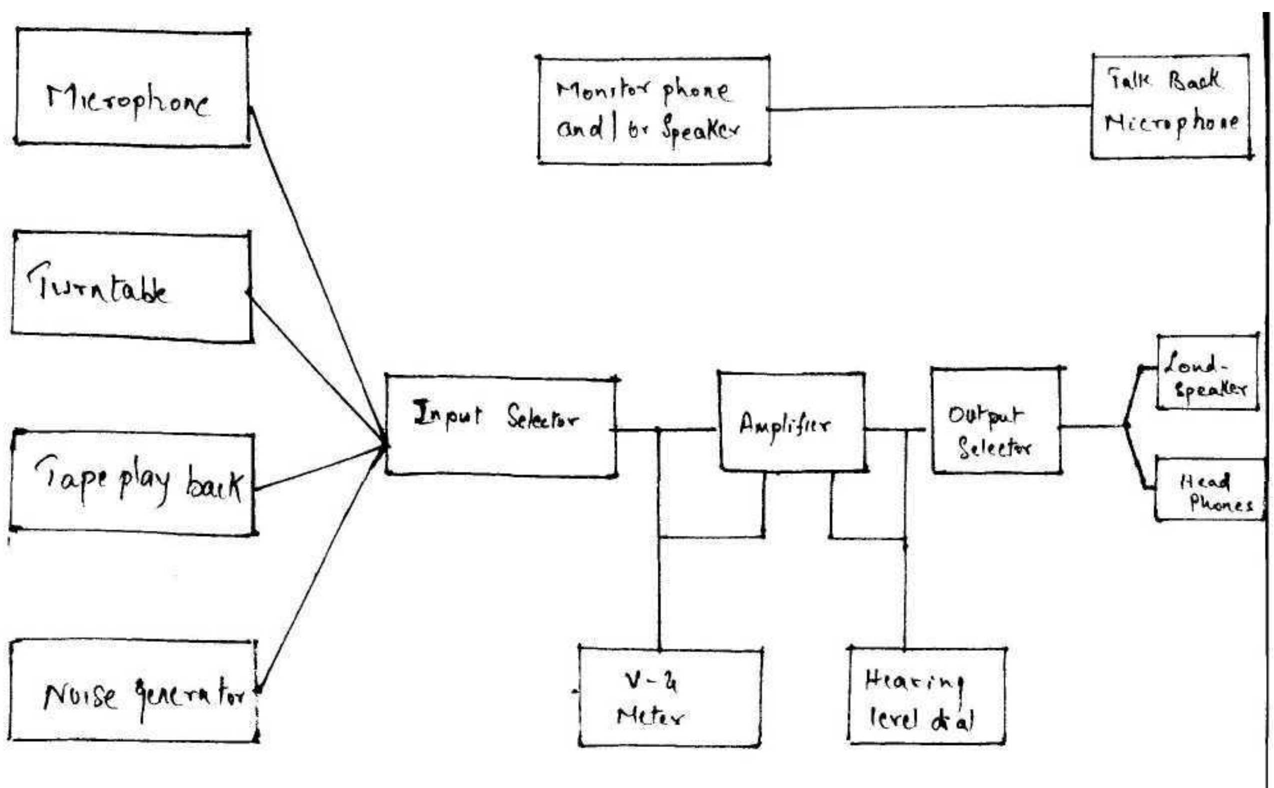
In the initial stages, speech audiometry was used only to measure threshold sensitivity with the advent of aural rehabilitat on programs during world war II

supra threshold speech audiometry was also included in the program.

Thus the clinical speech audiometry which is so widely used now came into existence from the basic work of Fletcher(l929) and his associates at the Bell telephone 1 boratory (cited in Jerger 1973).

<u>Instrumentation for speech audiometry:</u>

Fig.2 Block diagram of speech audiometric equipment (Rose, cited in 1973, P-234 P-33-39)



Variables in speech audiometry:

Interaction among a number of factors is encountered in the administration of speech audiometry. All these factors have a cumulative effect on the data, obtained from this system. To ennumerate the influence of these variables on the results, they are discussed under the following 4 categories.

1. Stimulus variables,
2. Procedural variables,
3. Response variables, and
4. Miscellan ous variables.

I Stimulus variables:

The main factor that will be taken up for discussion under this, is the material employed in speech audiometer tests.

Ample varieties of speech materials have been employed in the administration of different speech tests. These actually range from one extreme to another on a contiinum. At the lower extreme exist simple materials like phoneces, syllables and words. These stimuli are preferred lor their ease of pre- entation within a short duration of time and ease of scoring on the basis of right or wrong extension.

The main drawbacks of such samples are they do not actually conform to the audiotory experience of an individual in the real life situation. Though a certain relationship does exist between the two.

At the other extreme of the contineous are phases, sentence and connected speech. These actually are the representations of conversational speeci • "The drawback in using these is the difficulty encountered in scoring. One more limitation is the influence of language on these tasks. (Bess, et al. 1977).

Thus while selecting the material for speech tests, one should weigh the pros and cons of the different materials and choose the most appropriate for the task at hand.

Some light 111 be thrown on the different materials that have been in usage since the development of speech audiometry in the following section. The discus ion will be in a heirarchial fashion; that is starting from nonsense syllable and ending it up with connected discourse.

Nonsense syllables:

The application of theee syllablus can be traced way back to 1910, when the telephone industry was ir the process of evaluating the eficiency of various electro nectransmission systems.

The first systematic use of these syllables was by Campbell and Crandall in 19 . They constructed a list of nonsense sylables using CVE and VC combination and termed it as "standard articulation test"; This list was employed to compute efficiency of telephone circuitary

In 1929, Fletcher assigned percentages to the scores and came up with the concept of acticulation function describing the accuracy of speech perception as a function of intensity. This actually was used later as esti- mate of the speech discrimination ability of an individual.

Nonsense syllables were employed mainly because their perception was not dependent upon the vocabulary of the listener. Therefore it was assumed to present a true picture of discrimination ability.

The above assumption does-: not absolutely hold good us these syllables have quite number of limitations which overrules their potential applicability.

These items are considered to be quite abstract and thus difficult for most individuals. Lehiste and Peterson(1959) opicned that items which are devoid of symbolic content tend to measure recognizability rather than intelligibility. Thus it does not tap the right measure.

Hirsh(iy64) has also argued against the use of nonsense syllables by stressing the importance of contextual factors, in intelligibility measures. Leton (1966) has stated that nensenre syllables are net easily applicable as most subjects have tendency to look for meaning in the stimuli pree-en ed and respond to it in a known term.

Zakrezewski et al.(l975) in their study compared the discrimination scores for nonsense sylables and meaningful stimuli in chil ren. They obtained poorer scores for nonsense sylables. This was attributed to leser number of correct guess due to the lack of contextual cues.

Henceforth the use of nonsense syllables in clinical set up has not been advocated.

Monosyllables:

Monosyllables are lens analytic compared to nonsense syllables.

The first investigator to use monosyllables was Macfarlan(l940). His list consisted of first 500, words from thorndke's lists and first 50 from gates lists. The resulting word list was recorded and presented from inaudible to an audible level to obtain a measure of speech reception threshold.

Once the word was identified, the record was speeded up to cut off the low frequencies and response was obtained for this condition. A comparison of the two scores was then made to gain information regarding the individual's sensitivity in different frequency regions. The drawback of his list was the lack of phonetically balanced words.

The term phonetically balanced list refers to a "list of monosyllable words that contain a distribution of speech sounds that aproximate the distribution of the same sounds as they occur in conversational American English". (Hirsh et al.1952).

The first person to incorporate this concept was

Egan(l943). His list came to be termed as PAL PB.50 word lists.

All the lists which developed later, used phonetically balanced mono syllabic word lists. Some of these lists are: CID 20-22, NU-Auditory teat, Multiple choice tests like: Faribank's Rhyme test( ), modified rhyme list by Honbe et al(l965, 1963) and phonotically balanced rhyme list(PBRT) by Clarke (1965). These lists were used exclusively in the evaluation of speech discrimination ability.

A description of the above lists will be given under the section, speech discrimination tests

Though monosyllables are being used extensively Some suggest the use of disyllabic words inetead of monosyllables because of certain drawbacks of monosyllables.

Egan(l943) has started that with greater acoustic redendancy in a speech signal', the discrimination scores can be improved. On this basis, one can infer that an increase in the number of syllables, increases redundancy and in turn improves discrimination. If this be be the case, then, di/poly sylables are preferrable to monosyllables . The latter is more applicable in children with SN loss associated with signs of dysacusis. (Speech discrimination dinicul ty associated with loss of sensitivity)

Erber(l974) also opines that monosylables are difiicult for children with hearing impairment. Spondees are preferable because they give more cues. They also aid in the differentiation of those he ring impaired children who recognise speech using,, special emes and those who make use of time intensity patterns alone. The spondees are more meaningful and easier. Therefore more ap licable in children.in comparison to monosyllables/

nonsensesyllables

Egan (1948) disagreesmith use of polysyllables. He argue that, the scores obtained from polysyllabic lists are affected by psychological factors to a degree greater than for monosyllables. Therefore the validity of the scores obtained from former is questionable (cited in Watson & Tolan P.451).

In spite of certain limitations , monosyllables are being used even now as a measure cf speech discrimination skills.

Disyllabic words:

These words are still less analytic in a ture compared to the nonsense and mono syllables . The perception of words are easier, compared to monosyllables. This is because for discriminating monosyllables, one must perceive the individual phonetic elements where as one can discriminate dioyllables making use of phonetic elements and stre-as pattern.

Disyllabic word with equal strees on both are termed as spondees (Hirsh et al l952). The first use of spondiac words was in mditory test.-—No.9 developed at Harvard univ during the 2nd world war. This was used to measure the speed r eception threshold.

Most cf the lists of SRT have used spendiac words, some of these are CID w-4, CID-W-2 and PAL. auditory test No.14. The criticism against the usage ofspondiac words is that, they do not incorporate the changes in speech pattern oven time which has quit e an important role in the understandigg of ongoing speech. Therefore use of longer speech samples are recommended.

Sentences:

Fletcher and Steinberg(1929) were the first to incorporate sentences in the lists for speech perception ability. Their list consisted of interogative sentences, the response task being t o answer these questions.

Hudgins et al(l947) have used sentences in the construction of auditory test No .12 at PAL. & Even this list was a list of questions requiring one word answers. later at the central intitute for the deaf, a list of sentences which reflected everyday's speech with natural inflection, tempo and emphasis was constructed. The only drawback was the recordin s of this were not available for comrrercial use.

As such very few tests choose sentences, as their test stimuli material because of certain limitations of this material.

The meaning of a sentence is 'nctt often conveyed by one or two key words, Therefore one obtains an over estimated scores when ouch matter.ials are used.

Secondly for reliability checks, the formation of equivalent lists are quite ardous because of the influence of word familiarity, length of the word and sentence and the syntactical differences encountered in this kind of speech samples. Scoring is also a problem in such samples.

Egan(l944) has pointed out that the scores obtained from sentence lists are quite high and does not aid in differential diagnosis. The influence of memory is high in such materials.

Fletcher and Steinberg(1929) have found the correlation between the sentence and syllable scores. A score of 20% for syllables is equivalent to 75% for sentences. This is because the ear fills in effectively for most of the missing elements in sentence and thus compensate for the loss.

Therefore except in systems where in the syllable lists results in very poor scores, the sentence list have not been used in the routine clinical battery of lists.

Connected discourse:

Falconer and Davia(l947) were the first to suggest the use of connected discourse or cold running speech to measure SRT.

They found the results were as accurate as withapondees and the list took only about 5 minutes. This list was termed as "threshold of intelligibility for connected discourse".

later in 1952, Hirsh et al. also supported the use of connected discourse, they made use of a paragraph which was un-interesting and uniformly monotones. Use of such a paragraph yielded minimum variability in the intensity of presentation of stimuli. By manipulating the physical dimensions of the stimulus, the intellibility scores were . But the intellgibility scores would be

an overestimation, as in connected discourse the meaning conveyed

few keywords. The formation of equivlant lists and scoring is very d

Therefore though the use of can acted discourse has certain advantages, the "limitations are more so". Therefore it has not been advocated for routine use.

Some of the other parameters which are to be discussed under stimulus variables are, whether the:

1. list can be shortened,

2. lists should be homogenous, and
3. phonetically balanced.

Full vs Half lists:

Pull lists consume a lot of time and this acts as a severe limitation in certain cases and especially so in children whose attention span is quite short. This led to concept of shortening of lists. lists can be shortened either by using half or odd even division of the list can be made.

The criticism against use of half lists is that, in the construction of half word lists no consideration is given to the level of difficulty of words and the phonetic balance of words (Grubb 1963). He has stated that the pact whole co-relation obtained will usually be high and therefore should be interpreted cautiously.

Elpern (1961) and Campanelli (1962) and Resnick:(l962) have found high corelation between half list scores and full list scores in adults for to-22 and PB-50 lists.

Carhaart(l965) has also opined that there is little to be gained by using full lists.

Shutts(l963) constructed half word Hats giving consideration to average range of difficulty, phonetic balnce and frequency of occurence of phonetic elements. A high co-relation was obtained between half and full lists.

Kenneth and Berger (1971) have also reported of high corelation between full and half lists of W-22.

Maki and Beasley(1975) found a. positive corelation "between half and full lists of PBK-50 .word lists.

As the validity of half list is confirmed by many investigators these lists are being used in obtaining the speed reception threshold in Children as well as in adults.

Homogeneity:

Homogeneity can be achieved either by recording each word in such a way that all tend to be heard at the same intensity level or by selecting only, those words that tend to reach the listener's threshold, at the same intensity level (Hudgins et al.1947).

The relative homogeneity is represented by the slope of the articulation curve. The steeper the curve, better is the homogeniety (cited in Pulton and Lloyd 19 75)

The advantages of having homogenous words as the threshold of hearing can be reached within a narrow range of intensity/with precision.

as the articulative curve The from 0-100% in a narrow range.

of intensity (Tillman and Olsen (1973))

Phonetic balance:

This is based on the relative frequency of occurence of various sounds as they occur in English. To compute the frequency of occurs- either written or spoken material is chosen.

The written material is not apropriate as while measuring different aspects of speech pe ception, One is interested in conversational speech rather than the written form. Therefore, while forming a. phoneticaly balanced word list, one should select the words from spontaneous speech. Telephone conversation has been used by someto achieve the above.

Phonetic balancing of words is importan , if one wants to infer about a person's ability to understand speech in real life situation from the scores obtained on certain tests.

II. Procedural Variables:

These pertain to the factors that operate during the process of presentation of the stimulus Quite a number of factors have to be considered during the presentation of stimulus to obtain reliable results.

In this section only those parameters which have a major influence on the performance will be discussed.

A mjoor issue in the administration of speech audiometry is the controversy that exists regarding the mode of presentation. The two modes of prssentation available are live voice andl recorded. A number of arguments have been putforth for and against the use of both these procedures. A few of these will be highlighted over here.

Live voice presentation:

The criticisms against its usage is that the speakers differ in the may they present the stimuli and therefore the data obtained from different sources cannot be campared (Brandy 1966).

Brandy (1966) has demonstrated the variations in the pouostic waveforms of the same words list presented by different talkers to support his argument.

exist large difference between one recording to another as that between two live voice spekers (Garhart 1965). thus limiting the usefulness of recorded presentation.

Hugins et al. portman and portman (1961) state that the flexibility is lost in recorded presentation, that is, the provision to manipulat the material to suit the individual's need. Their stand is that, the familrity of the words differ from individual to individual andl each one taks his own time to respond. In such cases recorded presentation will be a*n* *u*tter failure. The other point on which they argue against recorded prsentation is that it floes not actually mesure the social adaquacy of an individual as it, does not take into account, tha ability to lip read which contributes to quits an extent in the understanding of speech.

'the dynamic range of in ensity is found to be wide for live voice compared to recorded, She range for like voice is supposed to be 80dB or more, where as it is limited to 30dB in racorded presentation.

Some studies have acutally reported of no difference between the two presentation (Havis 1946, and O'well and Oyer 1966).

Recorded presentation:

The drawbacks of this has already been mentioned. The adantages of this procedure has been listed by Watson and Tolan ( ).

1. Recording offers standard tests which are checked for .alteration, uniformity and accuracy.
2. Ambient noise does not affect mcuh..

3. Can test subjects both. monorurally and bi-namolly. This being sot possible by live voice in a single zoom test situation.
4. Accuracy of results is better assured with recorded procedure.

Some of the other advantges are - high reliability of results and ease of compaison between different date.

Thus when the two are weighed, each has its omn merits and demarits. To counteract some of the limitations-of live voice, monitored live voice presentation has been recommended..

The use of monitored live voice presentation has been found tobe quite useful in testing particularly children and aged persons. Presentation of tests word a influence the discrimination scores to quite an extent.

Northern and Downs(1974) have stressed the importance of earlier hase and suggest that it should be presented 10 to l5dB above the presentation level of the test word •

Mertin and Weller(l975\ have got results contradioting to alll other studies. They found that presence of caviar phase and its sensation level did not have a significant effect on the SRTs in adults. Ihey stated that this result cannot be genaralised to children-

Thus except for Martin and Weller's(1975)study all others have noticed a correlation between carvise-phase and performance specially in children.

Familarity:

Jegger et al 1959 Tillian and Jarger 1956 have stated that familarisation of the test word lowers threshold and results in better test retest reliability tapis unffamilarised words lists. The difference in the scores is given to be 6dB. Conn et al (1975) have also got similar results as Jerger and others. More number of correct responses and fewer erroneous responses were obtained for lists with familarisation.. They also found that 15 words of the CII 20-1 list was not affected by familiarisation,

Carhart.(1946) has also stressed the importance of pretest familiarisation especially in children..

De watchter and Schaerlacking (1969) point to the need for familarisation of words list in chidren especially those with low level of intelligence.

Licklider and Pollack have reported that scores obtained for lists not famailiraised will be *15%* higher than for familarised words lists.

All the above mentiond studies point to the existence of a posture correlation between familarisation and test scores. Therefore prior to testing, one should familarise the subject to the test material.

Some of the other procedurall variable are: level of presentation, channel and the test enviornment.

Level of presentation;

Most often the level chosen is that which is most comfortable to the subject. She material is presented at this level and once the response la elicited, then the level is decreased gradually to obtain the threshold for speech,

Channel:

Some prefer presentation through loud speaker. Their reasoning is, this is more or less a-imulates the real lift situation. But this procedure has limitation like, the sensitivity of the two ears cannot be measured individually which has importance for rehabilitation.

Therefore sound field presentation is preferred only when the subject does not accept the earphones. This is encountered most often in young children.

Test enviornment:

Sound treated room is opted most often, but in some, condition like testing of young children, an ordinary room is preferred. This is because the sound treated room will be unfamlliar to the children and will elicit fear in them. This inhibits their co-operation. Therefore in such cases a room with minimum ambient noise and assembling the natural enviornment is to be used.

The other main category which has significant effect on the results of the speech audiometeric testing is response Veriables.

Response variables:

In this category the two main factors thft will be discussed are mode of response and the influence of re-inforcement.

Mode of Response:;

The conventional type of response is the repetition of the stimuli presented. This mode is most inappropriate for children and for difficult to teat population. In such cased alternative type of responses like nonverbal responses are chosen.

Nonverbal responses can be either pointing to words or pictures, picking up the appropriate card or it can be a written response. The former methods pre most often em-ployed in the evaluation of young children.

Reinforcement:

Berlin and Dill (1967) have reported a signifi-cant decrease in the number of errors with reinforcement regardless of the race of the children on wepman auditory discrimination test.

Eisenberg et al (1974) have also reported an increase in response with reinforcement.

Merenolds (1969) has stated that the conventional intangible reinforcement like a smile or -verbal rein-for cement does not carry much value for children, there-fore in such cases tangible reinforcements have to be used.

Smith and Hodgson (1970)studied the effects of systematic reinforcement on the discrimination scorea of normal and hearing loppired children. The reinforcement used UPB marbles which could be traded for toys/candy. Smith and Hodgson observed a significant improvement in the scores in both groups of children in the reinforcement condition. This improvement was attributed to an Increase in the attention pnd interest of the children on reinforcing the correct response.

Gayer and Yankaner (1972) have also pointed to the value of tangible reinforcement compared to intangible ones. They further state that toys are better reinforces than pictures because the former provides for both visual and tartual reinforcements.

Mertin and Coombes (1976) also stress the use of tangible reinforces for children.

Therefore from the pbove studies, one can conclude that tangible reinforces should be adppoted while evaluating children to obtain reliable responses.

One point to be borne in mind is/the schedule of reinforcement should be formed elicits optimum responses.

<u>Miscellaneous Variables:</u>

These refer to factors such as memory, maturation, practice, duration and fatigue.

Therefore from the above studies, one can conclude that tangible reinforces should be adopted while evaluating children to obtain reliable responses.

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Miscellaneous Variables:

These refer to factors such as memory maturation practise, duration and fatigue.

While one essesses to speech detection, recertion and discrimination ablities in children all the variables listed and destribed above should be considered. These variables should also be included while reporting any data regarding speech audiometric measures, in order to facilitate comperison of studies.

Speech detection threshold:

Speech detection threshold is the level at which a listner may just detect the presence of an ongoing speech signal and identify it as speech(Mertin 1975). This is also refered to as "speech awareness threshold" (SAT). This is most often used in the evaluation of young children who fail on pure tone audiometry and other measures of speech audiometry like SRT and speech descrimination tests. SDT is considered to be an ldeal measure for children who are incable of giving verbal rasponses, that is, very young children and the difficult to test population.

The procedure involved in obtaining SDT is very simple. The material used is some common and simple words, sentences, or recurring speech. The child's task is to just lndicate whenever he hears the speech. The lowest level at which child can still identify the signal, is taken as his SDT. Speech signals are broad band signals and in SDT one is measuring only the level of detection and not either perception or comprehension, therefore the SDT can be more or less equated to the threshold for broad band signals, like buzzer, etc(Hirsch 1952, cited in Martin 1978).

The SDT does not reflect the pure tone configuration, but Frisina(1962) has tried correlating the SDT and pure tone audiogram. He has observed SDT to be within plus or minus 5dB of 500 Hz threshold in flat or high frequencies loss audiograms.. At other frequencies he failed to obtain a correlation. The reason expounded by him, is that in the spectrum of speech, energy la mostly concentrated in the Ion frequencies and therefore the SDT can be correlated to threshold for low frequencies tones and not for high frequency tones. In general, though SDT can be predicated from pure tone thresholds, the vice versa is not possible.

A correlation between SDT and SRT has been established by a number of investigators (Egan 1948, Rose (1978) Hudgins 1948). E-gen(1948)has found SRT to be 10-20 dB higher than SDT. Rose has given the normal SDT and SRT values as 9 dB and 20dB respectively. Beatlie et al ( ) has given the difference between SDT and SRT to be 9dB Thinlow 1948 and Chaiklin 1759 have also given it as 9dB. Thus a signif icant correlation between the two measure s, SRT and SDT has been establiabed by many studies and the difference between the two has been bound to be around 10dB. The relation considered between the SDT and speech discrimination has been given by (Hudgins 1948; cited in Frber and *W*itt 1977). He has observed the maximum speech discrimination to occur 20 to 40 dB above SDT.

Thus by compiting ths date from the above mentioned, studies, one can conclude that SDT is useful in predicting SRT but not so much to predict speech discrimination and pure tone loss.

The limitations of SDT are:

p) SDT does not provide such information regarding the pure tone configretation.
b) A normal SDT may be obtained In cases with high frequency lossa(Martin 1978) and
c) A normal SDT may be obtained in language disordered cases.

Therefore SDT may result either in An underestimation or overaetimation of the degree of hearing loss and thus lead to mis-diagnosis. Thus this measure does not carry much clinical significance,on its own. Therefore this measure should be attempted only as a last resort, that is when a11 atempts at pure tone testing and other speech audiometric testing has been a failure.

Speech Reception Threshold(SRT) :

SRT measures a more complex process compared to SDT. SRT is a measure of the perception of the speech signal. Here just identification of signal will not do as one has also to comprehend the signal to give a Response. Therefore this is a more approximates meassures of the commnication ability compared to SDT.

The first investigators to measure SRT were Hughson and Thompson(1942). They made use of Bell Telephone intellgibility sentences to obtain SRT. She SRT was defined as the level at which the subjects were able to repeat 2/3rds of the sentences correctly. But later, the use of sentences was substituted by spondiac words because of its many advantages, mentioned in page No. 14-16.......................................Hangins et al (1947) were the first to more use of spondiac words in a test for SRT. They were also the first to give importance to factors like familarity, phonetic dismilarity and homogenity of speech material.,, chosen for a test of SRT. They formed two lists of 42 disyllabic words of equal homogenity and called them as PAL(phychoacustic lab) test No.9. Each of the two list were recorded on a disc. The recording was Gone in such a way that, six words were reproduced at a level of 4dB lower then the previous eat of six words, with the last group be log 24dB weaker than the first group. Thus totally 7 sets of six words were recorded,This kind of a recording was done with the intention to provide for a quick estimation of SRT.. The standard error of measurement was found to range between 2.1 to 2.8dB in hearing impaired and normal subjects. Therefore they claimed this test to be equally applicable for both nomal and hearing impaired population. Later, the PAL test No.9 was modified to provide for the control of level by the examiner. To do so, the same lists of words were a11 records at the same level, instead of the descending order followed is the PAL, Auditory -test No. 9. This test is referred to as PAL Auditory test number 14. Thus the PAL Auditoy test No.9 and 14 were the first standardised tests for SRT.

Hirsh et a1(1952) felt the PAL tests to be cuabersone because of there length. Therefore he reduced the total number of items from 84 to 36. Tne selection of the 36 items was done in the following way. All the 84 items were administered to eiperienced and inexperienced listners at 5 levels. Basee on the number of errors for a word at all levels, the words were rated as either" easy" or " difficult". The criterion to be rated as "easy" was one or no errors and for "difficult" was 5 or more errors at all levels. He elimnated all the easy and difficult words. But In spite of this, some words still remained which were rated as easy or difficult on repeated administrtion of the test. Therefore, the intensity of easy words was reduced by 2dB where as the intensity of difficult words was raised by 2dB. This resulted in a test of words which were homogenous with regard to intelligibillity. The list was recorded in two different ways. First, all the words in the list were recorded at a constant level, that is 10dB lower than the level of 1000HZ calibration tone. The easier phase "say the word" was recorded at the level of the celibration tone. This list was designated as CIDW-1. The second type of recording was in such a way that, the level of each set of 3 words was reduced by 3dB progressively. The carrier phase was maintained at the level of the calibration tone for the initial 9 words, but later on the level was alternated by 3dB for every 3 set of words. This list was called , W-2. Thus the list CID W-1 and CID W-2 were adopted in most of the clinical sete ups for obtaining speech reception threshold.

The contribution of Hirsh et al (1952) did not end at the developnant of CID W-1 and W-2 lists tests. they gave the standard procedure for obtaining SRT in a clinical set up. The following ie the procedure outlined by them. First the lists are familarised to the subjects. Then ths words are presented at 30 to 40dB above the estimated threshold levels. If a correct response is ensured then the level is decreased in 10dB steps untill incorrect response is obtained. Then the words are presented at 10dB above this level. If the subject repeats 5/6 words correctly at this level, then onwards the level is decreased in 2dB steps until the subject repeats 5/6 words incorrectly. At this stage, the test is terminated and the number of correct responses are counted and reduced by one. Then this is subtracted from the hearing level setting at the test invitation. The resultant level is taken as the speech reception threshold. Hirsh et al (1952) recommended the use of this standard procedure in all centres to improvise the communication among professonal.

All the research data reported so far had been conducted on the adult population. Therefore whatever claims has been made by these investigators hold good only for the adult population. and not for children especially for younger and difficult to test population. An SRT test for childern should meet the following criteria.

1. The Speech signals used should be of known acoustic values.
2. The speech signals should be within the vecabulary of the children (Keaster 1947, Lesak Ross *and* Lerman 1970).
3. Test should elicit voluntary response which can be judged as evidence of hearing.
4. Test should involve active particepation on the part of the child (Lezak and siegenthales pearson.(1954)
5. Test should be short enough to hold the attention of the youngest age groups(Ross and Lerman 1970).
6. Test should be of sufficient appeal to draw and hold the interest of the child Ross Lerman 1970).
7. Should have a sufficient number of items to reduce the chance probability of response (Ross lerman 1970).

8. Should demand nonverbal responses (Keaster 1947) due to the incomplete language development in childern, the vocabulary will be limited. The reason for such a limitation may be the presence of a long standing hearing loss. or an articulatory problem which makes the oral response up-intelligible, rue to the age of tbe child, written response is out of question (Ross and Lerman 1970).

If one evaluates the tests decribed so far on the basis of the above mentioned criteria, the inapplicability of these to children becomes clear. Therefore an extensive research got started to develop tests more applicable to children. The two main areas of research interest were modification of the adult tests and the formation of new tests for various age group of children. The main output of such a research was the development of several picture identication tests for mesuring SRT in children. Kepster(1950) was one of the first investigators to develop a picture identification test. She selected 50 norums from the frist 1000 words from the international kindergarten word list which comprised of spoken vocabulary of children of 6 years or younger. The selection of the nouns was based on the pretext of common usage of words and the phonetic contents. The selected list of words were picturaised and presented to 75 children below the age of 6 ye ars. Only 25 words elicited reliable responses. Therefore a list comprising of these 25 words were formed and was advocated foruse in clinical set up. The procedure of administration was as follows:

The child under test was given instruction that •Some simple commands would be given to them, at first intense levels progressively at lower levels. He/she has to listen and act in accordance to the command heard. The commands were like "put the " "rabit on the floor" etc. The picture of all the words were placed within reach of the child and the child had to point to the correct response .and the lowest level at which the child was able to follow atleast 3 commands was taken as the threshold.

To validate this test, the scores obtained from this test were compared to threshold obtained from sentence test and pure tone thresholds (keaster 1942). A high correlation was observed between a11 three measures in children, therefore be claimed this Method to be useful inobtaining children's SRT. Siegenthaler Pearson and Lezek (1954) developed a formal picture Identification test. She test stimuli were selected on the criteria of famila-*rity*, phonetic dissimilarity, representativeness of speech sounds of english, and homogenity with respect to audibility. Thus the test list inclusive of 50 monsyllabic nouns were selected from among the first 500 words in Rinsland's basic vocabulary test and some words from the second 500 words in Rinsland's basic vocabulaty test and in addition some common words which were in the vocabulary of children. Monosyllables were used because of the greater possibility of picturisption. Totally 107 words were selected and were represented by brightly coloured pictures without any back-ground colour. They were then arranged in groups of 5 or 6 and presented to 25 children of age ranging froa 2 to 7 years and birth to 6 years with normal hearing and normal intelligence, The pictures which were not identified for 3/4 times, were eliminated. The remaining were present ed to 13 children between birth to 4 years and 8 years,who were a11 candidates for a school for the deaf. Here also, the pictures which were not identified two or three times were eliminated. Thus this process of elimination ultimately led to a total of 73 words, whose pictures were easily recognisable. These words were then recorded on discs at constant intensity level with the easier phrase "point to " also at the same level".

The test was these administered to 15 young adults and kindergarten childern at individual thersholds for calibration tones through earphones. Words which were abhigue on preliminary recognition tests and words which were missed most often or very in-frequently were a11 eliminated from the test, The remaining words were arranged in the order of their audibility value. Then groups of 5 words from each audibility catogory were drawn from the sample and 2 lists A and B were prepared. Six words from various audibility categories were used as practice items in each test, form the picture of all these words were mounted on posture cards with no relationship to each other and were attended with rings for ease of handling; these cards were numbered according to the presentation order. The procedure for administration of this test is as follows.

She child is brought into the test room and is made to sit on a chair comfortably. Then the assistent examiner sits beside tht child and handles the test cards and also conveys the response of the child to the examiner. The practice items are presen ed first, then the 1st test word of the first group is presented at 10-15dB above the estimpted threshold. If a response is seen, then all the words in that group are presented with 5dB alteration for each word, Then the second group of words are taken up and are presented in a manner similar to 1st group, by starting at the same level as for the first group. Thus as each first word in each group is presented at the same level, it results in the presentation of 5 words of varying difficulty being presented at the same intensity levels.

The threshold was defined to be the lowest level at which 50% of the items are correctly identified. The SRT obtained from this test was compared to the pure tone average and a high(0.93) correlation between the two was observed in 54 normal, articulatory defecture and hearing handicapped children(Muller) Therefore this test was claimed to be Valid and reliable test for children.

Vander Host(l969) developed a picture identificption test and named it as "Linister Test". He used a bo ok with pictures in it and arranged 4 picture in each sheet. These pictures were shown to the child, prior to testing and was made to name them. This was to ensure that the words were within the vocabulary of the child and also to make sure that the pictures were not ambiguous.

The 1st sheet was used for practice. The word were all recorded and the list words were of the form as follows: "tree", three", key and feet". The child was instructed to point to the picture named by the examiner. This test was standaraised on 106 childern of agae ranging from 5-7 years. Therefore he claimed that this list to be a useful test for both normal as well as hard of hearing children.

Rajeshekar (1976) has devloped as SRT test in Kannada for children. First he collected a set of words which occured most frequently in kannada. From these, 104.2 to 3 syllabic words which were picturable were chosen. These words were then subjected to familarity testing, that is these words were given to childern of 3 to 5 years of age and were instructed to rate them as most fami-liar to least familiar. Only those words which were rated as familiar were included in the test list. The pictures of these words were also shown to the children to rule out the existence of anbiguity in these pictures.,and finally the homogenity among words was also taken care of, then the final list was recorded with a carrier phrase: "Aidrnos Torism: at "0" meter defelction with an interstimulus interwal of 5 seconds. The instructions to the subject was to point to the picture named by the clinician.

The 15 pictures corresponding to the stimulus words were randomly divided into groups of three and were pasted on in-dividual sheets along with two more pictures that were not included in the test. The letter waS to control for the selection of pictures on an elimination basis. Totally 15 stimulus and 10 nonet isulus pictures were selected and were bound in the form of a booklet with 5 pictures on each page. The presentation of stimulus was based on random number table. The number of correct responses were recorded and in this study mean SRT of 21dB PL was obtained in children of 3-5years. This test was later standa-raised on, a group of children of 5-10 years of age. This is the test which is now being used in the clinics for testing children *in* our clinical set up.

Thus the receiver of these tests,have pointed to the validity of these tests in the evaluation of children. P-I tests have been found applicable to children because of the following reasons:-

1. It familates good report
2. It stimulates responses, related to the level of hearing activity,
3. It hold's the,child's interest
4. It helps in cliniting spontaneous responses.
5. It takes into account the short memory span.
6. It keeps the child in a sendentory position and
7. does not demand a verbal response.
(Siegenthaler, Pearson and lesak).

Thus the picture identification meets almost pll the criteria listed for a *SRT* test for children. But the picture identifica-tion tests have some limitations, like, difficulty in the selec-tion of words which are picturable, the failure of the picture to represent the stimulus word, the difficulty in developing equi-valent test lists. But the limitations of the picture identifi-cation are less compared to its many advantages. Therefore these tests can be inferred to be valid tests for obtaining SRT in children especially the younger age group.

For the older children with sufficient speech and language the standard procedure can be used with only a slight modification Here the child may be given the opinion, that an airplane game is being played, with the child as the pilot and the examiner as the controller. Then he is instructed to repeat the words presented to him through the earphones, The examiner has also to wear earphones to make it look more realistic. Thus this kinds of suggestions helps to motivate and cricit co-operation from the child Another possibility is to couple the earphone to the telephone receivers and test the child using the telephone. But if the child refuses to use the telephone receivers also, then one can resort to sound field testing. But here certain precautions should be taken, these are:-

1. The amplifier interposed between the loudspeaker and the audiometer should be properly calibrated.
2. The child must be made to sit in front ^nd facing the loud speaker (3' to 4'),
5. the child should not be allowed to roam about, as this will result in variations in the level of the signal reaching the ears at a given time.

Having taken care of the above, one can get reliable threshold by following the standard procedure.

Thus older childern, who co-operate with the examiner and who have adequated speech and language, can be tested by the procedure adopted for the adults. But for the younger children and difficult to test population. The adult procedure is not appropriate therefore, the picture identification tests seems the best method for obtaining SRT. Reinforcement of the correct responses, increase chances of eliciting consistent and reliable responses at levels nearer to the threshold of hearing.

The speech reception threshold contributes *P* lot in obtain ing at clear clinical picture of the problem presented by the subject. It gives an estimate of the extent of hearing loss. It aids in locating the damage a long the auditory pathoay and information regarding the degree to which the extent and type of loss combine with basic abilities and personality to cauae ? handicapping effect is PISO desired from SRT.

It verifies the pure tone audiogram This is considered to be one of the important applications of SRT.A Close correlation between pure tone average of 0.51K and 2KHs f»nd SRT has been reported by a number of investigators (Hughson and Thompson 1942, Karhant 1946, and Harris 1946$_t$ Keaster(1969) Carhant 1971, Fletcher 1950 Quiggle et al (1957), Lercoff 1958, williamson 1973 and many others). The difference between SRT and PTA is most often given to around 10dB. This close correlation between SRT and PTA has been reported to have ccnsiderable significance in cases who give in consistent pure tone responses, like for example, Functional loss cases, very young children, and difificult to test population etc.

Thus SRT reflects the pure tone configmation and on the other-hand SRT can be estimated from pure tone loss. A formula has been developed by Cahhaht(l971) (cited in Williamson 1973) to compute

SRT from PTA. This is as follows:-

SRT = (Hh0.5 + HL lke/s)-2dB.

The prediction was found to be within 10dB of the SRT obtained by the standard procedures. Thus this formula is advocated for the prediction as it is claimed, to reduce fatigue and time. But it does not really, same time as pure tone threshold have to be obtained to predict SRT. Another limitation is that the Carhaut's formala takes only 2 frequencies that is 500 and 1K and therefore it does not reflect the sensitivity at high frequencies tones. So Harris, Haineso Meyer(1956) suggested the prediction of SRT from regression equations. Bat this has many more limitations compared to Carhaut's formula. The following are the limitations The constant tobe subtracted, in this formula varies as a function of frequency, the reference level to which the audiometer is calibrated and the extent to which the instruments conform to the standards. Thus compared to be Harris et al formala, Carhant's is preferable as equal weighting is given to both frequencies in this formula.. But the best would be to obtain SRT by the standard procedure,

A high correlation between SRT and PTA has been obtained in children (Siegenthf»ler et al 1954) as young aS 3 years of age. Stark and Gannaway 1971 have not observed any difference between the SRTs in children and Adults. Therefore this alsopoints out to a correlation between PTAs and SRT in children similar to as seen in adults.

Thus from all these studies, one can conclude, SRT to be useful in the prediction of pure tone loss. The other advantages of SRT are it seems as a reference point for a number of threshold measurements like speech discrimination(Siegenthalec et al 1954), andit also aids is thediscription of patient's handicap and in predicting the prognosis (Hardy and paule 1950)

The reliability of this measure in children has been established by several investigators (Martin, Coombes 1976, Siegenthala et al 1956, Hodgson 1972s).

Thus through Hirsh et el 1955 and Meyerson 1956 consider SRT to be an unnecessary measure, its worth especially in ths evaluation of young children has been stressed by the majority of the investigators who have weaked in this area(Hardy and pauls 1950; Siengetheler et al 1954, Martin; Coombes 1976 Hodgson 1972. and others)

The two important functions of any speech list is to assess the social adequacy of a subject's hearing and to allow for differenatiation among various aduitory pathologics. The social adequacy refers to the general communication efficiency that is the ability of an individual to understand normal, conversational speech. The normal conversation occurs at suprathreshold levels, Therefore, SRT which is a threshold mesure fails to assess the social adequacy of an individual hearing and is not of much help in the differential diagnosis of the various aduitory disorders. Thus this necessitated the development of speech discriminiation tests which measures the ability to repeat speech presented at a comfortable level,

Logically the material to be used for speech discrimination test should be the kind speech used in every day life. But it is not done so because it is too redendant, and this will result in an over estimation of one's discrimination ability. Therefore other types of material have been used like, nonsense syllables, monosyllabus, Di. syllabus and sentences syllabus etc, The individual phonemus or nonsense syllable are not recommended for two reasons, first is that they are quite abstract and are decoid of symbolic content

The mono syllables have been found to give an accurate reflection of one is speech discrimination ability, The first speech discrimination test to utilise monosyllabic words as stimuli and to incorporate the concept of phonetic balance was the PB-50 lists developed at the Harvard PAL (Egan 1948, cited in Tillman and Olsen 1973). This list consists of 20 lists of 50 words each which were selected on tha basis of tha following creteria.

1. A monosyllabic structure.
2. equal average difficulty and range of difficulty
3. the words which are in common usage.
4. which have equal phonetic composition and
5. which are reflections of the phonetic composition.

This test had certain limitations, like,

1, these lists were not recorded for commercial distribution,
2. the phonetic balance was not perfect and
3. the list vecabulary contained a number of rare words.

In spite of its limitations, this list received extensive application in the assessment of hearing imparied veterans and this represented a milestone in the development of more refined speech discrimination tests.

These PB-50 words were subsequently recorded on discs at the central institute for the deaf by Rush Hughes. But due to the fast rate of speech of Rush Hughes, the lists become very difficult, there by limiting its application for routine use. This led to tha development of the CID co-22 words lists by Hirsh et al ( ) at the paychoacoustic laboratories, Maskins. The CID W-22 word list comprised of 4, 50 word lists which were familiar and were phonetically blanced. These lists have been claimed to be of more value in the differentialiah of diagnosis of auditory disorders.

Iehisto-peterson (1959) developed the CNC word lists by placing emphasis on the phonemic balance and rather than phonetic balance.

Some of the other test of speech discrimination test are:

1. Multiple choice lists = among these are the faribanks rhyme test (1958), modified rhyme list given by Honse et al 1963.1965 and clarke's (1965) phonetically balanced rhyme test. These list are not of much use in a clinical set up as sthe validity of these on the clinical poulation has not been very satisfactory.
2. Synthetic identification list, Jerger and speaks (1965). This testhas been widely used in the diagnosis of central auditory disordres.

There lists were standardised on the adult population and therefore may not be applicable for testing childern directly..

A clinican, who is set to administer a speech discrimination test, has a privelege to chose any materials from his armatorium as no single list or a particular material has been established as standard material. The choice should be made in accordance with the goals of testing and should be appropirate to the subject. But as far as the present day clinical practice is concerned, the PB word lists are being used in speech discrimination testing

The adult speech lists cannot be used for childern because of, 1. childern's probable retaradation in language developement, the test words may not be in their vocabulary and therefore the task will not be of auditory discrimination alone but will include language also. 2. Childern with long standing or congential hearing loss usually exhibit articulatory problems which frequently make their oral response to a word unintelligible to the examiner and 3. because of their age. written responses are not feasible. Thus these limitations of the adult lists led to the development of new test lists. or modification of adult lists for childern (Rose and Ierman 1970). A test for childern should meet the following criteria:-

1. It should have words which are all in the vocabulary of childern.
2. The response mode must be speech

3. Should cover a wide range of auditory dis- criminatin ability, thus an adequate number of materials must be included (Ross and Lerman 1970).
4. Should have sufficient number of appropriate stimuli to reduce the probability of chance selection.

A number of variables have an influence on the speech discrimination performance. Thse are:-

1. Type of material selected as stimulus itmes
2. The context in which the stimulus items are presented
3. the type of response required of the listner
4. the presence of background noise
5. inclusion of a training session to familarise the listner with the meanings of the at imulus words
6. Talker variations
7. Inclusion of carrier phase
8. Reutterenses of the list material by a given speaker.
9. the deliberately introduced destrostion
10, The standardisation of test.

As in the testing of SRT in Children ,here also pictures are used. Many tests of speech discrimination have been deve- loped using pictures. (continueated page No. 4.52)

Siegenthfler and Haspiel(l966) developed a test, termed as Discrimination by identification of pictures (LIP).. This list consisted of 48 cards with 2 pictures on each card. The list was administered to 295 normal childern, age ranging from 3 to 8 years at SLs of 0,5, and 10dB Three testlists ware contructed form the two picture matrie Reliability of the 3 lists at the three SL's ranged from 0.36 to 0.30 with an error of measurement of 5%. Correct scores due to chance selection was high as only. 2 choices were involved in any one matrin. In this list, selection of test words was based on contrasting acoustic dimension rather than on a phonetic balance concept. In a follow up study,the authors administered this test to a larger group of hearing imparied childern and obtained satisfactory results with a reliability co-efficient of 0.60 to 0.84.

Thus modifications of the adult lists was tried but it was not very successful as even the picture representations of the words comprising PB-50 and 20-22 lists were difficult to develop. Many of the words were not is the vocabulary as Already pointed. Therefore employing the concept of phonetic balance pnd word familartiy, Harskin(1949) and Hudgins(1947) modification a of adult list was made. The Haskins word list came to be termed as phonetically balanced kindergarten lists (PBK-50). These lists have been used very widely in the clinical set up. Four tests of PBK-50, were developed and standardised on normal hearing adults. The scores on these tests were compared with adult list PB-50 words. But data concerning the clincal significance of PBK-50 lists in hearing impaird children is very merge. No commercial recordings of these lists are available. Therefore more sudies are required for validating this test test.

Myatt and Lendis(1963 developed a multiple choice picture identification which consisted of words within the vocabulary range of prischool children. This was a 4 picture matrex. These lists were administered to normal as well as trainable retarded group. The results suggested, that the list was useful for children with am IQ of 50 or more. But in this test some pictures were poor representption of test words. The chance scores were high and some words were too difficult, therefore this list was revised by Ross pnd Lerman (1970).

She list developed by Ross and Lerman is termed as "word intelligibility by picture identification list"(WIPI).

WIFI: requires two clinicians an examiner and an observer. This can be administered either in sound field or through earphones. coloured picture cards are used as material. In each card 6 pictures would be present. Four of them pictures have words rhyme with other two are which is to decrased the probability of a correct guess. Each card is showed to the child. The intensity diat is set at a level above the SRT, and the child is instructed to point to the picture named by the clinician. The response is relayed to the examiner by the observer. For each correct identification of a picture, the child is credited with 4 percentage points. The total of 25 words in each list yields a possible maximum score of 100%. The WIPI test was recorded for commercial purposes and the pictures were a standardaised and therefore the value of WIPI in the assessment of speech discrimination of children is high.

Van def Hirsh (1971) developed speech discrimination test using pictures which is referred to as "Luister Test". The material for this test comprised of a book with pictures and material to enable quick and easy recording of scores. The text book consisted of 26 sheets, with 4 pictures on each sheet. The first sheet is used for demonstration. From the next sheet, onwords, the name of one picture is presented, the child pfter listening should point to the corresponding picture. The words used in the 1st sheet ranged from difficult to easy. an example of the words used in one sheet of the list; tree, three, key and feet.

A 1KH reference tone at 6odB was recorded prior to the recording of the speech material. This list was standardaised on 106 children of age ranging from 5 to 7 years. This list was found to distinguish between normal and hard of hearing quite reliably. Therefore this can be eoaloyed while testing children.

Gramer and Erber (1974) have also formed a spondiac recognition test using pictures as stimuli. In this list, 10 bisyllabic words containing A wide range of speech sounds and none of them sharing the same 2 vowels in the same order were included. These words were not phonetically balanced. The list words were first f amilarised and then presented. Picture cards were formed to represent the test items an interval All the stimulus words were neorded with initial and final syllable within A range of 256 - 400 msec and an interval between syllable peaks of 450 and 600 m.seconds. Thus it was so recorded that all the words were similar with respect to duration and intensity.

Each child was tested in a noise free room, Prior to the administration of the list, all the pictures were shown

Learson and Peterson and Jacquot have advocated the use of Tillomen and Cochart's (1974) Northwestern unversity test No.6. For the speech discrimination testing with childern.

Erber (1972) the effects of visual and hearing discrimination in normal hearing and severly/profoundly loss cases. N-hairing no problem with auditory cells alone, some hearing loss cases could recognised the word and voiceless. plosires and nasals that profouss loss manifested an overall poor hearing percaption.

In the combined needs, of presentation slight improvement was seen in the visual conditonalone, in profound loss group compared to the other 2 groups. As these tests was not of much use in the profound loss cases it was not adopted for routine clinicl testing.

Erber and Alencewicz (1970) have developed a uaudiovisual discrimination test. This test comprised of speech detection and speech discrimination testing. In this 12 picture cards illustrating 4 nouns in each of the 3 stress categories, Monosyllables, troches and sponders were used. In the first step of administration the children were presented all the picture cards and thy were instructed to have them and then had to identify each one of them when presented audiovisually. This formed the speech detection threshold test, for descrimination testing, each words was presented twice at the most comfortable level, which was determined during the first portion of the list, with no visual was scoring was, according to the percent of word correct and the percent correctly by stress pattern. This list was found suitable for children of 5 years of age. The clinical value of this was, it assisted in selecting the appropriate ear for a hearing aid and is deciding if winairal hearing and would be appropriate.

Ling ( ) has formed a test which involves vowels /a/u/and/L/and two consonants/s/and/S/. This list is claimed to tap-the hearing for particular formants and therefore useful in ** the child's potential speech discrimination ability. This test provided for testing under earphones and soundl field, eider and unaided. The author reports of this test being success 1 with children as young PS 6 months.

Thus above given tests are the ones which have been developed for testing, the speech discrimination ability of children, during the recent past. Some of these tests were compared between each other, to ** the validity of the tests.

The WIPI and PBK-50 word lists were compared by Joans and Studebaker (1974) WIPI was found tobe better compared to PBK-50. This was because WIPI is a closed set pradigon, and PBK-50 is an open set paradigon, In an open set paradign, the child has to select from an unlimited set of possitibilites, where as in a closed set, it is a forced choice between limited alternatives scores of WIPI test correlated hightly with other date regarding the hearing function, Therefore a closed set pardigm, is considered to reflect the speech discrimination ability more accurately. Sanderson and Reintelmann(1971) allso obtained higher scores on WIPI compared to PBk-50 list. But in comparison to NU-6, the WIPI and PBK-50 yielded better results. She conclusion drawn from these studies, is that, the WIPI is best applicable for young children, a combination of WIPI and PBK-50 works well for older children and to use NU-6 for older children, Only when on is interested in hearing aid evaluation.

Thus speech discrimination measurements,are important & aids in diagnosising the degree and type of disorder, in the selection of an appropriate remediation and for the selection of hearing aid, in children.

Mesking:

As unilateral loss is not common in children, one should look out for the contralasteralisation of the speech stiaiuli. Therefore when measuring either SRT or speech discrimination, one should take care for the above mentioned factor. The Masking is very much important for speech disdcrimination as it is conducted at suprathreshold levels.

In children masked SRT can be obtained by explaining the presence of noise aspect of the listening gave and by reinforcing the child contingently. Studies on masking of speech in children have shown that, children are more effected by the noise and gave to poor performance in the presence of noise centred to the adults. This diffe- rence has been attributed to the following reasons:-

1. underdeveloped speech skills,
2. less knoledge of the language,
3. a lack of well developed listening skills, and
4. stratigies employed by tbe child.

Difference kinds of stimuli have been used for masking;

Frank and Raymond and Karlauh have recommnded the use of masking in measureing SDT and SRT.

Bone Conduction speech audiometry:

As in the case of puretones, bone conduction testing can be employed for speech lists as well.

The bone conduction speech measure would be very useful in children, when, the pure tone tests are often a failure. Both bone conduction SRT and »pea-eh and speech discrimination has been found to be very useful in a clincical evaluation of hearing of young children.

Goetzinger and Proud (1955) have found a high con-relation between the pure tone averages and BC speech reception threshold. They recommend, a comparison between BC and AC speech receptionthreshold as, this would con-tribute to the diagnosis of conducture hearing loss.

Herrell et al (1964) have found the mean BC SRT was 40dBre". Speech zero. that is a 40dB of energy re-sulted when speech was routed through the audiometer is BC circuit. stockdell(1974)have all found a high cor-relation between AC and BC SRT and BC PTA and AC PTA, Srinivas(1974) has advocated the use of BCSRT in the testing of children especially under 4 years of age (cited in valente and Spark 1977)

The BC speech discrimination mepsuramacts have been considered to be of importance in assessing the success of stapediatomy operaton and also in diagnosis of severs mixed type losses; determine speech discrimination ability when the air conduction spending discrimination cannot be obtained.

A high bone conduction speech discrimination score also helps eliminate any doubt that the pure tone bone conduction thresholds may have been the result of tactile mather than auditory perception(Mobar 1970) cited martin 1978).

Thus bone conduction speech audiometry la specially of clinical significance in the testing of children.

There are some children who have normal hearing but still manifest problems with the discrimination of speech and lag behind the others educationally and fail to develop adequate language. These children, fail to be identified by the routine audiological tests. Therefore, for the identification of these cases, supra threshold speech audiometric measures have been very successful. Some speech tests that have been employed for the diagnosis of central audiometry disorders are: (a) Filtered speech test, (b) Time compressed speech test, (c) Staggered Spondee Word Test, (d) Synthetic sentence identification test with ipsilateral competing message and contralateral competing message test etc.

As in the case of other test battery, even these tests were originally developed for the adult population and therefore norms for children are not available for all the tests. Some investigators have tried to apply the same tests to children (Palva & Jotcenen (1975), Aston (1972), Magatuchi (1974), Shriner and Beaslwy (1969), Maki and Oehik (1976).

The application of filtered speech tests to children has been advocated by (Boothroyd, 1970; Palva and Jokenen, 1976).

Boothroyd (1970) administered low pass and high pass filtered speech to children and found higher scores of speech discrimination in children compared to the adult counterparts. The high pass filtering had a more pronounced effect on the scores in children. The discrimination source of children was found to approximate that of adults by 8 to 12 years.

Palva and Jokenen(1975) administered undistorted and filtered speech tests to subjects of 4 to 19 years of age. In both the tasks, the younger age groups scored poorly, compared to the older age groups. This poor per- ormance of the younger age groups were explained on the basis of an absence of a complete set of phonemic categories, inadequate vocabulary and higher incidence of articulatory disorders.

An ear difference was obtained in the younger age groups but not so in the older. This was attributed to a functional asymmetry in the auditory system or due to a cerebral dominance in the younger age groups (fenfield and Roberts, 1959) (cited in Palva and Jokenen, 1975).

The blnaural scores did not differ from the monaural better ear scores. This showed that the binaural synthesis of the two different frequency bands is not developed in the younger children.

Thus, on the distorted test, the scores improved from age 3 years to 11 years. Therefore, filtered speech tests can be used in children older than 11 years or by obtaining new norms, it can be used to test younger age groups.

Ashton (1972) administered filtered speech test to hearing Impaired children of 9 to 14 years of age. Frequencies above 700Hz were all filtered. The results showed no difference in the scores of hearing impaired on the filtered and unfiltered speech tests, but normal counterparts showed significant difference. From this, it was implied that, the hearing impaired do not make use of the spectral information provided by high frequencies to perceive speech, in contrast to normal children.

The learning of correct place of articulation is dependent upon the high frequency spectral information. The hearing impaired, fail to raake use of high frequency spectral information and they also fall to use the low frequency and durational cues. Thus, all these combined together is the cause for the poor speech discrimination scores in hearing impaired children.

Nagafuchi (1974) studied the responses of mentally retarded children to filtered speech tests and found the scores were poorer compared to normals for all the three bands of filtering, that is low pass filter, high pass filter and band pass filter. But the scores were poorest for low pass filter compared to other two in both normals and mentally rsetarded which supports the hypothesis that frequencies above or around 1000- 1500 Hz are more important for intelligibility.

The studies of filtered speech tests in normal and norms for filtered speech tests are not available for children. Therefore, these tests have limited clinical application for children.

The other test of central auditory baltery which has been studied for its application in testing children is the time compressed speech. Beasley, Maki and Orchik (1976) temporarily modified the WIPI and PBK-50 word test to equalise their difficulty and obtained the speech discrimination scores in children of age ranging from 3 to 3 years. The percentage of correctly repeated words and categorised correctly with stress patterns were measured. The maximum discrimination obtained ranged from 77 to 100% at a level of 24-36 dB. This maximum discrimination level coincided with the level preferred by the subjects. Therefore they concluded that time compressed speech could be employed for hearing aid evaluation.

Oelschiasger and Orchik (1977) studied the performance of a case with central auditory disorder on tine compressed speech discrimination test. The performance was poorer in the ear contralateral to the site of lesion. Thus from this they concluded that time compressed of WIPI discrimination tests can be used for the diagnosis of central auditory disorders in children.

Beasley, Flabfcrty and Bintelmann(1976)used temporally distracted sential approximation of varying length and studied the normal 2nd and 3rd grade children's perception on these tasks. The results showed that as the length of the sential approximation was increased the perception improved and vice versa when the length was decreased. As age advanced the scores were found to improve. The number of correct results also decreased with increasing sentence length. On the basis of the results obtained in these normal children, they inferred that sential approximation can be used to assess the integrity of central nervous system in children.

Thus temporal alterations of speech signals have been found to be useful in identifying chlld with the central auditory disorders.

SUMMARY

Thus the speech audiometrlc tests are valuable tools for the clinician in the testing of children's hearing .

The SRT measures, estimate the extent of hearing loss for speech. The threshold obtained has a close relationship with the pure tone thresholds (Carhart, 1946; Fletch, 1950; Graham, 1960) Hume, 1946 and others). The two measures SRT and PTA are found to exist within a range of 0-10 dB. Therefore SRT can be used to predict the threshold for the child, in whom the pure tone audiometry is not relaible. SRT also provides a base line to predict ear's sensitivity at supra threshold measures,which is very much used in obtaining threshold in the difficult to test population, and provides information regarding the sensitivity of the two ears separately, which aids in the diagnosis.

The SRT provides information] the subject's ability to detect speech. This can be equated to the threshold for broad band noise. The information provided by this is centered between the frequencies 300-3000Hz which are the critical frequencies necessary for understanding speech.

The speech discrimination measures, aid in diagnosis, differential diagnosis, selection of aid and

in making proper referrals and provide the social adequacy index. Thus the measures of speech audiometry aid the clinician to make an accurate assessment of the handicapping effect of the hearing loss.

CHAPTER V

IMPEDANCE AUDIOMETRY IN CHILDREN

The middle ear is interposed between the source of the signal and the cochlea. Therefore the condition of the middle ear has a major influence on the flow of energy to the cochlea that is the input to the cochlea. Any pathology affecting the middle ear structures will impede the conduction of sound to the inner ear and thus might adversely affect the development of the child. Many studies have reported of the effects of middle ear pathology on several aspects of a child's development (Holm and Kunze 1969, Libby 1974 and Rock 1974, Schwartz and Redfield 1915, Ling (1972)

The middle ear pathology resulting in minimal loss or fluctuating loss has been reported. to impede the development of speech and Language (Holm and Kunze 1969) Schwartz and Redfield 19*73). A delay in the development of language skills requiring the reception or processing of auditory stimuli or the production of verbal responses has been reported by (Holm and Kunze 1969). Schwartz and Redfield (1975). have reported of lower scores on vocabulary and reading tests in children with mild conductive loss compared to the normal children. Hamilton (1973) has also reported of findings similar to that of Schwartz and Redfield (197r).

Ling (1972) has reported of a causal relationship between otitis media and educational retardation. A mean loss of 25dB in children of age 9 to 10 years was observed to result in retardation in the areas of problem arithmetic, mechanical arithmetic and mechanical reading. Libby and Rock (1974)have also reported of educational handicap in children with middle ear pathology.

The middle ear dysfunction has also been observed to deprive a child, of proper sleep and thereby resulting in an impairment in the ability to live and learn in one's environment (Sitter, Kozelskey and Wood ford 1976.

Medical complications following an unidentified and untreated middle ear pathology has been reported (Sitter, Kozelsky and Woodford (1976). The types of complications which can result from a middle ear disease are: permanent S.N. loss (English, northern and Fria 1173), mastoiditis, meningitis, and other intracranial complications (Sitler, Kozelsky and Woodford (1976), B1ue stone (1977)

Thus, all the above studies, point to the importance of an early accurate identification and assessment of middle ear disease in children. The traditional method of identification of -middle ear disease in children has been through 'Otoscopy" But an otoscopic examination has certain limitations. In very young children one often faces difficulty in conducting adequate otoscopic examination, another limitation is, not all pathologies are revealed by otoscopic examination. This necessity for a more refiled method for an accurate identification of middle ear pathology led to the use of impedance audiometry for the diagnosis of middle ear pathology.

Impedance audiometry is an objective means of assessing the integrity and function of the peripheral auditory mechanism. The impedance audiometry aids in the determination of existing middle ear pressure, tymoanic membrane mobility, eustachian tube function, continuity and mobility of the middle ear ossicles and the condition of the Sensori-neural system (Northern and Downs 1974). The earliest investigators to use impedance measurements in chidren were Robertson et al (1963, cited In Northern and Downs 1974). An impedance/compliance and acoustic reflex threshold provides significant information, the diagnostic value of each increases when the results from all three procedures are considered together (Northern and Downs, 1974).

In this chapter, the contribution of each of the above mentioned test procedures individually and in combination, in evaluation of children of varying age groups will be discussed.

Tympanemetry:

Tympanometry refers to the measurement of the compliance or the mobility of tho tympanic membrane as a function of mechanically varied air pressures in the external auditory canal. (Northern and Downs 1974). The compliance of the tympanic membrane at specific air pressure are plotted on a graph, which is referred to as 'Tympanogram'. A tympanogram provides information about the pressure status of the middle ear, the integrity and mobility of the eardrum, the integrity of the ossicular chain and the resonant point of the middle ear. Thus an interpretation of the tympanogran includes the analysis of (a) Pressure peak (b) amplitude, and (c) shape. Within this framework, it is possible to differentially diagnose the various pathological conditions affecting the middle ear. In the analysis of tymnanograms, one can use either a coding system approach (Liden et al, 1974 and Jerger 1970) or a descriptive analysis approach (Feldman 1976). In this chapter the coding system approach will be used to describe the different pathological conditions

Jerger (1970) and Liden et al (1974) have described types of tympanograms and have associated each type to a group of specific middle ear pathological conditions,

All the data mentioned above were obtained from the adult population, whether this would hold good to children is the question, that is to be answered. Many investigators have reported of a similarity in the basic type of tyrapanograms between neonates, older children and adults (Fulton and Lamb) (1972), Jerger (1970) Keith (1973), Morthern and Downs (1975).[1] One difference in the type of tympanogram which has been reported is the presence of a

W shaped tympanogram, obtained using 220 Hz probe tone. But this configuration was observed, to approximate the adult pattern with the advancement of age (Cannon, Smith and Re ace 1974 and Keith 1975). Cone and Gerber (1975) have also reported of changes in the type of tympanograms with maturation. Bennett (1973) have observed a double notch tympanogram in some donates of 5-213 hrs. of age which returned to a single notch tympanogram with increase in age. He denoted single notch tympanograms as and double notch tyrapanograms as D. He made a further subdivision in these two categories. The S was further subdivided into S_1, S_2 and S_3. The S_1 which was similar to the tympanogram obtained a in normal adults (Jerger 1970; i.iden et al 1974), that is the position of the notch was at 0mmmiddle ear pressure. The S_2 referred the tympanogram with a broad notch, with a mean width of 30mm. The S3 referred to the tynspanogram which manifested a rapid increase in the acoustic impedance, with the application of positive or negative middle ear pressures. The D type tynpanograms were further subdivided into D_1 and D_2. The D_1 referred to the type which was similar to S_1 but with a double notch. The D_2 referred to the type which was similar to S_3 but with double notch. The type D, in general was the type which manifested a positive notch at +12.9mm. H_20 and a negative notch at -30rara, H_20 with the separation between the two notches varying from 15 to 88mm H_2O . This type D was observed in almost all the neonates of 5-11 hrs. and as the age increased, the incidence of single notch tympanograms also increased.

The double notch'was attributed to the flaccid tympanic membrane seen most often in neonates. This flaccid eardrum improved the transmission characteristics of the middle ear on application of positive or negative pressure, resulting in a double notched tympanogram.

As the otitis media was found to be very common in neonates and young children, more importance was given to the middle ear pressnre measurements. (Lamb and Dunckel (1975). The first indication of the serous otitis media, is a negative pressure peak in the tympanogram. But what constitutes normal pressure in children is still being debated. A lot of controversies existing regarding the cut-off point that is to be employed to demarcate normal and abnormal pressure in children. Keith (1973) found normal pressure in neonates of 36-151 hours of age. The average pressure was found to be 4.5mm. Beinett (1975) also found normal pressure with a range of -45 to +45mm in neonates of 5-213 hours after birth. Allerd et al (1974) reported a positive pressure in neonates 20 to 50 hours following birth, but which was found to become slightly negative at the age of 6 weeks. Poulsen and Tos (1978) studied the middle ear pressure changes at birth, 3 months, and 6 months following birth. At birth they found a negative pressure of -100 mm in 10.6% and only in *3%* did he find the negative pressure of about -125 mm H_2O. At 3 months in 17.9% of his subjects, a negatlve pressure of less than or equal to -100mm H_2O was observed. At 6 months of age, in 39.2% of the subjects a negative pressure of less than or equal to -100mm pressure was noticed, and in 13.1%, a flat curve was obtained, and in 9.6%, a middle ear pressure ranging from -200 to -300 mm pressure was obtained. These investigations also, revealed normalization of air pressure with increasing age. But a parallel increase in the incidence of type C_2 (-200 to -300 ram H_20) was also observed. Therefore they analyzed the cause for such pressure changes, and attributed such changes in pressure to the increased incidence of catarrhalia. At 3 months, 23% had catarrhalia, where as at 6 months of age, 60% of the infants had batarrhalia. Thus, the increase in negative pressure with age was correlated to the increased incidence of serous otitis media resulting from catarrhalia, with age, upto about 1 year.

Poulsen and Tos (1979) studied the middle ear pressure status in children who were in their latter half of the first year of life. At 6 months of age, a pressure of 0-99mm was obtained in 62% of subjects, but at 9 months, with 1% - flat type, the middle ear pressure manifested deterioration and at 12 months, in 40% a pressure of 0-99mm H_2O was observed and in 28% a pressure of -100 to -199 mm H_2O was observed and 13% gave a flat tyrapanogram. Thus, a deterioration in the pressure status was observed as age advanced from birth to 1 year. These changes were again attributed to the increased incidence of catarrhalia from 6 months to one year of age. Tos et al(1978) observed a pressure of -100 to -350 ram in 39.5% and a flat type in 10.8% of subjects of two years of age. But in older age groups, a steady decrease in the negative pressure has been reported by many studies (Walton, 1975; Brooks, 1969; Brooks, 1974; McCandle and Thomas, 1974; Harker and Van Woagoner, 1974).

Walton (1975) found the mean pressure to be around -46 mm H_2O in children ranging from kindergarten to 5th grade age level. He observed a -104 mm of H_2O for kindergarten children and -55 ram H_2O for 5th graders. This trend supports the earlier findings, that otitis is most prevalent in younger children and that it decreases with age. Based on the trend of changes in. middle ear pressure, with age, some investigators have tried to give norms for middle ear pressure for different age grouns (Albert and Kristensen (1970, 1972), Reunal et al (1973), Brooks (1969). Albert and Kristensen (1970, 1972) have given the cut off point for normal Vs. abnormal pressure greater or enual to 30mm has been considered an indication of middle ear pathology. Renvallet al (1973), indicated that pressure less than -30mm of H_2O to be considered as normal, and greater than 30 mm H_2O, as a reflection of abnormal condition based on his study of 7 to 10 years old children. Brooks (1969) has suggested that only when the pressure exceeds -170 mm H_2O, should it be considered as an indication of middle ear pathology, based on their findings in children of 4 to 11 years old. Brooks (1975) Liden and Renvali (1977) claim, the ideal criterion of normal pressure to be less than or equal to 150mm H_2O. But a compromise has been recom-Tended as a cut off point between normal and abnormal pressures in children upto 5 years (Jerger 1970; Harker and Van Wagona, 1974; McCandles and Thomas, 1974; Bluestone; 3eecy & Paradise, 1973; Feldman, 1973; Porter, 1974; Jer ger and Jerger, 1972).

<u>Static Compliance:</u>

The term compliance refers to the mobility, or springiness, of a system (Northern and Aorous, 1975). As the compliance measurements are made during resting conditions of the system, the terra '<u>Static Compliance"</u> was suggested (Jerger). In the discussion of static compliance measures, three main characteristics of middle ear mechanical system should be considered. These are the mass, friction and the stiffness of the system. The mass is provided by the bulk of the ossicles, the friction is contributed by the suspensory ligaments and the muscles supporting the ossicular chain. The stiffness has been attributed to the resistence components of the stapes foot plate, the latter has been considered to have the major influence on the units of static compliance. The units of exoression for static compliance is cubic centimeter.

The static compliance is the inverse of acounstic impedance. A measure of acou-3tic impedance can also be used to measure the same entity as the static compliance. But the measures of acoustic impedance will be inverse of static compliance. Here the immobility or resistance of a system to movement is measured and the expression is in acoustic ohms. Thus the mobility of the system can be determined either by measuring static compliance or acoustic impedance.

A review of literature in this area, reveals that the static compliance values in normal children varies from that of adults. The different norms for the two groups has been attributed to two reasons. One is that, tho neonates manifest high static compliance because of the hyper mobility of the tympanic membrane and/or due to the relatively soft walls of the ear canal, the - other reason was, that, the norms which have been developed for the neonatal period, may be probably influenced by a rather high incidence of mldile ear diseases which occur in this age group and thereby decreasing the compliance.

Keith (1973) found a median compliance of 1.2 cc with a range of 0.25 to 1.65cc in a group of neonates of 2½ to 20 hours of age. Fromm ( ) in an earlier study of neonates of 27 to 150 hours old observed a median compliance of 1.10 cc with a range of 0.54 to 1.75 cc. Keith (1973) obtained a range of static compliance of 0.54 to 1.75 cc with a median compliance of 1.1 cc in neonates of 36 to 151 hours old. (Cone and Gerber (1975) (cited in Cone and Gerber 1979) measured the static compliance in infants ranging from 5 days to 13 months of age. For the youngest group a median compliance value of 6.79 cc was obtainedand ? in the oldest group it was 0.39 cc. The difference between the two oldest groups was not significant. Thus all the above studies indicate a decrease in the median and range of the compliance with advancement of age, especially between ths ages of three to 5 months (Gone & Gerber 1973)(cited in Gone and Gerber 1977).

The impedancevalues in childern has been given/some investigators (Jerger 1970; Brooks 1971, Keith 1973). Keith (1973) has given a value of 935 ohms as normal in neonates. Berger (1970) and Brooks (1971) have given values as 2250 and 7500 in children of 2 to 5 years of age. Northern and Downs (1974) has given the normal value to be 900 to 1300 ohms in children.

Thus both the measures, indicate that the compliance varies as a function of age, but overlap with the adult values is also encountered. As a guideline, Jerger (1972) has given the following cut-off points to ,1udge the compliance as normal and abnormal. The range/given to be 0. 28 cc to 2.5 cc. A variation in the value as a function of sex has been reported by Jerger 1972 (cited in Northern and Dowas 1974) He has reported of higher compliance values in all females. But as in case of adults, on overlap in the compliance values between the normal and pathological ears occur even in children.

Jerger etal (1974 has reported of the compliance values in different pathological conditions in subjects, age ranging from 3 to 79 years. The pathologies and the associated mean values for each of the condition is as follows:

(a) Otosclerosis, 0.35 cc (b) Otitis Tiedia: 0.29 cc; (c) Cholesteotoma: 0.16 cc, (d) scarred or thickened tympanic membrane 0.37 cc and (e) ossicular discontinuity : 1.93 cc.

Thus the large variations in the compliance values with age, sex and an overlap among the normal and pathological ears, clearly points to the limited value of static compliance measurement in the differential diagnosis of various middle ear diseases in children.

Acoustic Reflex Threshold Measurements:

Acoustic reflex threshold is the sound pressure level of the activating stimuls which results in the smallest detectable stimulus locked changes in conductancae, derived from the recorded tracings (Hirefarh et al. 1978) The acoustic reflex threshold can also be defined as the singal threshold level at which the staredial muscle contracts (Northern and Downs 1974) This reflex has been claimed to have a potential value in the evaluation of peripheral and central auditory system (Himelfrah, Shenon, Forelke and Mangolis 1978). The relex measurements have been consdiered to be a simple, quick, non-invesive and invxpensive metehod in the adult population (Himlfarh et at 1978). Many attempts have been made to investigate the feasibility of this method in the evaluation of childern.

Allend et al. (1971) have reported of measurable relexes in 97.3 % neonates of 25 to 50 hours (cited in Lamb and Dunckel, 1975). Keith (1973) has reported of the presence of ecoustic reflex in only 30% of the neonates of 36 to 18 hours. In 40 of the relex measures were inconclusive as they were masked by behavioural artifacts, and in the 26% no reflex was observed at all (cited in Gerber 1977). Robertson and Figgees (unpublished) also studied the acoustic reflexex in nenonates and could obtained resonses in only 4/68 ears tested.

The incidence of acoustic reflex in neonates has been reported by some investigators (Allerd 1974; Keith 1973; Pennett. 197, Kieth and Bench 1978) but the incidnece data........

given by the investigators Vany, Kcoth (1973) and Allerd (1974) have reported an incidence of 30 to 33 %, Benneth (1975) has reported of an incident- of 16%% Keulte and Bench (1973) have also reported of an incidence lower to that of Beneth (1973). The possible explanations that has been attributed to lower Incidence of reflex in neonates are : (1) The presence of the senchyme in the Middle ear which could impede the movemenets of the ossicular chain (2) The depth of sleep and (3) the incomplete development of the neurological system which is responsible for the elicitation of response. The latter explanation has been confirmed by Wolf and Goldstein (1977), especially for the contralateral elicitation of reflex, The ipsilateral reflex has been observed to be present in neonates by Wolf and Goldstein (cited Keith and Bench 1973).

In infants also, the acoustic measures have been stndies malgolis and Ropleka (1945) have obeserved acoustic reflex in some infants aged 55 to 132 days. Stream (1977) have reported of the prevalence of acoustic reflex at different ages in infants ranging from birth to 15 months of age. An incidence of 4.2 % has been reported in infants of 25 to 43 hrs, a 11.9%, In infants of 49 - 72 hrs, no reflex in infants of 73 to 136 hrs and 53 % in the infants of 15 weeks, has been reported.

Jerger (1974 d) has indicated two systematic changes with age, in infants of age ringing from 3 mths to 6 mths of age. The first was an increase in the number of reflexes at lower hearing thresholds as age increased and second was a decreased number of hearing reflexes as age increased (cited in Lamb and Ounckel (1975)

Many attempts his been made to investigate the relation between age and acoustic reflex threshold, and the frequency of the prense or absence of reflex (habener and Snyer (1974) Robertson, Peterson and Lamb (1903) Maegolis and Ponelka (1975). Habener and Snyder (1974) have also reported of a higher mean acoustic threshold levels in the first two decades of life in children of age 3 years and more. Robertson, peterson and Lamb (1963) (cited in Genber 1974), havae found reflexes in only 3 of the 10 subjects tested at the age of 12months.

They obtained same mean reflex threshold values for all the age groups selected for the study, that is 2 mths, 13,24,& 36 mths, but the greatestvariability was seen in children age ringing from 24 to 36 mths.. The thresholds when com-. pared with to that of normal hearing adults, the mean thresholds was lower for the adults with each group of children having higher thresholds, progressing from the 36 month old to the 13 month old group. In the 12 month group, very few yielded reflexes which were available for comparison. Magolis and Popleka (1971) found the reflex thresholds to fall within a range of 70 to 90 dB HL In Infants of 25 to 50 hrs. This poninted to the agreement between the reflex activity In normal infants and adults. Brooks (1971) also has reported a reflex threshold of around 95 dB HIL or less only In 70% of the children, aged 4 to 11 Yrs.

Two reasons for the absence of reflex has already been explained, "Some other reasons given for explaining the poor results in infants are; the developmental and evaluational factors associated vith reflex may influence the responsiveness in some children, The other possibility is the presence of slight conductive component resulting in an absence of Loss, even when the loss is very mild.

The Maturational process in the mechanical and neural pathways of the reflex will not be complete in the neonates. Thus this incomplete development interferes with the acoustic reflex threshold measurement, Keister and Bench (1977) have also stated that " the decassating tracks in the auditory nervous system at the brain stem might not be fully developed in the neonates.". This statement was made on the observations of Wolf and Goldstein (1977), The latter had observed an absence of contralateral reflex and a presence of the ipsilateral reflex in neonates. Thus they concluded that the maturational process of the reflex pathways vill not be complete in neonates and will go on untill 3 month of life. This delay in maturation was adopted to explain the differences between the reflex thresholds in adult and children.

Thus, the, maturation of the reflex nathvay, the reflex threshold and presence of entitles, reflex are interevaluated. Some of the other factors that have an influence on the acoustic reflex are the type of the stimuli, frequency of the stimuli, and the move ment antifacts.

Robertson et al ( ) have reported of the differences in the threshold as a function of stimulus frequency, They observed a 10 dB difference between adult thresholds and infants, of 13 mths, at 500 Hz, 6 dB at 2KHz.

Jerger et al(1974) studied the reflex activity in children younger than 10 years of age by presenting tones of 500 Hz, 1KHz, 2KHs and 4 KHz • The exoerimental group compressed of children with both normal hearing and hearing loss, which was less than 70 dB, He observed reflexes in only 4% of his population.. The children who failed on reflexometry had abnormal tympanogram and had loss greater than 70 dB.

allerd (1974) has reported the prevalance of reflex in neonates of 25 to 50 hrs, at different frequencies. The prevalance of reflex found in his study was 33%, 20% and 15% at 500 Hz 2 KHz and 4 KHz respectively.

Gone and Gerber observed a reduction in the frequency of occurance of reflex, thresholds as the frequency of stimulus increased. The mean reflex threshold also decreased with advancing age Threshold was 106 dB SPL in youngest age group) (0 - 3 months old); 97 dB SPL in the middle group (5 - 3 months) and 98 dB in the oldest group (10 - 13 months), The difference was not significant between the two older age group groups.

The prevalence of reflex was found to vary with the type of stimulus. The reflex vas more often present for noise stimuli compared to pure tones. The difference between the reflex threshold for the pure tones and wide band noise was more in infants compared to neonates. The difference was found to be 23 dB in infants, whereas it was 9 dB in neonates. The reduction in the difference between the two stinuli, limilted the application of Nieymax and Sisterhants (1974) and Jerger et al (1974) formula in neonates.

<u>Clinical applciation of impedance audiometry in childern:</u>

All the three test procedures of the Imedance test battery, Tympanometry, static compliance and acoustic reflex threshold, measurement provide information of potential value for diagnosis and differential diagnosis, but the clinical significance of the impedance audiometry increases when the results of all the three procedures are considered in combination. impedance audiometry (Jerger, 1970) provides information regarding the threshold of sensitivity, the type of loss and the type of pathology, and the site of lesion.

Tympanometry has been found useful in the identifying middle ear pathology, in following UP the entire progression and resolution of serous Otitis media in * children and in monitoring the recovery of the middle ear following surgical intervention, (Northern and Dawons 1974). Thus tympanometry is -mainlv useful in differentiating middle ear pathologies but is of little use in differentiating 3N Pathologies. The value of tympanometry in the identification of middle ears fusions in children, especially the younger ones has been demonstrated by many investigators (Bengali, Liden, Jungest and Nilson (l973), Brooks (1975), Liden and Rennall (1977), Bluestone, Berry$_t$ Paradise (1973)). The commonest parameter of tympanometry Which is employed for identification of middle ear effucion is the 'Pressure' peak, as the prerequisite condition for middle ear effusion is 'negative pressure ' in the middle ear. Though this has been found to be of significant value in adult population, the same cannot be claimed in the younger population. This is because the pressure variations in children are large and also the cut off point for nornal versus abnormal pressure has not been agreed unon. But still some kind of a diagnosis can be made by adopting - 150 mm water as the cut off point. (Brooks (1975), Liden and Rennall (1977)). Any subject who manifests a pressure beyond - 150 am, are grouped under the abnormal category and as requiring theranuetic intervention. If middle ear pressures is it them - 150 mm

H_2O then, a regular follows will aid in ensuing normal, middle ear function.

The progression and resolution of middle ear effusion can be monitered by noting the changes in the types of the tympanogram as the disease progresses or regresses. The first sign of the disease is negative pressure peak,, (c type). Then is the disease progresses the type 'c ' changes to type 'B',

As the disease regresses type 'B' gets changed into type 'C' and when complete resolution occurs then type "C' changes into type 'A', indicating normal middle ear function. The resolution of the disease after Regional intervention can also be monitored-in a similar way, some classify the type 'C ' tympanogram into C_1, C_2 and C_3 on the basis of the amount of negative pressure.. C_1 refers to a negative pressure,peak ranging from -100 to 150 mm , C2 refers to the negative peak ranging frou -151 to -200 mm H_2O and C3 refers to negative peak ocurring at a pressure greater than -200 mm H_2O.(Orchik, Morff and Dann 1978). A C_2 type tympanogram is claimed to a better predictor of middle ear effusion than C_1 type of tympanogram (Orehik, Morff and Dunn, 1973) But Flellan & NlkolaJseen & Loues (1979) have reported of a very poor correlation between C type tympanogram and middle ear effusion irrespective of the extent of the negative pressure. They observed a good test retest reliability in cases showing B type tympanograms. Thus according to this, B type tympanograms are better indices of middle ear effusion than the C type tympanograms. Paradise et al (1976) have also reported that normal tympanogram can result from highly compliant external auditory canal even when fluid is present in the middle ear of a neonate.

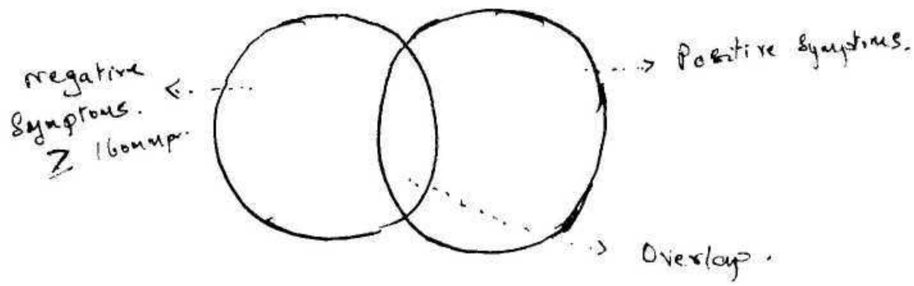
Lindholdt et al (1930) have computed a formula for the identification of middle ear effusion in children, as they felt that 'pressure peak' was not a valid pressure. The formula given by them is as follows:

TPxTN/FPxFN = relative reliability of children with disease to show a positive indication of disease compared with the tendency of children free of disese to show positive indications of disease.

TP = True Positive disease present
TN = True negative
FP - False positive
FN = False negative

The higher the value obtained, the more reliable is the response (Abrahamson, 1974). Thus the formula was claimed to have a high predictive value.

According to Lindholdt et al, the cut off point should be taken as 160 mm pressure but even then some amount of overlap does occur, which is shown in flg( ).



Thus, they advocate the use of the formula to check the reliability of date obtained.

Therefore aore research with good planning and validity to check the importance of negative pressure or the pressure peak for the differential diagnosis of conduct ive loss is imperative

The other parameter of tympanometry which is used for differential diagnosis of conductive pathologies is the amplitude or the slope of the curve. Stiffness pathologies have been observed to result in a reduced amplitude, whereas the Mass problems have been observed to result in increased amplitude due to an increase in the compliance of the middle ear system (paradise and Smith} • Actually paradise and smooth advocate the measure of gradient for differentiating various middle ear pathologies.

Thus, the data obtained from tympanometry gives some view regarding the hearing function of the child.

STATIC COMPLIANCE

The nature of static compliance either in diagnosis or differential diagnosis is very Halted, due to the large variability in the values, especially in young children. But B1uestone, Berry and Paradise (1973) have differentiated between the middle ear effusion with high viscosity and low viscosity using compliance and Middle ear pressure status. They observed low compliance and normal middle ear pressure in aiddle ear effusions of low viscosity, on the other hand, in high viscosity effusion, a low compliance with a high positive or negative pressure was observed. Ststic coapliance values are found to overlap among normal middle ears, otosclerotics and ears with discontinuity (Alberti and Kristensen, 1970; Jerger et al, 1970; cited in Northern and Downs (1974). Considerable overlap was seen among different pathologies, otosclerosis (9.35 cc) otitis media (0.29 cc) Cholisteotoaa (0,16cc), thickened tympanic membrane (0.37cc) and ossicular chain discontinuity (193 cc). Thus they showed that the distribution of each abnormal condition extended into the normal range of compliance.

Variations in static compliance with age and sex add up to the already existing large variability. Jerger (1946b) has found static compliance to be the least informative test of impedance battery in children under 6 years of age. (cited in Northern and Downs, 1974).

The static compliance values are found to vary from 0,35 cc. to 2.29 cc. The compliance value is found to change with age; youngest 6.77 cc - 5-8 months old. 0.35 cc and 0.39 cc oldest 5 days to 13 months (Gerber and Cone 1975, cited in Gerber Cone and Gerber 1977). Thus they observed a significant decrease in the median and range of static compliances occurring between the ages of 3 months and 5 months and not thereafter. Thus, in general they found the new borns to have high static compliance due to tympanic membrane hypermobility and/or the relatively soft walls of the internal auditory meatus.. The other reason for high static compliances is the static compliance measured in children are affected by a high incidence of middle ear disease which occure is that age group and decreases in compliance. It is of not much importance when taken alone, but with other impedance measurements can contribute significantly to the diagnosis of variety of ear disorders in children.

ACOUSTIC REFLEXES

As reported earlier, the reflex findings has been reported to similar to that of adults.......- - I though a systematic increase In the frequency occurance of/reflexes is seen with increasing age. The acoustic reflex measurements have mainly two clinical application: (a) threshold determination and (2) Differential diagnosis.

Threshold determination:

For the adult population a number of formulae for the computation of threshold are available. But whether they can be applied to children also was studied. Investigators found the application ofthere in neonates was not possible. This is because in the reflex threshold to tone stimuli is still higher in neonates than in infants There-fore as the threshold for both tones and wide band noise is more in children, the difference between the two is very much reduced and equals to 9 dB as compared to - 23 dB in infants. Thus the methods described by Nieymer and Sesterhan(1974), Jerger et al (1974) are inadequate for determining threshold la neonates, as for thecomputation of threshold a minimum of 15-25 dB is necessary.

Margoils and Popelka (1975) (cited in Himelfarb et al 78) advocated a bivariate plot method for determining the threshold. In this method, the average of

3 tone stimuli (500 Hz, 1000Hz and 2000Hz) is first plotted as a function of the ratio between reflex threshold for noise (ART WBN) and the average reflex threshold for tones (ART tones), the two thresholds were plotted using regression equations which defines the normal region. Scores falling to the right of the line predicts hearing impairment. A vertical line implies that in noraal hearing subjects, the ratio:

$\frac{\text{ARTWBN}}{\text{ART TONES}}$ Might Increase upto a certain value, but since the threshold for tones is constant, normal hearing is independent of reflex threshold for tones upto a certain point. The other line has a slope of -1 because in profound hearing loss the ratio. $\frac{\text{ARTWBN}}{\text{ART tones}}$ might decrease.

To evaluate the blvariate method as an index of hearing threshold in neonates, the $\frac{\text{ARTWBN}}{\text{ART tones}} \times 100$ was plotted on the graph. Out of 27 plotted, only 6 fell in the noraal region. Therefore to quantify reflex thresholds, more research is needed. 22% of normal neonates fell in the normal category as with respect to adult criterion lines. Therefore this method'major applicability in assessment of hearing sensitivity of children (Young/neonates).

Reflex measurements also aid on the differential diagnosis as it is a mediated by loudness, it is considered a sensitive Index of cochlear pathology. The acoustic reflex threshold has been reported to occur at intensities less than 60 dB SL. This was seen in children younger than 6 years as well (cited in Northern and Downs, 1974). The acoustic reflex meausre are good indications of the conductive hearing loss. Klcockhoff stated that-(D61) a recordable reflex confirms presence of conductive loss. Anderson and Barr (1961) obtained distinct acoustic reflex responses in 18/19 children after surgical intervention. Most often in unilateral conductive loss, reflex would be absent on both sides. Jerger(1974b) has shown that the amount of A-B gap necessary to abolish the stapedial reflex was approximately 25 dB with the earphone on better ear and approximately 5 dB with probe tip in the poorer ear. The above phenomenon can be used to differentiate bet we en conductive and SN loss.

Thus, each entity on its own has a lot to offer to the diagnosis as well as differential diagnosis. But with a combination of tympanometry, static compliance and reflexometry the usefulness of impedance audiometry, gets enhanced.

The limitations of impedance audiometry in the testing of young children:

The test cannot be conducted while the child is vocalising, crying, yelling etc.
This is because the reflex arc prior to each vocalization causes the stapedlus muscle, to contract spontaneously and thereby altering the compliance of the tympanic membrane at random and makes impedance measurement impossible.

If in order to wuietan the child, he is allowed to suck, then also the middle muscle ear will be activated.Therefore each clinician should device his own techniques to counteract these problems, like - respiratory distortion (Northern and Downs, 1974) Lamp and Norris (1969), cited in Northern and Downs, 1974), child should co-operate for testing, that Is allow probe to be put in each order. These restricts the used of impedance audiometry in difficult to test population. But nevertheless, its value in the testing of normal childern is in no way reduced.

CHAPTER II VI
ELECTRO COCHLEOGRPHY

In children majority of the bearing losses are due to perpheral impairment. Therefore a knowledge of the function of the periphesal system is necessary for diagnosis as well as for the recommendation of hearing aid. Even in rear cases where the lose is due to retrocochlear or central impairment, information regarding the peripheral function is necessary for differential diagnosis and for selection of an apropriate remedial avenue(Aran 1978) Thus the demand for information regarding the functioning of the peripheral system led to The development of 'Electrocochleography' (ECoG). ECoG ia a test vhich notes, records and measures the averaged electrical signals, which are set up between the bonypromontary of the cochlea and the lobe of the ear in response to very short acoustic stimuli of alternating phase (lortman and Aran 1971)• In more general terms, ECoG can be defined as the recordin of the electrical activit y of the peripheral auditory system with electrodes- placed near the cochlea(Mendel 1977). The potentials generated at the level of cochled ca n be classfied as cochlear potentials, summating potentials. and action Potentials.

The cochlear potentials/cochlear microphomics (CM) are the ones which are evoked, immediately after stimulus presentaion. There are linearly related to the amplitude of displarement of the cochlear partition. Over a considerable frequency and intensity range, the waveform of ECoG reflects the waveform of the aconstic stimulus being in phase with the amplitude of the movement of the cochlear partition.

The summating potential is a direct current shift that continuous throughout the presentation of the stimulus. The magnitude and polarity of this potential is dependent on the recording site, frequency and intensity of stimulus.

The action potential occurs within 3 M.Seconds of stimulus onset, due to simultaneous discharge of many individual nerve fibers in an all or none fashion, in the production of neural spike in the auditory branch of eighth nerve.

Among the thtee potentials CM, SP & AP, the AP is most often employed as the index of hearing. Some importance is given to CM also but SP is not usually used as a measure of hearing sensitivi y. The action potentials are used to compute thresholds, and a combination of CM & AP,are used for differential diagnosis. Thus ECoG has its application both in the measurement of threshold as well in differential diagnosis.

Historical aspects:

Though the technique of electrocochleography as is presently understood can be traced back to (1971), the electrocochleographic evoked potentials were known way back in 1931, 1931. Among the potentials, the CM and AP were the ones to be discovered first. Wever and Bray (1930) were the first to oberve CM but they mistook this to be AP (cited in mendel 1977). It was Adrian 1931 who identified the CM and named it as cochlear'micro-phonics '(cited in Mendel 1977). He observed the electrical changes that were generated in the cochlea which were passively conducted by the nerve to the recording site, and attributed them to some kind of microphonic action and hence the name cochlea microphonic. It was felt that Wever and Bray's observation of electrical changes were a a misture of CM and AI. Therefore many studies were conducted to separate AP abd CM (Davis etal 1949, Ruben et.al 1961, 1962,1963 and Othews).

The isolation of the two potentials became successful with the development of differential electrode placement as a result of a series of research studies (Saul and Davis 1932, Davis et.al 1934, Hallpike Smith 1934, Davis et.al 1949). Thus this was a major breakthrough which led to the development of tht modern electrocochleography.

This new development led to more and more researches which as a result led to the discovery of summating potential (SP) (Davis et.al 1950). Thus the recording of three potentials was achieved. But most of these studies were conducted in animals and therefore it could not be ap lied directly to humans beings.

Fromm - Nylea and Zotterman(1935) extended the recording techniques to human subjects and were the first to record electrocochleographic potentials in humans. But the recordings were very small and not so clear. Andreer, Arapona and Gersuin (1933) also found a similar problem when they recorded thene potentials from the vicinity of the round window in cases .with tympanic memborane perfection. Therefore until the ear 1940-S there was not much progress in this field. Lampert et.al (1947, 1950) came up with the suggestion of the placement of electrodes through an intact tympanic membrane onto the promontary at the time of surgery. They also assigned the term electrocochleogram. to the graph obtained with the above,recording technique. But the recording technique of Lampert et.al 1947 and 1950 did not elicit clear distinguishable response. Therefore until late 1960"s not much research was done in this area. The second major breakthrough occured with the employment of computer averaging techniques by Ronis (1966). This actually served as basement for the rapid development of electro-cochleography-as the modern era of ECoG began shortly after this, with the publications of 3 groups of investigators, (Yoshie et.al 1967) Portaram et.al(1967) and Sohmer and Fairmesser 1967).

The application of ECoJ to children was primarily reported by investigators in three laboratories, that of Portman atd Aran (1971) in Bordeaux, Berlin and Callen (1376) in New Orhans and Sohmer and Feinmesser (1972) in Jerusalem. These three groups have advocated different recording sites. lortraan and Aran(197l) recorded ECoG from the promontary. Berlin and Cullen (1976) recorded from external auditory miatus near the tympanic membrane where as Sohmer and Feinmesser recorded from earlobe and Scalp (1972) using surface electrodes, irrespective of the site of recording all three groups have concluded that reliable potentials. can be evoked in most new bones and infants. Though a number of studies have been conducted investigating the aplicability of ECoG in children, not much, normative data is available, mainly because of the need to administer General anesthesia to children in order to obtain an electrocochleogram ic ted in Gerber and Mencher l978).

In clinical elect rocochlography the interest in mainly focused on AP but of late, even CN is being given some importance thereforein this chapter, first a discussion about the recording and application of P will be taken up.

The action potential is the electrical potentials from the auditory nerve noted initially by Derbyshire and Davis (1935) (cited in Northern and Downs 1974). This potential consists of netne impulses in the eighth nerve which ars trigered by the cochlear microphomics. A recording of the action potential exhibits a waveform with thrre negative peaks N_1 a well synchronized volley of impulses followed by smaller waves known as N_2, and N_3

The principal characteristics of AP waveform are latency, amplitude and share, The latency of the AP waveform is considered to be a clue to the frequency region of the cochles contribution to the response. The amplitude of AP ic considered as a reflection of the nurber of active elements contributing to it and the synchroney of their discharge. The shape of the waveform is considered to be the result of a corapromise between the electrical field of neuron 3 which have discharged and newrons which are discharging at the given moment. the latency and amplitude and shape of the N_1 is considered mainly in the development of cochleogram. But for the description N_1 N_2 and N_3 are considered,

Procedure:

'The most, important feature of the procedure which has direct bearing on the responses recorded, is the recording site. The three most commonly used sites are:-

Portnontary (Portman, Lebert and Aran 1967, Aran and Lebert 1967, Aran et.al 1969, 1971, 1972 and others.)

External auditory meatus towards the tympanic membrance (Coats and Dickey 1370, 1372, Coats 1974, cullen et.al 1972} and earlobe, Sohmer and Peinaesser 1967, 1970 Dood 1970, Moore 1971 and others.) Of these three sites, the best and clear response is shown to be elicited from promontary recordings (Portmar, Lebert and Aran 1967). The responses magnitude of the different sites were ccmpared at constant intensity level of 90 dBSL. It was 10µv on promontary recordings,µv ear canal recording and 0.3µV when recorded from the

the earlobe. The above study reveals clearly that to obtain a good distinguishable response, the site of recording. should be nearer to the source of these potentials, that is the cochlea. Therefore, the promontory recording technique appears to the optimal approach for Ecoe (cited in Gerber 197 7}. promontory recordings involves a transtyampenic reach. This recording should be dune under general auestnesia(G.-,) The procedure is as follows:-

The infant is placed in the crib and GA is given Once the child is auestistised, a sueal gauze needle ispassedthree)thetympenicmembraneuntillitcomes to rest against the promontory. The otuer end of the electrode can be either fixed or freely flested. The latter is preferred if one wished to use earphones (Yanz 1976), cited in Gerber l977). This recording techniques; has been found tu yield reliable responses even in neonatce of 1 day to adults up to the age of 79 years. But in some cases, the permission may not be granted toput the child under CA. In such cases the recording.

can be obtained by placing the silver chloride electrodes wrapped in saline impregnated cotton (Cullen ct.al 197?) or expandable clips (Coats and Dickey 1970) (cited in G-erber 1977). Reference Electrodes can be placed on forehead and mastoid respectively. The other alternative recording site in such cases is the earlobe. Even this site has been shown to give discernible responses (Moore 1976).

Thus the AP can be recorded from either promontory external auditory med-tus or from earlobe. All three sites have be n shown to give quite diatinguishable responses, even through the recording fron the promontary are the best. The major principle of recording of discernable cr clear reponses is to separate the electrcoes sufficiently) that is differential electrode placement is the key for obtaining clear responses, irrespective of the site of recordin. . Martin (1973) has opined that the selection of recording site as dependent upon the biases,professional training and expertise of the tester as well as the subvert's permission.

Once the electrodes are fixed in place, the ear is stimulated with short tone bursts of alternate polarity or elicks. This stimulation evoken CM and Ap which are picked up/the electrodes and are sent to an averaging computer. The job of the computer is to cancel the CM *and* sum up the AP responses. Thus a record of the AP waveform is obtained. This is subjected to analysts in terras of its amplitude* latercy and shape.

<u>Analysis of response:</u>

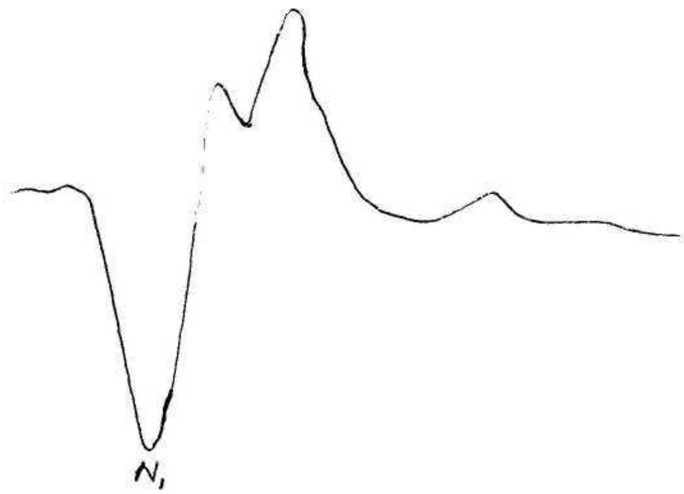
The Diagnosis is based on the tried characterstics of the AP waveform. ....

1. The amplitude and latency of the response to click at each intensity level and the input - output functions.
2. The absolute amplitude of the maximum response in µv. This gives the degree of cofidence in the accuracy or thresnold determination and the significance of the pattern of response.

3. *The* latency of response near threshold. Thus by a simultaneous and compe rative analysis of the three main characterstics of the AP waveform, the response can be classified into five categories, that is, normal, conductive loss, SN loss of cochlear origin with recruitment and retrotrocochlear.

Among the three measures, the latency of the waveform is considered to be the most stable and reliable measure. This is because, the amplitude and shape of the waveform is found to be influenced by auditory and nonauditory constraints such as, tissue and electrode impedance, current paths etc., but the latency remains unafected by all these factors (Berlin 1978).

Therefore by analysing the AP waveform with respect to its 3 parameters and with special emphasis on the latency, one can make a diagnosis with a fair accuracy, The abnormal waveform can be identified only with reference to a normal response. The normal response in neonates and infants is judged on the basis of its similarity to the adult's normal response. The normal response in adults is found to be as follows:



In Infants of less than/normal response itself is found to have a prolonged latency, diminished amplitude and elevated threshold as compared to adults. By the age of 1 year the infants response is found to closely approximate the adult response. The normal threshold in infants and neonates is found to be 35 und 45 dBHL as compared to 28 dBHL in normal hearing adults. In figure- is depicted, a normal AP waveform:in children.

The *AP* waveform varies as a function of *.type* of stimulus, intensity, intenstimulus inteival, recording site, and type of anesthetic agent administered. The influence of each factor on the response will be discussed beforestating the optimal conditions for the elicitation of a clear and marked response.

<u>Type of stimulus:</u>

The frequency and the temporal parameters of the stimuli is found to influence the AP waveform. High frequency stimuli, iat that is 2KHz—1KHz and 8KHz are considered to elecit clear specific response. The low frequency stimule are said to be ineffective (Davis 1976). According to Davis (1976b), the AP response following the stimulation of a low frequency stimule, like 500Hz is initiated at the basal turn of the cochelea by the low frequency transient. Therefore this response is cosidered to be of limited use for audiometric testing(Mendal 1977).

The traveling wave of Bekesy has been observed to take 3 M.Seconds to 7 M.Seconds to move from base to apex. The velocity of the wave is uneven. Its rate is faster at the base compared to apex, and thereby discharges more hair cells and nerve fibers synchrononsly at the basal turns. In ECoG the AP response latency is about 1.5 to 3 M.Seconds. Therefore by combining the above two points, one can clearly make out that AP response seen on stimulation is only the response of the basal turn of the cochlea. As it is the high frequencies which are represented at the basal turn, high frequency stimuli are-found to be conducive to elicit clear AI response. Therefore ECoG can be claimed to be mainly a high frequency measure that is frequencies above 1 KHz. This being the case, a person with normal basal turn, that is with normal high frequency response but with low frequency loss will give a normal response on ECoG. Thus one should bear this in mind while interpreting the ECbG response.

Intensity effects;

The general observation has been that, us the intensity of the stimulus is in reased, the latency of the response is found to decrease upto a certain point and maintain a plateau beyond the critical point. Zerlin - Naunton (1965 1953) observed a latency shift of 1M .Second ever a wide range of intensity. These changes in latency were attributed to the changes in the latency of the high frequency units which - had been activated at lower intensies and not to the acfition of neural elements. Berlin 1978) has reported of a shift in the latency from 4rmseconds at 20 dBHL to 1.2 m.seconds at 35 dBHL.

The amplitude of response has also been found to increase gradually at lower intensities, up to about 50 to 60 dBHL. Alt higher incensities the amplitude incease much more rapidly upto about 50 dBHL and at this level it forms a plateau. Yoshime (1:36:3) has termed the low in enaity range as I-curve and high intensity range as the M-Curve. The explanation offered for such a behaviour was that, there axe two populations of the auditory units, the outer and the inner hair cello which gives rise to the two curves respectively. Elberling (1974) and Eggermont et.al(1974) have given another explanation. According to them the two populations are hair cells located in the middle turn and the basal turn of the cochlea (cited Gerber 1977).

Thus from the above reports one can conclude that high frequency stiumuli is optimal for the elecitation of clear AP responses. The intensity of the stimulus has an effect on the latency and amplitude of the response wave-fore. Therefore while juding the response.", are .should account for all these factors.

Anesthesia:;

for testing children usingECoG, the children must be given general anesthesia. The anesthetic agent given has bee n shown to h ve some effect on the response (Zvonar, 2yonar, Kuhndle odenthal 1974), Crowley, Davis and Beagley 1273). The most commonly used anesthetic agent is Ketantine HCL. This is found tc reault in excenive swallowing action and Minor movemets in the jutient, which in turn produces electrical and mechanical artifacts in the recording • Therefore tc eliminate the interference of these, inhalation anesthesia has been advocated (Zvonar et.al 1974)» Inmitzer and Schnud(l973) have advocated an injection of droperidcle and feutanyl prior to the administration of ketmnine(cited in Gerber 1977). Thus while administering anesthesia tc the child, *one* ;;u>.Jld *t->Ve* precaution, to minimise the effect of anesthesia on the response.

Electrode placemen:

As has already been informed, the AP response varies with the placement of electrodes. Eggermont and Odenthal (1974c) have given the threshould obtained at different recording site.

Hound window 0 dBHL

Promontory 5 dBHL

Anaulus typaranicus 10 dBHL

External ear 30 dBHL (Cited in Gerber 1977)

The above table shows the variations in thresholds that occurs with different recording sites. The external recording shows the poorest response. Even Davis(l954) has advised against, the use of external car recording. But Somarer(1972) advised to use external ear to be electrode recordin. as it is a nontramatic technique. He observed clear and reliable AP responses from the earlobe electrode recording in infants of 4-31 months of age.

Thus from these reports, one can make out that the site cf recording has a significant influence on the AP response. It is better to do promontory recording but if this is not posible then an earlobe recording can be opted for, but taking precaution to account for the difference in threshold, while judging the responses.

After having reviewed the variations in response waveform due to the influence of a number of variables, one can tentitively suggest the

the conditions that are optimal with respect to response accracy. These conditions are as follows:-

Site Promonmony

Stimule	Broad band Signals with a band with of 100 - 4000Hz or a center frequency of 4000 or 3000 Hz
No.of stimulus presentation	64 to 100
Inter stimulus interwal	100m.seconds(Eggermont Oderithal 1974)
Duration of. tone Bursts	4 to 6 m.seconds
Age	more than one year (Aran 1978)

Thus as far as possible one shouldi try to maintain optimal conditon's while adminstering ECoG is *the* clincal set up.

The electrocochlsography has both advantages and limitations in Its application in testing the peripheral function of children. By reviewing both one can judge its relative valve as a clinical tool in the audiologica1 evaluation of rearing sensitivity in children.

Advantages:

ECoG has been claimed to be a very reliable test in the determination of threshclds as as well as for differential diagnosis between sensory and newral disorders(Aran et.al 1969, Aran 1973, Yoshie and Osthasic 1969, Odenthal and Eggermont 1976).

Threhold determination:

For determining the threshold only the AP waveform's is taken into consideration,, the CM being in no way related to threshold identification.

A good co-relation between ECoG thresholds and behavioural thresholds in children also, have been reported by a number of investigators Somarer et.al 1972), Cullen and Berlin 1976), Spoor-Eggermont et.al 1993).

The difference between ECoG threshold and voluntary threshold had been reported to be 10 dB or so in older children, and less then 20 dB in younger children(Spoor-Eggermont 1958).

But the ECoG threshold was found to vary with frequency. At higher frequencies except at $8KH_z$ the differnece lies within 6 dB where as at 3KHz and 500Hz it is found to be 10dB. Thus totaly the difference between the two is found to range from 6 to 11 dB (Spoo r - Eggermont 1958).

A variation in the relation between the two threshold is observed as a function of degree of lose and tjpe of loss as well. At low frequencies (500 IK) the ECoG threshold are 10dB higher compared to behavioural thresholds in cases with mild hearing loss, but the difference is seen to decrease with an increase in the degree of loss. Especially at 500Hz, if the loss is severe a reversal of the above might be observed, that is the ECoG may be better than the subjective thresholds. The relation bet.een the voluntary thresholds and ECoG thresholds varing with the type of loss. on an sloping type of loss, the ECoG thresholds are elevated compared to behavioural thresholds, but in flat or rising type of looses. the voluntary thresholds are greater than ECoG thresholds. This is especialy the case, for test frequency 500Hz. The reason given is that, probably the high frequency elements which are located in the basal turn of the cochlea contribute most to the AP response and thereby resulting In poorer thresholds in the presence of a high frequency loss (Spoor-Eggermont 1958).

For the 3KHz teat frequency, the condition is the reversal of that of 500Hz, that is, in slopin, audiograms, the ECoG thresholds are better compared to the voluntary thresholds. This is explained on the basic of the 8KHz tone burst spectrum. In 3KHz tone burst spectrum, the 2 KHz component is seen to be 40dB below compared to 8KHz which is the main component, Therefore in steeply sloping audiograms, it is possible that the response bein, measured is from the 2KHz region rather than at 8KHz region. This hypothesis was confirmed by the observation of longer latencies, which corresponded with that of a 2KHz response. Thus while making threshold measurement, one should make sure that the latency of response at threshold is in the region that is normal for that frequency in normal hearing subjects.

In the youn er children that Is 5 years also the difference between the behavioural and ECoG thresholds is found to be less than 20 dB. If the differences are larger, then the implication is that these children have some other disturbing factor influencing the performance. This is most often the reflection of the ability of the child to respond voluntarily to stimuli.

These children were categorised Into 3 groups on the basis of their hearings loos, that is, 20-60dB, 60-90 dB and greater than 95 dB. The co-relation between ECoG thresholds and voluntary thresholds were evaluated in each of these groups. In the group with greater than 95 dB loss, no AP responses were obtained indicting a severe peripheral hearing loss. In the group with 60-90 dB loss, the AP responses conformed with voluntary thresholds only in 50% of the cases. In the group with 20-60 dB loss, the ECoG measurement did not confirm the above results^ in all. Thus these results imply, that whenever a subject ranifeste some degree of loss, then one should do ECoG to obtain a reliable and valid data regarding the peripheral hearing of the subject.

Thus Spoor-Eggdermont (1953) concluded that the accuracy of threshold determination by ECoG wae comparable to conventionalaudiotnetric procedures and also that ECoG provides reliable data when conventional techiques are a failure.

Aran (1973) has also made a statement lik e'higher the ECoG thresholds, better the agreement between behavioural threshold and ECoG or, the better the peripheral function the less accurate is the BOA" (Aran cited in Gerber and Mencher 1973, P-2 4). The meaning of this sentence is that severe the loas, better is the u^r cnent between the two, As,if there io no loes or if it in very mild, then it is dii'i. cult to elicit response from the subject at lower inten3itivea by the comie^vtional method. Therefore this results in a large discrepancy between the ECou threshold and subjective threshold. This finding oi aran (1973) agrees with those reported by Spocr-iLbermont (195 3)•

Aran (1978) observed some discrepancy between the early EGoG and later behavioural iseaaures^n his follow up study the discrepancy was in "both directiona, that is in some, the ECoG thresholds were better tnan behavioural where as in some others it was reverse. He explained these discrepancies on the basic oi" patho-physiolo^iccl differences, exiotin.,; at different timeK of tectin^.

In some cases w&^&e- BCoG thresholds wcit better than voluntary thresholds, was explained as . ue to either a SUT;eriropoEed concttctiWe lo; a at the time of behavioural tenting or *us* due to the presence of a progre Give lors of central ^•oaiX •

The caseG v,here the I;CoO thresholds were pcorer than behavioural threfiholca, it was explain ed as due

v

due to preseme of a contiuctpWe IOFS eledn.^ BCoU testing.

Thus according to Aran(l973) the co-relation between the two was very good, once the discrepancies had been accounted, all the studies for reviewed report of a good co-relation between ECoG throrholde and behavioural thresholds• This implies, that ECoG is a vreliable method for threshold determination and therefore can be adopted for daily rountine in the testing of young children.

An important aspect of threshold determination by ECoG is that, the threshold of each ear can be obtained separately wi thout any masking. This property of ECoG is very valuable especialy for children, where it is very difficult to obtain the thresholds of the two ears accurately as roost often masking canr.ot be employed• This infomation is valuable in the selection of hearing aid and in making proper referals. With this technique unilateral loss cases can be traced Aran 1975)

(Thus the potential value of ECOG in the determination of threshold is good. t' Therefore one can adopt this technique as a daily routine for the evaluation of children)

The value of ECoG in the determination of threshold is high, especially in case of young children who fail to give reliable responses to other audiometric measures like puretones.speechetc.

Differential diagnosis:

The two potentials which have made differential diagnosis possible by electrocochleagraph are, the aution potentials and the oochlear microphones. Of the two, the potential value of the forms is greater than the CM aS the APS are highly sensitive to the status of the peripheral auditory system. In contrast to AP, the CM derives its significance for differential diagnosis only in combination nith AP measures. Therefore in the discussion of differtnial diagnosis by ECoG, prime importance will be given to the measures of action potentials.

As has already been mentioned, the configuration of the AP waveform is very sensitive to the condition of the peMpheral auditory system. Therefore any significant alteration in the peciphera1 system will alter the normal configuration of the AP waveform. These alternation is the configurmation pre reflected PS changes in the latency, amplitude and pattern, of the waveform. These changes are found to be specific to the type and extent of the pathology in the auditory system. Therefore an analysis of the AP wave form to stimulation in terms of the following parameters will aidl in differential diagnosis. These parameters are: 1. Threshold of AP 2. Input-output function of the N_1. peak. of AP response, thpt is the amplitude variations of N_1 aS A function of stimules intensity. 3. the intensity-lptency functions of N_1.wave and 4. the waveforms of AP

AP as a whole.

Each pathological condition manifests specific changes In these measurers, andtherefore the characteristic types of response one obtains in various pathological condition will be discussed here.

Conductors loss: in this condition, the threshold of AP will be shifted by an amount equal to the degree of loss, the amplitude of the N_1 peak will be reduced and the latency of N_1 will also show a shift (Yoshic, Ohastu 1969, Berlin and Gonad 1976), But the shape of the waveform-remains the sam AS is seen in normals.

SN Loss: The SN Loss has also been decribed as "subteontnce loss:" by Davis 1962. He has defined subticulims loss as the loss of sensory units in a quantal fashion. He has further described 4 types of subtianture loss on the basis of ana-tomical distribution of lesion, as follows:-

1. A total subtrative loss in the basal turn of the cochlea, usually associated with an abrupt high frequency loss.
2. A *graded* subliacture loss most often associated with a gradual high frequen-cy loss.
3. A random subtiacture loss, realted to old age and aconstic tumors and
4. a selecture subtiacture loss, associated with menisrele disease..

But irrespective of the type of loss an elevation of AP threshold is observed 1B SN loss cases. Tha variation among the different pathologies ins reflected only in the pattern of response. Each pathological condition will be taken up individually and discussed.

Cochlear Loss:

In a typical cochlear loss case, the following types of AP response is most often observed. These are 1, A SHort latency interweal at threshold of about 2.m seconds 2. A disphasic pattern at all levels of the stimulus. 3. a rapid increase in the amplitude without reaching a pleateau with an increase in intensity is observed. The increment in the an-plitude is 10 times of that seen in normal for a similar in-crease in intensity. Eg, In the ccchlear cases the incre-ment seen for a 10dB increase in intensity is equivalent to a 50dB increase in intensity in normals. (Portarman et al 1973 • cited in Northern and Downs (1974)

The response of AP to an increase in intensity has been described in terms of L and H waves
They haves also decribed some other types of AP response seen in these cases as

1. the appearance of a double peaked or disccociate waveform.
2. an obsnce of L curave with normal values for H curve and
3. a normal or moderately elevated AP threshold
4. A short leatency of N_1 Peak

population and therefore the increments of N_1 was not very marked. This also indicated that the lose in such cases was not due to the involvement of the entixe length of the cochlea, but more so in the high frequencies(Yoshie 1973). The intensity - latency relation pnd the latency of N_1, was similar to that of normals.

In the unilateral sudden hearing loss cpses, the waveform of the AP in the two ear vary. In the normal ear the AP occurs as a composite wpve of two peaks, N_1 and N_2 where PS in the ppthological epr the input-output ourve of ft. is similar to N_2 curve pattern, but the pattern of input-output curve of N_2 remains identical to the H curve of normal ears. Thus this kind of a differential pattern of N_1-N_2 peaks aids in the diagnosis of writ sudden hearing loss.

In meniere's disease the changes in the AP response depends upon the severity of atttack. The more source it is, the greater the distration of AP waveform. This distortion has been attributed to the increased Endolymphatic pressure in such cases- this kind of distortion results in in indistinction of N_1 component which becomes prominent as the diseses progresses. Elivation of the AP thresholds pnd deformation of the modal peak has also been reportedYoshie (1973) has reported of an expggerated difference in the AP response to condensation and rarefraction clicks in these cases. The latter findings has been explained in the following way; The hyperexcitability of the nerve endings due to the sense organ malfunction, may give rise to abnorma1 nerval activity. This abnormal activity was correlated to the rarefraction phase of the movement of bsasilar memberne in the basal turn. This is turn resulted in the differnece in repsonse between the condensation and rarefrction clicks.

In retrocochlear loss the AP threshold was found tobe elevated and pattern of response was also obnormal. The abnormality was the prsnce of a sharp postive peak of very short latency (<1 msec) followd by a slow negative wave . This kind of a response was oberved in children as well as in adults with retrocochler pathology. Aran (1971) had made similar observation but had attributed this specific pattern of response to cochlear disorder but later on he consisitenly observed the abnormal response in retrocochlear loss cases, and considered this type of abnormal response tobe chacracterstic of retrocochlear loss.

Gibson and Beaglay (1975) have reported the following type of AP responses in acoustic neuroma:

1. The presence of a distorted AP waveform with gross prolongatin of N_1 peak to form a shallow trough extending fro about 5 m.seconds to 15m.seconds in duration.
2. A higher AP threshold compared to subjective threshold
3. A higher AP threshold compared to the psendo threshold of CM.

Though all these variatons in AP response in retro-cochlear cases, observed the most prominent response was a widening of the N_1 peak. The better finding has been attributed to the damange to the afferent waveform of the 8th nerve. This damage has in turn been related to the presence of tumour on the nerve, She damage of the 8th nerve fibers effects the conduction velocity along the afferent fibers (Gibson and Beagley 1975, Yoshie 1973) has reported yet another type of AP response in retrocochlear cases the input output curvers for a11 the frequencies were similat to H curve pattern, and the amplitude of N_1 formed a plateau at the maximum value. The latter was considered as evidence for a rapid saturation of afferent information carrying capacity of the cochlear nerve due to a large newong loss but not neccuarity due to hair cell loss.

The differential AP response specific to the pathology of the auditory system aids in the differenial diagnosis among various clinical conditions.

The AP response has been found to be useful in differentiating the psychotic children from hearing inspired children. In suspected case of phychosis, a normal AP waveform is expected, but if it is a severe hearing impaired child than a total absence of AP response is expected. Therefore by testing these children using ECochg the required differentiation can be made. This kind of dilimation is important as the two cases require different kinds of treatment.

Thus the AP responses of the ECochg seems to be a valuable clinical tool in the determination of threshold as well as in the differenial diagnosis of the various clinical conditions.

The other potential of ECoG, that is the cochlear microphones (CM) adds up to the battery of measures avaiable for the differential diagnosis a mong the various pathological conditions.

The CM measures was not given much importance until the development of differential electrode recording technique with the development of such a recording techniques, the knowledge about the intra cochlear events increased pnd with this, the clinical significance of CM also increased.

The method of recording of CM is similar to that of AP. But here the AP responses are cancelled by inverting the phase of the stimulus alternately and at the same time by subsracing the input information instead of adding it up as is done in the recording of AP. The latter process is accomplished by an avaeraging computer.

The CM in combination with the AP aids in differsntial dipgnosis, and by itself provides precise temperal modulation of nerval activity. The modulation is achieved by the suppression of the chemically mediated neural responses to acoustic stimulation by the cochlear microphonics. Negative instead of peak posture peak is taken as an indication of the initiation nerval activity. Thus CM marks the initiation of AP and maintains the temperal procison of the neural activity, but is not directly related to the generation of AP (Eldrgdge)

By comparing the CM and AP responses, a diffierentiations between the sensory and nerve, disordrs can be made. The presence of both AP and CM indicates normal hearing, the obsence of AP presence of neural drys function with a normal fucnctioning cochlea. The absence of the both CM and AP indicates the pre-sence of senaorinesal loss. In some cases one observes the presence of AP but an absence of CM. This kind of response has been reported by Nianssal and Legovi(1967) in cases with complete degeneration of the organ of corti in the basal turn. but in human beings this kind of response has not been reported. The occurence of such a response has been considered unlikely as the basal turn of the cochler is muchmore wider compared to the xodents. Therefore presence of AP, always indicate atleast a partial functioning of the cochlea. Thus the two potentials, together provide significant information for differential diagnosis.

The value of CM in the determination of threshold is not much as CM lacks an absolute threshold. A pseudo threshold has been obtained for CM. This refers to the intensity level at which the CM is observed above the background activity. In noumals most often psendo threshold approximates 60dBHL. but in some the psendo threshold may be as low aS 30dBHL. Hence CM is not a reliable measure to determine threshold of hearing but is valuable in the differentiation of neuro-logical and otological disorders.

Thus the Electrocochleography has a significant value in the determination of threshold PS well as in the differential diagnosis of various pathological conditions and in the identification and differentiation of childern with psychiatric problems.

The limitation of ECoG are aS follows;-

1. ECoG measurement through as infant tympanic memebrane has been found to be of much use, therefore a trans-mpanic approach is a must and this neccesstates the administraton of general abesthesia in childern Most often the parents of the childern do not give permission to use general anesthesia, and therefore ECoG, cannot be used as A routine test in the evaluation of young children. The information derived from ECoG is needed to take P decision ragarding the course of treatment tobe followed. But as A record-ing of ECoG requires a surgical intervention, the information will not be of much uae(Bekesy . cited in Northern and Down 1974). The record ing of ECoG involves many technical problems pnd there-fore is not appicable on a routine basis (Lerben Stal) 1961). Berlin (1978) has given the three major limitptions of ECoG technique.
   1. The stimuli which one normally percrives does not elicit the action potantials. This indiates that, ECoG does not actuplly measure. One's hearing sensitivity in the traditional sense, that is in tha sense of behavioral response to sound.
   2. The acoustic contraints of P short tone burst are such that, an uncontaminated WAVE cannot be

generated unless atleast 2 periods of the singnal pass during the rise time. This basically restricts the use of signals of frequencies of above 2KHz.

3. Audiometric tones have slow rise times and are continuous, and elicit single unit activity, but these single unit activity will not be synchcorous enough to average a compound potion potential. Therefore relating an audiometric threshold to an ECoG response in tenacaions. Two studies have reported of the disagreement between voluatory threshold and ECoG three hold (Sggermont 1976; Berlin 1978). But many other studies have reported of a good agreement between the two measures, that is, the subjective threshold pnd ECoG threshold. (Copts 1976, Monney et al 1976, Nauton and Lerlin 1976ab; cited in Berlin 1978).

The frequency selectivity of ECoG response is poor (Eggermont Et al 1974).

Therefore ECoG can be used as a supplement to behavioural measures but not as a substitute in the evaluation of hearing sensitivity of children. The difference in the threshold sensitivity obtained at the different recording sites should be accounted for, while interpreting the results.

CHAPTER 7

BRAIN STEM EVOKED RESPUSE AUDIOMETRY

ON presentation of an anoustic stimulus certain potentials are gen rated which can be recorded from the vertex. Those potentials which are evoked with in the first 10 m.seconds following/stem evoked potentials." These potentials represent the bioelectrlca1 responses of the 3th nerve and brain stem nucleci. These were first reported by Sohmer and Feinmes (1967). They associated the multiple waveforms recorded from the ve tex to repetitive firing of tne audit ry nerve. Jewett(l970) also observed tess waveforms and reported them as a unique response instead of associating them with the repetitive firings of 3th nerve. His work instigated a number of invectigators and resulted in an extensive research in this area.

The brainsteam evoked potentials can be grouped into two distinct categcriee based on the stiaulus charater- istics. These are (l) Onset potentials and (2) frequency specific potentials. The onset potentials can be further clssified as follows.

(a) Par field potentials (Jewett and Williston l971)

(b) Far field ECoG (Teekildseen et al 1975)

(c) Surface recorded ECoG

(d) Brain stem auditory evoked responses

(Hecox and Galambes 1974) and

(e)transient responses occuring,within l.m.second duration Picton et al 1977)

The frequency specific potentials can be catagorised *an* follows:-

(a) Far field frequenqy following response,

(b)2arly tone evoked response.

(c) .Frequency folowing response,

(d) Brain stem responses to low frequency sounds and

(e) sustained responses.

Out of the two potential, the onset potentials have been more widely adopted in the clinical set ups. Jewell's observation revealed a waveform with 5 or postive, waves with latencies varying from 2 to 7 Msecs and amplitud varying from 1 to 4 mv subsequent to presentation These potentials were stated to arise from multiple locations in the brain stem and as characterised by the presence of 7 peaks. These peaks have been referred to as P I, II,or wave I, II, etc. Jewett(l970) has associated these waves to different anatomical sites., that is he has given the neural loci for all these weaves, which are as follows:-

Wave I	Whole nerve action potential,
Wave II	Oochlear nuclear complex,
Wave III	Superior olivary nucleus
Wave IV	Nucleui of lateral leminiscus and Brachium of inferior cclleculus,
Wave V	Inferior colleculus
Wave VI & VII	Higher brain centers or lower brain stem auditory centers.

The source of these waves as given by one other investigator varies slightly from that given by Jewett(l979) Jte have attributed the 3rd wave to contralateral olivaty bodies and that of 4th to lateral leminiscus and pre olivaty region. This kind of allotment of waves to different anatomical sites gives the impression that these waves are arranged in a serial order. But this notion should not be entertained as studies have shown the presence of wave V even in the absence of wave I(Menniera meryl976, cited in Martin 1976). The findings of Ormtz et al (1930) also support the above contention. They investigated, the influence of click sound pressure direction, on brain stem evoked responses in children of 2½ to 11 years old. They observed significant differences in latency for the two directions respectively and this latency difference was not uniform across the waves. Based on these observations, they confirmed the absence of same order in occurence of these waves.

Among the sevel waves observed by Jewett the 5th waveis referred to as J V (Jewett V) or VN_7 (Davis), which the most stable negative peak at vertex with characteristic latency

for the following reasons:-

1. It is independent of state of arousal and age of the subject.
2. Less time consuming.
3. Easily accessable for recording.
4. Can be obtained at Hear behavioural threshold levels (10 dB HL).
5. Is stable and reliable even at high click rates.
6. Variability of its latency is within an age group is very small and manifests systematic variation with maturation.
7. Its latency is short enough 4 to avoid masking by psychio response, and long enough to avoid confusion with cochlear microphonics or stimulus artifants.

8. Good frequency differentiating indicator of hearlng(Oster - Hamrruel).

II. Contrary to the general contention, Mendelson and salany (1979) claim have I to be more reliable than wave V. Thier arguement is that the have I manifests less inter subject variability and the maturatin of wave I is earlier that is by 6 weeks compared to V which mature by one year of age. Another stand given is that wave V voltage is very small (O.lμv) a complete relaxation is quest to be able to detect response sat lowe Sls. Thus according to their wave I is to be preferred while testing very young infants and monates.

There are some was have recommended, the latency difference between wave I and V for differential diagnosis. In a clinical set ups, the latency of V,LI and latency difference between wave I and V are tobe considered in the mesurement of auditory sensitivity and for differential diagnosis

Procedure:

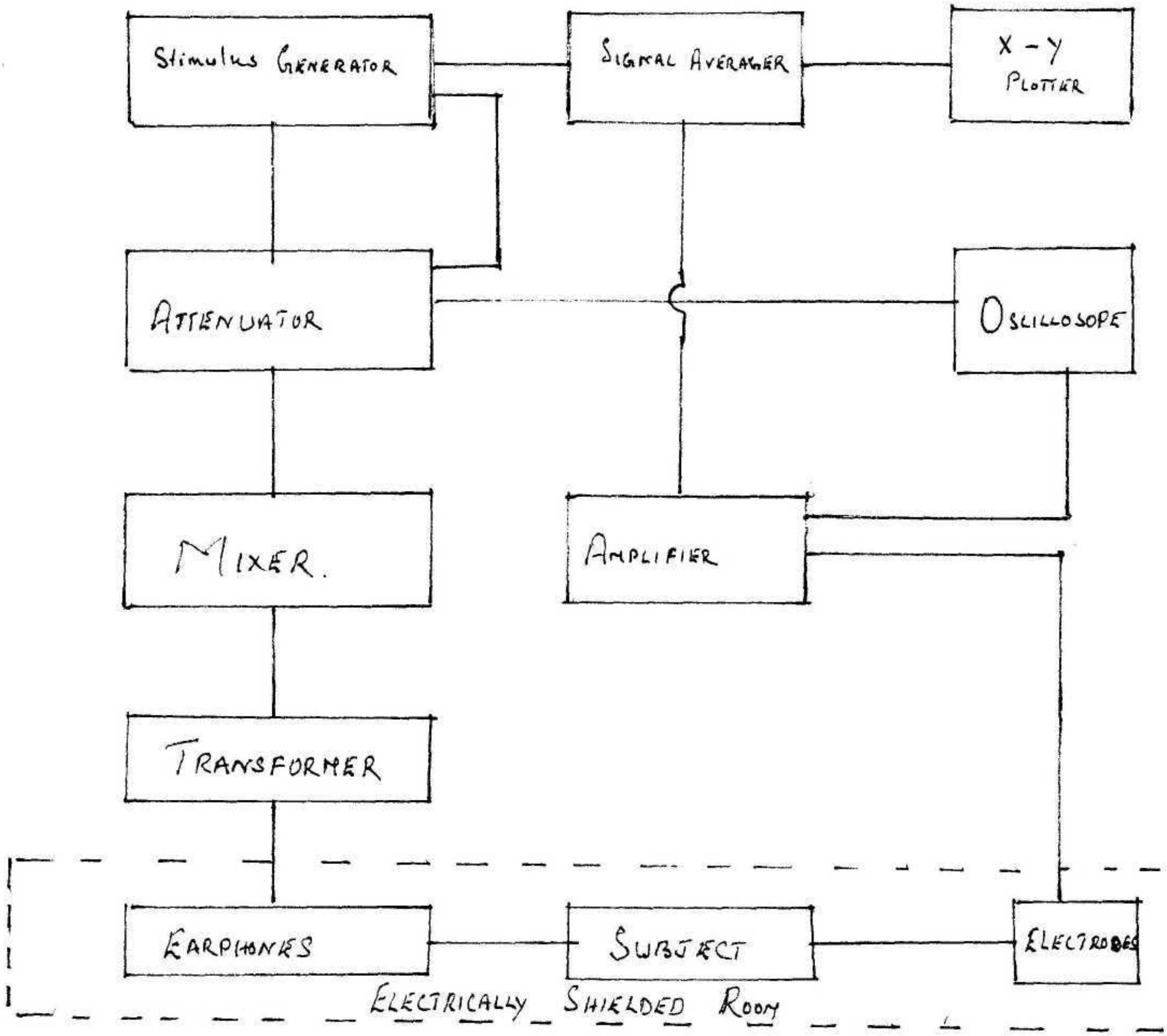
The basic requirements for reliable valid testing has been proposed by Davis and Hirsh (1975). They are

1. Good muscular relaxation to avoid muscle action potentials,
2. Electrical and magnetic shieldin to avoid electro-magnetic stimulus artifacts,
3. Appropriate frequencies should be selected low frequency should not be used because the responses obtained will cot be clearly discernible and un-reliable,
4. The rise and decay time should be re-pid as it has to elicit * the early components of the evoked potentials,
5. High pass filte should be used in recording system to account for the complex brain stem responses, this complex response is because each nucluri responds with its own latency, waveform, and voltage resultin in a psuedorhythmic and super-imposed waveforms.
6. A sumdrin computer to average low voltage responses.

Equipment:

The equipment required tc record BSER re ponses are: A stimulus spectrum which generates clicks of 0.1 M.seconds with an interstimulus interval of 30 a.seconds, An attenuator to control the click intensity, a filter with

with a bandwidth of 300Hz to 1KHz, an averaging computer to sum the responses, and an oscelloscope to monitor the response. The block diagram of the set up is given in (Figure). (   )



Electrode placement:

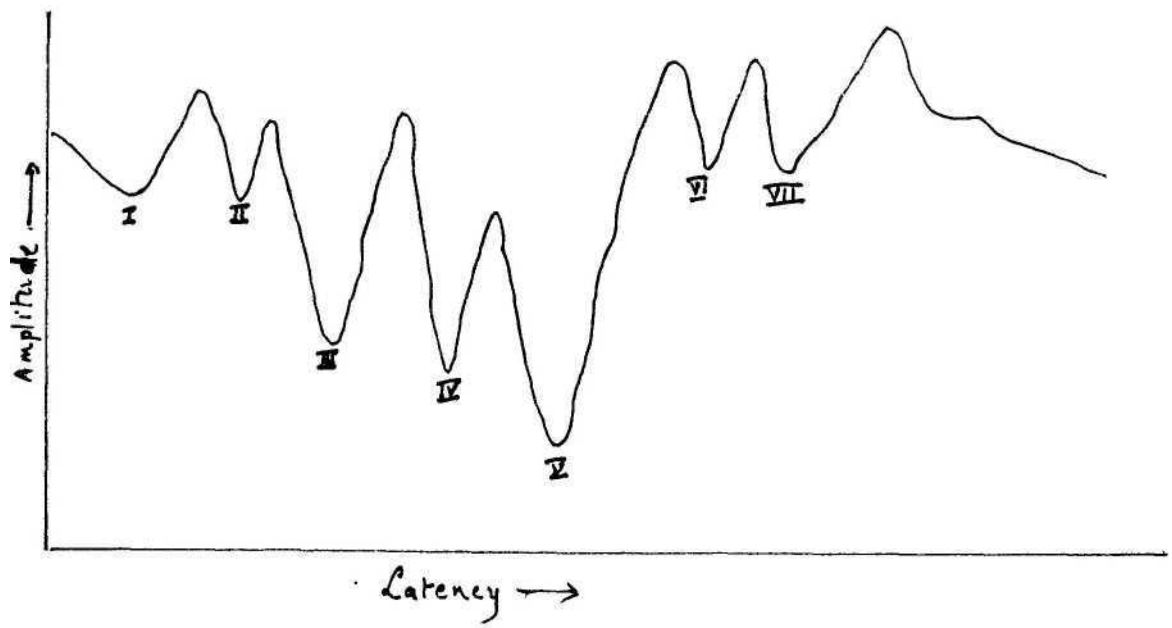
The subject is placed inside the test room. If necersary the infant is seaten on the mother's lap. Natural sleep conditition is chosen. T en the electrodes are fixed to the scalp. The placement of electrodes are varied for the masurment of different waves. For the measurement of wave I, the active electrodes are attached the vertex and reference to the ipsilateral mastcid. For wave V, the active electrodes is placed on vertex, and the reffrence is placed on the contrulatcral side of nect. For the placement of ground electrcde, either forehead or opposite mastcid or neck is used. The alternative placement pos tions can be targets reference on vertex and earlope re pectively with ground electrodes on forehead.

Recording of response:

To obtain a single response, an average of 1024, 2048 or 4096 clicks are presented. Initially these arc presented at 60 dBHL. Once a responce is obtained, the intensity is gradaully decreased to obtiinthresbold The normality of the response is based on an analysis of the following parameters:

a) waveform
b) latency of altwaves
c) latency of wave V and I,
d) latency difference between wave I and V and
e) the amplitude of eachwave.

The typical normal adult brain stem response is as given in Figure ( ).



Variation occur in the topical response, due to the influence of a number of factors. The first and foremost factor which exerts a major influence on the response is the Maturation of the auditory system.

As age advances the maturation also proceeds steps by step. This brines about veriations in the wave-form, amplitude and latency of response.

The influence of saturation on latency of respons is reflected in the latency of wave I, V and the latency differcnce between wave I and V.

Lieberman, Sohmer and Szalo (1978) observed short earing of the latency of wave V with advancement of age in infants. Hecox and GalaKbas(1974) have shown a decrement in the 1atency of wave V as a function of age upto about 16 months. Schulman, Gala-:besh-Galambos(1973) have also reported of shorterning of latency of wave V in a systematic manner with age. A decrement of 0.3 to 3.5M.Seconds was observed for every week during the developmental period of life. Salamy and Mckean(1976) have reported of shift in the latency of wave V with age. The maximum shift has been reported to occur between 6 weeks to 6 months and 6 months to 1 year of life. Hecax and Galmbcs(l97/) observed in infants ranging from 3 weeks to 3 years, observed the shortening of the latency of wave V progreesively as are advanced to gain adult values be the age of 12 to 18 months of age.

Thus all the studies have reported of an decrease in the latency of wave V with increasing age. The Adult value is said to be reached by the age of 12 to 13 months.

A decrease in the latency of wave I has also been reported, as in the case of Wave V (Salamy and Mckean 1976). The adult value is add to be reached by 6 weeks. Thus the wave mature earlier to wave V.

SchulsGan, Galambos and Gala bos (1975) tried to give norms for premature and full term neonates for the latencies of wave I and V. Their subjects age ran ed from 7 hours to several days. They have shown a consistent picture cf the orderly developmental changes taking place in the peripheral auditory apparatus. They report, the appearance of brain stem responses at around 28 weeks gestalicnal age, that is 3 months premature. They report that a threshold can be obtained even in premature babies at 30 dB above threshold of hearing for adults the latency shortened systematically with inccreases in gestational age.

The effect of maturation on the latency difference between Wave I and V has been described by Starrs and Aachor. They have defined the latency difference between I and V, as the time duration required for the conduction of nerve impulses free auditory nerve to inferior colliculus. They have given specific values for different ages. In newborns the latency differen e is given to be 4.5m.seconds- Thus this study clearly indicates the influence of maturation on the 1atency difference between I and V waves of BSER.

Thus all the above reviewed studies have indicated a systematic shortening of 1 tency of I, V and the internal between I and V with saturation, The age related latency changes have been attributed to the progressive myclination the auditory nerve in infants (langaworthy 1933, cited in Gerber 1975). The other explanation for a decrease in the latency between I and V is, that, it is due to an improvement in the ability of ccc lea tc excite its auditory nerve and to myelination and or increased synaptic efficiency the brain stem tracts and nucleri(l975).

In general one can conclude that the auditors, system uptill the level of brain stem reached functional maturity of the first year of lift

The other l'actors which influence the response are intensity of the stimulus and the presentation rate of stimulus. The efect of intensity on response has been described by several investigators. Lev and Sohamer (1972) have reported of charges in latencyand amplitude of response with changes in intensity. Hecox and Oalambos (1974) have also reported changes in latency as a function of intensity, Galambos and Schulman(l975) in chil ren, age ranging from 6 weeks premature to 15 years, observed shortening cf latency of wave V with an increase in the intensity of stimulus. They report that a clear respose is obtainable only at an intensity of 60 dB L. But an identifiable response can be obta rsed at intensities as low as 10 dBSL (Hecox and Galasbos 1974), Ist complete relaxation is achieved in the subject undergoing test.

The rate of clicks presentation also have a major influence on the response. Jewett and iilist-n (1971), Hecox and Galambos (l'J74) have reported that the wave

I and IV as highly sensitive to the rate of presentation of stimuli. But wave V is reported to be stable and reliable even at high click rates. Fujikawa and Weber (1977) studied infants of 7-8weeks old. Their study presented the stimuli at different rates. They observed larger latency shifts when the rate was very fast. (Prah and Soher 1976). This study have relatad latency shift to the refrantcriness and a decreased eiffciency of the synaptic juction at fast rates of presentation. Jerkildnen et al. (1975), Throruton and Coleman(l975) have explained it on toe basis of increased nerval asyncliway and reduction in nerval Airing rate on increasing the rate. The optical rate is given to be 10 to 30 clicks per second. Therefore in recording BER are should take care to control the influence of there factors.

The factors such as state of the infant, frequency of stimuli stages of sleep and sedation have not been found to have any effection the brain stem evoked response thereby enhanicing the efficiency of the BSER in the estimation of auditory throsholds, disserential diagnosis in neonates as well as in elder children.

The advantages of this technique can be summarised as follows:-

1. Eliable prediction of threshold
2. Eliable differential diagnosis
3. Eliable economical
4. Eliable risk of anesthesia is absent
5. Eliable absence of habctuation(Schulman,Galambos 1975)
6. Eliable responses independent of stages of sleep, and scdation.

A number of studies have revealed the usefulness of this procedure in the prediction of threshold usually in differential diagnosis.

Prediction of threshold:

Starr et al(l975) have reported that ever in premature infants (33 to 41 weeks gestational age), a response could be obtained at intensities as low as 25 dBHL(2Ort adults threshold). Schulman and Galambos and Galambos(l975) also have recorded onset potentials at 30 dBHL premature infants of 36-39 weeks gestational age. Mokotoff et al. (l977) have reported of a good correlation between the threshold obtained from this procedure to other tests like impedance etc, in children ranging from 6 weeks premature to 15 years.

Hecox and Glambos(l974) also obtained a threshold of 20 dBHL in children ranging from 3 weeks to 3 years of age. Thus all the above studies point to the efficacy of this procedure in the prediction of threshold.

Differential diagnosis:

A few studies .Were conducted to investigate the utility of this technique in differential diagnosis

Berlin(1978) on normals and antishes, presented postive and negative polarity pulses. The responses of autistics were 190 out of phase for the two pulses respectively. In normal only minimal changes in latency was observed.

Fujikawa and Weber(1977) presented the clicks at faster rates that is, 33/seconds to 50/seconds. In normals no shift in latency occured for the presentiation rate of 33/seconds but in brain stem disordered subjects, a large shift was observed even at the rate of 3 /seconds.

Have reported of prolongation of wave I latency even at high intensities that is 55 dBSL, in children with otitis media.

Chisin, Perlman and Sohmer(l979) administered both BERA and ECoG to hearing imparid children with a history of hyperbilirubinemia and with no history of hypebilirubuering. They observed an absence of BERA and ECoG response in children with no history of hyperbilirubinemia, In the other group the brain stem evoked response was absent but the ECoG response was present.

Thus from the above data, one can conclude that thisprocedure does aid in differential diagnosis.

Screening: Galabos(1978) sugested the use of this procedure for screening in nurserice tested the feasability of this procedure for screening. He presented clicks at 60 and 30 dBHL to neonates in neuseris. All the neonates in his study gave responses at 30 dBHL. Thus be concluded that this procedure can be adopted for screening.

Reliability apd validity:

This technique is considered to be quite reliable and valid. Hecox and Galambos(l974) consider this procedure to be a eliable and sensitive prediction of the sensitivity of the peripheral auditory system Galambos(l977) has reported of a good agreement between the results o this procedure and impedance. and thus conclude that this is a reliable method for the estimation of hearing sensitivity. Galambos(l973) states that" auditory brain stem audiometry readily identifies the baby with a significant hearing loss at the earliest possible BERA moment in his life." He considered to be a precise and reliable method, and claims that no infant is untestable. He also claims that few/any of normal hearing infants will be diagnosed as hard of hearing, and only rarely will a hearing imparted be diagnosed as normal. Therefore one can infer, this method to be reliable and Valid in the evolution of auditory sensitivity as well as for differntial diagnosis.

Inspite of its many advan agesBERA does have certain limitations. There are:-

1. This is a pror test of sensitivity of the cochlea for frequencies below 2KHz (Davis and Hirch 1976, Galambos 1977).

2. This does not provide any information regarding the activity of the higher levels of auditory system. Normal responses can be obtained from anencephalic neonates as well.

3. Choice of ear for hearing aid is not possible from this procedure, an one cannot delimate the participation of each ear. Both ears are invclved in this measure due to the trace crucial transmission especially at high intensity.

4. Even for BE, similar problem arises unless maskeing is done. But data on maskeing in BERA is not available.

5. The electrical shielding, cos on mode rejection, muscle actifact and ambient electrical activity might observe the recordings and confirmed identification of response.

6. Finally as both sides of the auditory system are being stimulated at levels above the Cochlear nucleus in certain cares, t

the response gets cancelled. In such cases, one is liable to make wrong interpretations regarding the hearing status of the subject.

Summary:

The brain stem audiometry is a measure of the early components of vertex evoked potentials. The latency period of 0 - lOm.seconds is considered for analysis in this audiometry. The threshold obtained from this procedure is found to correl te well with other behavioural and objective tests. This being an ojective,test, it requires minimal co-operation from the subjects. Therefore this can be used in the evaluation of children of all ages and difficult to test population, as the brain stem rerpoares are not afiected by state of the child stages of sleep an well as sedation. This also aids in the differential diagnosis. Therefore this measure can be considered to be a reliable and valid technique and its value in testing. children is is significantly high.

CHAPTER VIII

EVOKED RESPONSE AUDIOMETRY

Evoked response audiometry is a development of the EEG audiometry, whereby the cortical responses of the brain to sound stimuli is summated by means of an averaging computer which allow the snail buried cortical responses to be detected. It is based on the observation that minute changes occur with ongoing brain wave actively in humans, when an auditory stimulus is introduced at the ear.through

The initial efforts at reading these EEG changes can be traced very back to 1930's. But in very early times, attempts at recordings of these responses were not very successful because of the large amplitude of the background activity. Therefore with the introduction of small purpose computers, have enabled to extract the stimulus specific responses from the random background activity. Thus the apnearance of any specific pattern can be suspected to be a response to the signal if it followed the stimulation of the presentation/stimulus presentation.

The strategy for employing these techniques are when an infant falls to cooperate for other subjective techniques and in when the other technique of BSER has yielded in contradictory results.

The evoked response can be categorized as follows:

Middle evoked potentials, late components - vertex potentials. These potentials can be differentiated on the basis of the latency of different peaks which characterize the ERA wave form.

The middle potentials are responses which occunred at a latency of 8 to 56 msecs following auditory stimulation. The late potentials are those which occurs within 50 to 500 msecs of the following acoustic stimulation. The response that occurs with a latency of greater than or equal to 300 msecs is termed as "contingent negative variation", response. Some characteristic response occurs within the 0-2 msecs. following stimulus onset, these are the cochlear potentials and those which occur within the time duration of 2 to 8 msecs, are the early components, the source of each of these components are contributed to different neural systems.

The early components are claimed to reflect the activity of the eighth nerve and the successive brain stem nuclei. These potentials pertain to the brain stem evoked potentials. The middle and late components together can be termed as cochlear potentials. Later some research has been conducted on the utility of these potentials as an index of hearing. Among the two, the late potentials have been most widely studied.

<u>Historical consideration</u>

The first person to report of EEG changes on stimulation was Davis et al (1939). Macus (1949) among the first to suggest the determination of threshold using EEG changes fallowing auditory stimulation. This was later given by (Davis et al 1939, Macus (1949), the first to report of the use of EEG to measure the relation to sound in young children during barbituate sleep was Macus, Gibbs and Cibbs (1949). The earliest report to measure the pure tone audiogram using changes in EEG was published by Gidoll in 1952, in 18 month old infants with suspected hearing loss.

The averaging was of the response was given by Dawson (1947), Wherein the responses were photographically superimposed. This technique gave a waveform, representing the evoked potential which was time locked to the presentation of each stimulus, whth could be detected against the background EEG activity; whose temporal duration is random. But the begining of modern era of evoked potential audiometry was by the development of digital computer (1960).

The instruments required for the recording of evoked potentials are as follows: Signal presentation system, averaging system, recording system and storage system. The set up the instruments is as given in Fig (   ).

By varying the stimulus parameters, the different evoked potentials can be recorded. In this chapter, the discussion will be limited to middle and late potentials.

Middle components/potentials

These were reported by Geiser, Frishkopt and Rosenblith in 1958. These potentials occur within 8 to 50 msec subsequent to stimulation. The peaks of this waveforms are: N_0, P_0, N_a, P_a and N_b. These potentials are recorded maximally at the vertex with the reference on the enrlobe or mastoid. As regards the origin of middle potentials, Giesler, Frishkopt and Rosenbllth(1958) have suggested that these potentials are cortical in origin. 3ut 3rick ford, Jacobson and Cody (1964) and others have attributed the middle components to the domain of muscles of head and neck. Therefore the origin of middle potentials is still being debated. The middle components may be obtained by averaging the responses to 400-500 tone bursts with a rise fall time of 2.5 asecs. and a duration of 2 secs.

The waveform of the middle components comprises of three negative and two positive peaks within 8 to 50 msecs. following stimulus presentations. The amplitude between peak to peak is found to be about 0.6 to 2.0 . The amplitude has been found to vary with variations in the intensity of the stimulus. An increase is observed uptill about 50 to 60 dBSL, and after this level, the myogenic potentials get generated.

The feasibility of using the middle components of auditory evoked potentials in testing of neonates and infants was investigated by many studies (Mandel et al 1975; Goldstein et al, 1967; McParland et al 1977, Wolf and Goldstein (1978).

Studies have reported of an stable and repeatable middle potentials in asleep neonates of 34 to 96 hours, and in infants of one, two and 8 months of age (Mendel et al (1974), Mendel et al (1977), Wolf and Goldstein (1978). The threshold obtained from the middle averaged potential of evoked potentials in neonates of 24-96 hours and infants have been reported to correlate well with the adult behavioural thresholds. The difference between behavioural and this threshold has been found to range from 10-20 dB (Wolf and Goldstein, 1978).

The wave form of neonates was found to differ very slightly from that of adults. In the waveform of children, the peaks P_C and N_c which occurs between 50 to 80msec following stimulation was not seen. The peaks N_a, P_a, N_b occurred independent of age. Goldstein and McRandle, 1976). The latency of the peaks was shorter compared to the adults latency. The amplitude of the waveform of children was shorter, 0.2 to 0.6 compared to that of adults.

One noticeable difference between the adults and neonates was in neonates, the response was better in the ipsilateral ear compared to the contralateral. This asymmetry was not seen in adults. This a symmetry was attributed to the immortality of the commisural system in neonates.

The wave forms were not affected, by sedation. The middle components of evoked potentials, could be used to get frequency specific information also. Thus all the data, point to the efficacy of this measure in testing children.

The other components of the auditory evoked potentials is the late potentials which occur between 50 to 300 msecs after the stimulus onset. These potentials are also referred to a 'K' complex (Davis). This was first described by Davis (1939). According to Davis (1939) the late components are polysensory response that resume activity simultaneously in the primary auditory, cortex, the temporal auditory association cortex and the frontal association areas. Therefore these can be elicited with auditory, verbal or tactile stimuli, but the response to acoustic stimuli can be delineated because the auditory response manifest the shortest latency.

The late potentials have been reported to be maximal when recorded from the vertex with a reference on the mastoid or earlobe. The optimal response has been reported to be elicited with pure tones having rise fall times of 20 msecs and a duration of 20 msecs at freqencies 100 and 2000Hz (Skinner and Jones 1968, Onishi and Davis, 1968; Antinoro, Skinner and Jones 1969; Evans and Deatherage, 1969; Rachmann, 1970; 1972).

The waveform of the late components of auditory evoked potential is comprised of 2 prominent negative and positive peaks, designed as N_1, N_2, P_1 and P_2 with peak to peak amplitude ranges from 5 to 20 . A clear response has been found to be elicited with just 30 to 56 stimulus presentations. The refractory period of these components has been found to be longer than that for other potentials. Therefore a longer interstiaulus interval is required, more so when the subject is asleep(Davis et al, 1966, Nelson and Lassman 1968).

These potentials also vary with variation in the intensity of the stimuli. As the intensity is increased, a decrease in the latency is observed and an increase in the amplitude is observed uptill certain level, after which a further change occurs (Moore and Rose, 1969; Picton, Goodman & 3ryce, 1970; Beasley & Kellogy, 1970 and others). The threshold obtained by late components was found to correlate well with the behavioural threshold, that is the two thresholds were within ± 20 dB. The normal threshold in awake infants has been established as 30 dB SL (Mendel etal 1975, cited in Gerber (1978).

Many studies have been conducted to investigate the value of this measure as a diagnostic test in the assessment of the hearing function of children. (McCandles (1968), Suzuki and Origuchi (1969), Fatem and Gordon (1972), Rahko and Laitakari (1975).

Pattern and Gordon (1972) evaluated the responses of infants of 1-7 years of age who had failed on pure tone audiometry to late evoked response audiometry. They could gat a consistent response in 68.6% of the population tested and also a high correlation was also observed between the threshold for late SPA and Behavioural threshold. The two thresholds were found to be neither .+ 15 d3. Rahko and Laitakari (1978) testing children using a 4 channel electric response audiometry. Their results did not favour the usefulness of ERA in differentiating normal from hearing impaired children. A large overlap was observed in the scores of the two groups. The variability was very large sentences. Some normal subjects gave responses at 80-90 dB whereas some hearing impaired gave responses at 30 to 35 dB. For diagnosing the child as hard of hearing, large amount of time was needed.

So based on these results, they concluded that ERA has limited application for children below 3 years of age, and that ECOG and BSER should be preferred while testing very young children.

Though Rahko and Laitakari (1978) have suggested that ERA is not of much use in the testing of children. Many studies have reported of a high correlation between this test and other standardized tests, thus emphasizing the place of ERA in test battery for the evaluation of children (McCandles, 1968; Price and Goldstein (1966), Tyberghevi. T and Forrez (1971), Lowell et al (1975) and others.

The validity of this measure has been established with the Late component of the evoked response potential thresholds in children

The validity of this measure has been established by comparing the behavioural thresholds with the LERA" thresholds in children of varying age groups. Price and Goldstein (1966) observed a good agreement between the behavioural and 3RA thresholds in children of 2 months to 13 years. McCandles (1968) has reported BRA thresholds to be within 5 dB of behavioural thresholds in infants. Lowell etal (1975) have also found the behavioural threshold and LERA thresholds to be within .+ 20 dB in infants of 9 days to 36 months. Tyberghevit and Forrez (1971) compared the CORA thresholds with LERA thresholds in children of one to 4 years of age. The two thresholds were within 10dB Suzuki and Origuchi (1969) also compared the CORA and ERA thresholds in children of age ranging from 4 months to 4 years.

* Late Component of the Auditory Evoked Potentials

They observed the EPA thresholds within 0.20dB of the CORA thresholds. All the above mentioned studies have established that a good correlation exist between ERA and behavioural thresholds. The test-retest reliability was also checked and was found to be high (Lowell et al 1975). The accuracy of prediction was found to be 70% in the initial test and 85% on retest (Lowell et al 1975). Thus, by compiling all the above reported data, one can conclude that late components of the evoked auditory potentials are a valid and reliable measure of hearing sensitivity.

The wave form of the late components of auditory evoked potentials are found to resemble that of adults but differences are observed in the latency and amplitude of the waveform in infants. The latencies N_1 and P_2 and N_2 peaks are found to be longer in infants compared to adults. The N_2 peak demonstrated maximum changes as a function of maturational process. The latency of N_2 and the amplitude increased with the advancement of age. 3ut in contrast to N_2, the peak P_1 and P_3 did not show any significant changes with increase in age. The P_2 was also constant compared to the N_2. The P_2 remained con-stant or increased slightly for almost 6 weeks after birth and later diclined(Suzuki and Taguchi 1977; Sennet 1968; Engal 1967).

In infants the N_2 and P_1, have been observed to occur between latencies ranging from + 150 - 300 msecs whereas the N_2 peak has been reported to occur anywhere in the range of 85 msecs to 550 msecs. But an N_2 at 300 msecs latency has been considered as a good indicator of hearing (Wliiam, Jepas, Morlock 1961) for general in the waveform of children, 2 peaks are prominent. They are the N_2 and P_2. The peaks P_1; P_3 and N_1 are found to be uncommon especially if the children are fasleep.

The amplitude of the peaks has been observed to vary as a function of intensity and in children. An increase in the amplitude is observed with an increase in intensity. The effect of intensity is more pronounced on P_2. A decrease on Latency is also observed with an increase in intensity (Taguchi, 1969).

The stage of sleep of the infant has been found to have an effect on the response waveform. An increase in the latency during sleep for all the peaks except P_1 has been observed in infants of 16 days to 3 months old(Suzuki and Taguchi, 1977). A increase in the amplitude and latency of N_2 was observed in the infants older than 2 days old in the deep sleep (Taguchi, 1969). An ideal state for testing is suggested to be quiet sleeps (Fatern and Gordon, 1972) natural sleep or nuiet awake condition (Price and Goldstein, 1960). On frequently needs to use sedatives while testing children, especially the difficult to test ones. 3ut the use of sedatives influences the response on the ERA. A deep anesthesia has been reported to abolish the response correctly (Saff, 1966). An administration of nitric oxide has been found to change the impedance of the modelle ear and this modifies the EBA waveform (Thompson, 1968). The oral administration of sedatives has also not been advised as the full dosage will not be consumed. Therefore intramuscular administration is recommended (Ladder and Norris, 1963).

While administering sedatives, one should take care of the drug that is used as some drugs have an effect on the response waveform whereas others do not. Phenobarbital and Nembutal have been found to have an effect whereas Phenergan has not been found to have any effect on the response waveform (Faltern and Gordon, 1972),(Price and Goldstein, 1966), Hume and Cant (1977).

The effect of sedative was manifested by changes in N_2, the N_1 peak was found to be resistive to sedation (Price and Goldstein, 1966). Therefore if the child remains still for 30 to 45 minutes,administration of sedative should be avoided.

The frequency of the stimulus was not found to have any effect upon the response waveform (Suzuki and Origuchi, 1969).

The age of the child and the presence of hearing loss was observed to effect the waveform. Studies have reported of an decrease in the latency and threshold with advancing age (Suzuki & Origuchi, 1969). The gestation age maximum for the elicitation of response was given to be 252 days (Taguchi, 1969).

Presence of SN loss was observed to result in sharply defined waveform at an intensity level, close to the threshold. This was attributed to the recruitment, which is often seen in cases with cochlear loss (Suzuki, Krlchiro & Taguchi, 1979), Cody et al (1968) also observed a similar phenomena in adults with end organ disease. This phenomena actually increased the reliability of measurement of, at threshold the response waveform was very clear.

The late component of the auditory evoked potential has been found to be influenced by the prestlmulus state, sedatives administered, the age of the subject, the intensity of the stimulus and the presence of a hearing loss.

In comparison to late coaponent, the middle coaponent of the evoked potentials are not affected by any of the factors mentioned above. Thus the middle coaponent measures are oreferrable for late coaponents in determination of overall hearing sensitivity of the child. But if fresuency specific inforaatlon is desired, then late coaponents measures are to be preferred.

CHAPTER IX

RESPIRATORY AUDIOMETRY

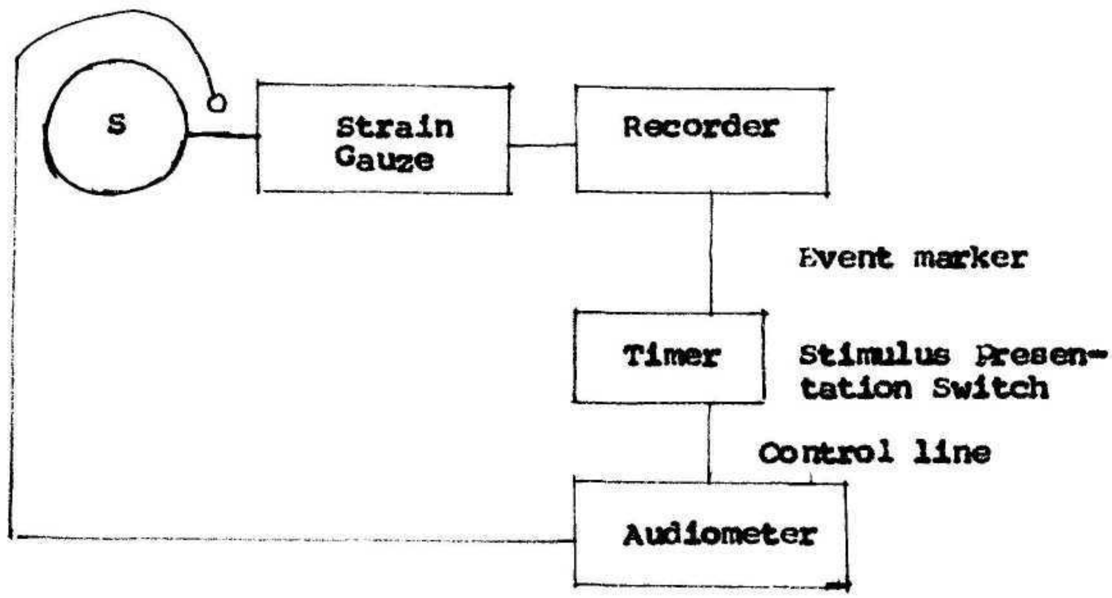
ReaPiratory audiometry refers to the assessment of auditory sensitivity in terms of alterations in respiratory cycle consequent to acoustic stimulation. This was first utilized in the testing of infants by (Caneatrini 1913; cited in Bradford & Bradford 1975). He observed a slowing and a flattening of the respiratory curves following the Presentation of various uncalibrated stimuli. As the alterations were consistent with onset of stimulus, he advocated the use of respiratory measures in the evaluation of the auditory sensitivity of children. Following the lead of Canestrini (1913) an extensive research was conducted to examine the value of respiratory measures as a Potential clinical tool for audiological evaluation of children.

The techniques of measurement of respiratory changes to stimuli varied widely from one study to another. The simplest and also the crudest method was the use of an inflated girdle, applied around the child's chest to measure air Pressure changes caused by breathing (Rosenare 1962, cited in Gerber, 1977). This type of mechanical transmission of breathing movement was found to be inefficient. Therefore, the inflated girdle was supplemtned by strain gauze systems. (Bradford etal; 1972, 1975). The latter has been the most accepted technique. This will be described in detail a little leter in this section.

Two ether techniques have also been employed (Hezon & Jacobs 1967, Kankkunen & Liden 1977). The first is the measurement of differences in temperature in the nostrils during inhalation and exhalation as a measure of breathing Pattern (Heron & Jacobs 1967, 1968). This involves the Placement of a thermester in a cage over the infant's nostrils, that is within ½ cm. of the nostrils. Due to the cumbersome Procedure involved* this was rejected as an appropriate measurement technique.

The other method is, the measurement of changes in impedance, a Procedure employed by KanKkunen & Liden (1977). In this, the electrodes were Placed on both sides of the infant's (6 months old) chest. A weak high frequency current was given to the electrodes. The breathing movements which changed the volume of air of the lungs manifested as changes in impedance, such changes in impedance were recorded in the form of variations in voltage across the electrodes. These voltage variations reflected the breathing rhythm. These variations were amplified and recorded on a micrograph. This method is referred to as Impedance Plethysueoaraphy, and has been considered to be quite sensitive technique for the measurement of respiratory variations following stimulus Presentation. But the strain gauze system is more widely used.

The strain gauze system is a bellows actuated Photo–electric unit. This is connected to a stimulus timer and to a one channel Polygraph with an event mark. The set up of the equipment is given in the figure (   ).



(Courtesy Bradford and Rousey 1972)

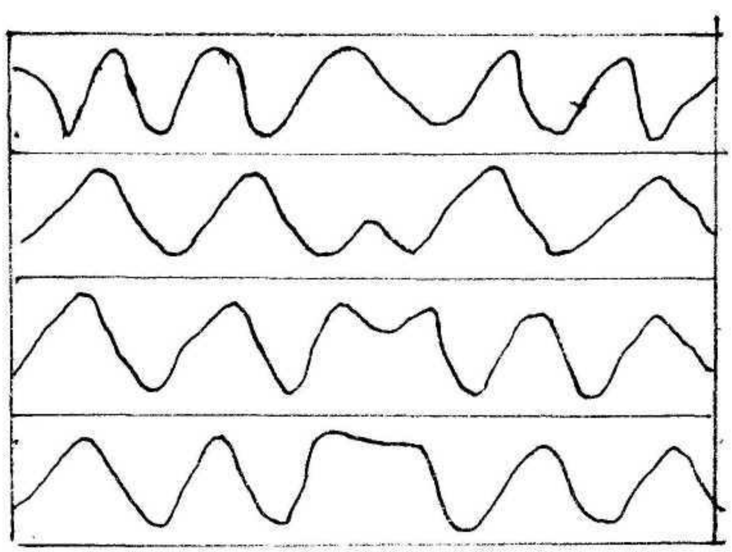
PROCEDURE:

The infant is seated on its mother's lap. The strain gauze is wraPPad around the thorax of the infant. This strain gauze generates a signal corresponding to the infant's respiratory cycle and is recorded on the Polygraph as a sinewave. An audiometer is used to aresent the stimuli. The duration of the stimulus is controlled by a timer connected to the audiometer. The location and duration of the stimulus is indicated by the event marker on the Polygraph. Prior to the Presentation of the stimulus, a minimum of two successive regular respiratory cycles are recorded. The stimulus is applied at the initiation of the respiratory cycle using the ascending method of presentation, in 5dB steps starting at 0 dB. The post stimulus respiratory cycles are recorded and analyzed with reference to the pre-stimulus respiratory cycles (Bradford & Rousey 1972).

NORMAL RESPONSES

A normal response is considered to be either a reduction in the amplitude or depth of inspiration, a jamming of two respiratory cycles, a flattening at the positive peak between the inspiratory and expiratory phase of respiratory cycle or a combination of the above types at an intensity level between 0 - 10 dB (ANSI 1969) (Bradford & Rousey 1972); (Bradord & Broadford 1975).

The figure ( ) illustrates the pre stimulus and post stimulus normal breathing patterns/normal respiratory curves.



Pre stimulus normal breathing

Post stimulus respiratory curvet
Reduction in amplitude

Jamming of two respiratory cycle

Flattening of the positive peak

(The figure is reprinted from Bradford & Rousey 1972)

Variations in the typical response occurs due to the influence of a number of variables. These variables can be categorised as follows for convenience:

1. Stimulus variables
2. Response variables
3. Analysis variables,and
4. Miscellaneous

Stimulus Variables:

The two parameters of the stimulus which are suggested to erect an influence on the reaponse are, the type of the stimulus and the intensity of the stimulus. The type of stimuli to be adopted for respiratory measurement is the most discussed and least argued upon parameter. A number of studies have been conducted which have measured the responses like auropalpebrai reflex and moro reflex for a variety of stimulus. All these studies have come to barying conclusions regarding the applicability of various stimuli in respiratory audiometric measures. Studies measuring the respiratory response changes to various stimuli have also been reached, regarding the ideal/optimal stimuli for use in this audiometry. Another aspect which has been studied quite extensively is the pitch discrimination ability in children. This aspect has relevance to the selection of an appropriate stimulus. A review of some of these studies will be given to highlight the difference of opinion existing in this area.

Stubbs (1934) in her experiments on infants 1 to 10 days of age observed no differential response to different frequency stimuli (cited in Gerber (1977) Suzuki etal (1964) evaluated the neonate's responses to pure tones and environmental stimuli (Cow mooing) at different intensity levels. Mo significant difference in response was noticed for the two stimuli, (cited in Gerber 1977). Heron and Jacobs (1967, 1968) used pure tones and warble tonea and observed better responses for warble tones. Thus they recommended the use of a low frequency (250-500 Hz) modulated tone with a modulation rate of 10Hz and a duration of 4 secs. Kump and his associates (1966, 1968, 1970), cited in Gerber 1977) have advocated the use of a subject's own breathing sound to white noise and pure tones, to be used as stimuli for further testing. Bradford (1975) has recommended the use of pure tones. He did not observe any difference in the response to the l000Hz and 3000Hz pure tone stimuli in infanta of 2 to 24 days. Gerber and Gilechrist (unpublished) used high pass and low pass filtered speech in testing neonates of 8 to 12 years. They did not observe any differential response to the two stimuli. Thua an audiologist has a multitude of alternatives in the selection of stimuli, as no one stimuli has been proved to be the ideal.

The other parameter of the stimulus, whose influence on the response is still debated is the intensity of the stimulus. One encounter diverse viewpoints and results, while going through the number of studies that have studied the parameter. One set of investigators, report of an absence of significant correlation between the intensity of the signal and the response except at very high intensities, which results in a gasp reflex (Heron and Jacobs 1967, 1968), Mcaleen (1976), Geens and Hagberg (1978). But contrary to this, some have reported of a positive influence of intensity on the response. Stubbs (1934) has reported of an increase in the rate and magnitude of response with an increase in the intensity and duration of stimuli in neonates of 1-10 days. Susuki etal (1964) have reported of an increase in the response (deep inspiration) with an increase in the intensity and the maximal response was observed to occur at 70 - 80 dB.

Gerber & Gilchrist (unpublished) have reported of an increase in the amount of respiration rate change with an increase in intensity. The duration of changes in rate is also reported to be related to the intensity of the stimulus. Hayes and Jerger (1978) also have observed an increase in rate with an increase in intensity but it was not found to be more significant as the change was only 7% over a 40 dB range. Majority of the most studies reviewed here report of positive correlation between intensity of stimulus and response magnitude and rate.

Some studies report of an maximal response at threshold level (Poole etal (1966), Kankkunen & Linden (1977). The explanation offered for such a phenomenon is that, at threshold the sound will be very faint, and therefore to hear the sound, the child will have to reduce or stop breathing. This results in marked reduction showing of the respiratory cycle which is easily identifiable.

Thus all these studies reveal the disagreement that is existing regarding the influence of intensity on the response. Therefore more research is desirable,to make any kind of concluding statement with respect to the relation between the intensity of the signal and the respiratory response.

Response variables:

The index of response is either changes in rate, or pattern of response or the presence of a gasp reflex. The rate of response refers to the frequency of the expiratory and inspiratory cycles. Thisis computed by counting the number of respiratory cycles per time period. The ideal time period to be chosen for computation of rate has not been given. Lipton, stenischneider & Richmond (1960) have recommended the use of 5 sees whereas Cilchrist recommends 20 secs. Therefore the clinician should chose a time period, which he feels to be adequate to get a reliable measure of the rate changes prior to and after stimulation.

The pattern of response refers to the shape and magnitude of the response curve. Changed in the pattern of response following stimulation is most often employed as an idea of response.

In a respiratory response curve, one sees peaks and troughs which corresponds to the inhalation and exhalation phases of respiratory cycle. One cycle is comprised of one peak and one trough. To determine one cycle, either peak to peak or trough to trough measure is employed. One normally seea a regular curve prior to stimulation but on stimulation,some changes occur. These changes are of varied type. Suzuki etal (1964) have reported of a decrease in the negativity of response or the appearance of sudden deep inspiration manifested as an increase in the magnitude of peaks following stimulation. Heron & Jacobs (1967, 1968) have reported of a prolongation of inspiratory cycle after the cessation of stimulation. Bradford (1975) has described three types of changes in the pattern of response on stimulation. These are : (a) a decrease in the amplitude of response, (b) a Jammed or an M shaped curve or (c) a flattening of the peaks within a specific time period. All these changes may be seen or only a combination of any of the three may be seen on stimulation. All these studies claimed the changes in the pattern of response on stimulation to be a more reliable measure than a measure of the changes in rate. But Gilchrist (1977) considered the changes in rate to pattern of response, for the following reasons:

a) The changes in rate were amenable for comparison between and among subjects,

b) The changes in rate were easily connectable into a ratio or shole number integer,

c) the norms could be established without much difficulty and,

d) the variations could be compared for statistical significance.

For clinical purpose, one can either frame the criteria of normal response, on the basis of variations in rate or pattern of response. The ideal, would be to consider both.

Analysis variable

Basically, three methods of analysis are available. These are (1) Measurement method (2) Visual identification method (3) a combination of the above two (cited in Hartley and Hetrick, 1973).

The measurement method involves a direct measurement of the rate and amplitude of the cycles following stimulation. Hence the number of cycles by the paper speed on Oscillograph was converted for a unit time. A computer searching method was used to count the number of cycles instead of manual method to increase the accuracy of measurement. Once the measurements were made, arithmetic and statistical methods were applied to see whether the changes in the number of cycles and the amplitude wan of sufficient magnitude and duration to be judged as a response (cited in Hartley & Hetrick (1973).

The visual identification method was given by Bradford (1972). Hence the traces are monitored visually, and the set criteria of response is applied to the obtained traces. Depending upon the agreement between the two, a judgement of response is made.

The two methods, measurement and visual identification has been compared to study the value of each in the analysis of respiratory responses. Bradford (1972) claimed visual identification method, less time consuming than measurement method and therefore a better method compared to the measurement method. But Hartley and Hetrick (1973) (in their study in adults) found the visual identification method to be ambigous as it yielded high false positive responses in adult subjects. Therefore they considered the visual identification method not a very useful and valid method.

Hogan (1972) (cited in Hartley & Hetrick, 1973) compared the visual inspection of rate; amplitude and waveform variations to the respiratory response under computed by the respiration rate and the time length. His observation revealed the respiratory response idea as a more sensitive measure than the visual inspection method. Thus all these data point to the superiority of measurement method over visual inspection method in the analysis of respiratory responses.

One other measure which has been used for analysis is the median cycle duration. The highest median cycle is considered as threshold (Ronaey etal (1964) (cited in Jones and Martin, 1977), Poole etal (1966) and Teel etal (1967). But this has not been put to use very often.

Thus a clinician can employ any of the above methods for analysis of data, the choice being dependent upon the philosophy followed by the clinician.

Miscellaneous Variables:

Some of the other variables which influence the respiratory responses are age, environment, knowledge of the task, pre-stimulus state, interstimulus interval, and the repetititon of test. Each one will be discussed in bries, just to stress the importance of these variables while judging a response.

Age: The infant's respiration pattern immediately following birth to 6 months of age is deviant from that of the adult's form. At birth the breathing is reported to be very rapid and shallow (Desmond etal 1963). The breathing pattern in the initial months is predominantly abdominal and diaphragmatic in contrast to thoracic breathing in adults. In addition to the above differences, infants manifest a wide variability in their response even in the control or no stimulus conditions. Therefore the above reasons, the responses in infants to stimulation in not found to manifest a specific type of response. Therefore while judging an infant's response, one should bear in mind the above mentioned factors. It would be better to judge the response, by comparing the subject's own response at higher levels. This lessens misinterpretation to some extent, as the child will himself be his own control.

Environment: plays a very important role in the determination of response. It has long been known that any novel sound will result in startle response in a sudden change in the respiratory pattern of the infant. Therefore, while making respiratory measure, the surroundings should be very quiet. This minimises the erroneous interpretation of response atleast to some extent.

Knowledge pf task: Jones and Martin (1977) investigated the effects of listener sophistication on respiratory audiometry. They selected to adults and the knowledge of the task, was provided, in variable degree* to these subjects. Mo significant effect of knowledge, on the response was noticed. Hetrick (1973) had also obtained similar results in adults. But has and Hagberg (1976) noticed a significant difference in the response in the instructed and uninstructed college students. The instructed group (pave more responses than the uninstructed group. The reason for improvement was, on instruction, the voluntary control on the breathing pattern increased. The discrepancy between his study and Jone and Martin's (1977) have been explained as due to the large inter Judge variability, subjective judgements and few responses analysis in Jones and Martin study, which resulted in erroenous interpretation and results.

Ronsey etal (1964) and Hogan (1975) have also reported an alteration in the voluntary control of ANS with attention is an important factor in determination of response. Therefore knowledge of task improves response best results in habilitation of response.

Pre-stimulus state of the subject: Eisenberg (1965) has stated that "the auditory behaviour of newborns is dependent upon the physiological state of the subject, that is the level of arousal. "According to him, the most conducive state is that of sleep. Afferent investigations have specified the state and time of testing which ia conducive for testing. Many researchers have recommended the recording during the post feeding stage of sleep. Canestrini (1913) consider light sleep to be ideal. Heron and Jacobs (1968) opine that the sleep within one hour of feeding as best. Bradford (1978) have also reported, the relaxed sleep after feeding as ideal state. Gerber and Gilchrist (unpublished) have reported the sleep ½ to 2 ½ post feeding as the optimal state. Thus all the studies emphasize an inactive state/ state of sleep to be conducive for testing. This state is preferred to minimize the influence of extraneous muscle activity on the recordings of response following stimulation. Thus, always the test should be commenced, only after ascertaining that the child is asleep.

Interstimulus interval: Hetrick and Hartley (1973), Jones and Martin (1977) have stressed the importance of the interstimulus interval in the administration of respiratory audiometry. According to them, sufficient interval is to be provided to allow for the respiration to go back to pre-stimulation level after every acoustic stimulation. This is very important, for the correct identification of response.

Having reviewed the influence of various variables on the respiratory response, one can tentatively suggest some conditi ns which are conducive for recording of reliable response. These are:

Stimuli: warble tones(Heron & Jacobs, 1967,1968)

Environment: Sound treated room/quiet room(ambient noise)

State of the child: Asleep(regular respiration, eyes closed and no movement - Fiach (1967)

Age: Minimum 7 days old

Timing: within an hour of feeding Heron & Jacobs 1967, 1968.

Method: Ascending (Gilchrist)

Handling & Positioning :should not disturb the child. Clothing should also be conducive for testing (Haron & Jacobs, 1967, 1968)

Duration of presentation: 2 - 8 secs. (Gilchrist)

Thus the above conditions have been claimed to be the optimal conditions for the recording of reliable responses. But prior to adapting any technique as a clinical tool, its reliability and validity should be investigated. The reliability and validity of respiratory audiometry has been investigated (Heron and Jacobs, 1968; Kankkunen and Liden, 1977 and others.). KanKkunen and Liden (1977) observed that the respiratory audiometry identified 100% of their jats with normal hearing and in 67% of the subjects the threshold was within 15 dB of conventional threshold. Gaus and Hagberg (1978) also observed that respiratory audiometry was successful in 92% of infant subjects. The correlation between this threshold and behavioural threshold was found to be high. The realibiality of response was reported to be good even at low intensities. Therefore from this it can be concluded that the reliability and validity of this audiometry is good.

Having established the reliability and validity of this procedure, the next atep is to evaluate ita value as a clinical tool in testing children. This can be done by weighing the advantages and disadvantages of this technique.

The advantages of Brain Stem Evoked Response Audiometry are:

1. The administration of the technique and the interpretation of the response is easy;

2. The instructions are simple and therefore any subject can easily follow it;

3. Sedation is not required for ita administration;

4. The response curves are more marked at the threshold; and

5. Not much of preparation is required.

The only drawback is, it has limited application for the difficult to test population, because of the effects of sedatives administered to these children. But this technique can be still used for testing population, by accounting for the effects of sedatives on the response. Therefore, respiratory audiometry can be considered to have a potential value in neonatal and infant testing programmes.

Summary:

Respiratory audiometry is an autonomic nervous system measure. This measure is adopted by an audiologist to assess the hearing sensitivity of mainly neonates and infants. Inspite of the variability of response observed from one to another, some regularity in the response to stimulation can be established. Thus by comparing the respiratory curves prior to and after stimulation, one can estimate the hearing sensitivity of the child. This measure, as an index of hearing has been found to be quite rated and reliable, and therefore, this can be adopted aa part of clinical evaluation procedures for children.

CHAPTER 10

CARADIAC AUDI0METRY/ELECTR0CARDI0GRAIHY

Electro cardiography is the measurement of the electrical changes resulting from the contractions of the heart. A measure of there changes consequent to acoustic stimulation;

The physiological precedes underling cardiography are as follows: Prior to each contraction of the heart, electrical impulses are initiated. Thsee impulses as they traverse though the muscles of the heart, set up electric absents which spreads to the tissues surrounding the heart. A part of this electric current reaches the skin of the body. This can be picked up by placing the electrodes an either side of the heart; By feeding this to an cardiofarhometer, a training of +he electrical changes in the heart can be obtained. This traiaing is teraced as the "Electrocardiogram". The above procedure is repeated on presensation of an acoustic stimulus. The cardiogram obtained is compared with the stimulus cardiogram. An estimate of the auditory sensitivity is arrived at, by noting the variations in the two traceing with reference to certain parameters or measures.

The cardiac mesures that are manifested to predict the index of audition are: Absolute heart rate, change in the heart r&te and the internal between the heart beats.

The most commonly need measure is the changes in the heart rate on aconstic stimulation (cited in Northern and Dozlon 1974).

The chances in the heart rate, on Presentation of stimuls is quite a Rel-known fact. Though this phenomenon was known; body had got the idea of using such a response in the assessment of auditory sensitivity. The initial efforts of monitoring cardiac responses to sound stimulation was by Santag and Richards (1936). They actually adopted this Measure in the examination of the hearing of human fcetuses. Following this lead, a number of inverstigations were done in the usage of such a measure in audiologic evaluation. But all there studies wer on human foetuses. Only in late 1950's was the splication of this measure to neonates and older group was probed. A number of studies experiments were conducted which showed that the cardiac measures could he emyloyed, for the audiological evaluation of children. The firrt person to use it ir; children was Men'argia. . He tested normal hearing and deaf subjects. He did not observe any change in heart rate on stimulation, the deaf but did so in normal hearrings. Therefore he recommended the inclusion of cardiac measures in the battery of tests for children, This study stimulated extensive research, to examine the applicability of cardiac measure in the evaluation of the auditory sensitivity of children.

Procedure:

The basic requirements to measure the changes in heart rate to stimulation are; a stimules generator, an amplifier and a loud speaker, to present the stimule for recording the response a cardictachemeter in required.

The stitaules generator, must commonly Used is an calibrated audiometer. This is connected to a marble tone adapter which mod lates the tones, 5% of thebasic frequency at the rate of 6/seconds. The output from the audiometer is fed to an amplifier and to a loud speaker. The a plifier is provided with a switch to control the onset and offset of the tone, and to trigger the event records. The speaker is mounted on a cabinet which in is accounted on a sta dard frame. This frame provides for the adjustment of height ard angle. The position of the speaker is fixed pointing downwards at approximately one meter above the subject's head.

The cardiotecheMeter is a beat to beat Measuring device, which te triggered by the Rwave(prominent deflection in the cardiogram) of the subject under test. The time intervals between the successive R waves is continously measured und con ected into instanstaneous rates. This conversion is done by determining the reciprocal of the rates (1/t) and recording the resulting valves on a caliheated scale, as "NIXIE" read outs of instantaneous heart rates.

Once the instrument is set to the required standards the subject is brought into the list situation. The subject is firstly prepared for the application of electrode by massing the inner surface of the wrists with electro cardiographic solution. After this, the electrodes are attached to the units by means of electroplast tapes. these tapes further taped at aproximately 1" above the wrist to minimieze movement actifacts. Some prefer to place, the electrodes in the area beneath the elavicles to avoid the interference of heard motion. Placement or the leg is advocated by soe to minimize the noise in the signal due to electrical interference. As no consesus has been reached regarding the placement of elctrodes, the choice is left to the tester. He/she should select an area, where the responses are minorally influenced by the different kinds of artifacts.

Sometimes to reudce the artifacts resulting, from gress muscular activity and desctration in recording, the infant is smaddled (Ref). To reduce the movements of the infants. A pacifying solution is administerted. This solution is a corn syrup searked, ganze ped delected with water. Once the in ant ia made to tie quitely, he is placed in a stabilimeter. Then the electrode leadwices are coupled to a cable going to the tachometer by means of a connector mounted on a perforated aluminium shield.

At a preamplifier gain of 0.5/cm, an EEG reading is taken to estimate the basic heart rate of the subject. This is led the a cardiotechometer, to obtain a due of

reading of heart rate.

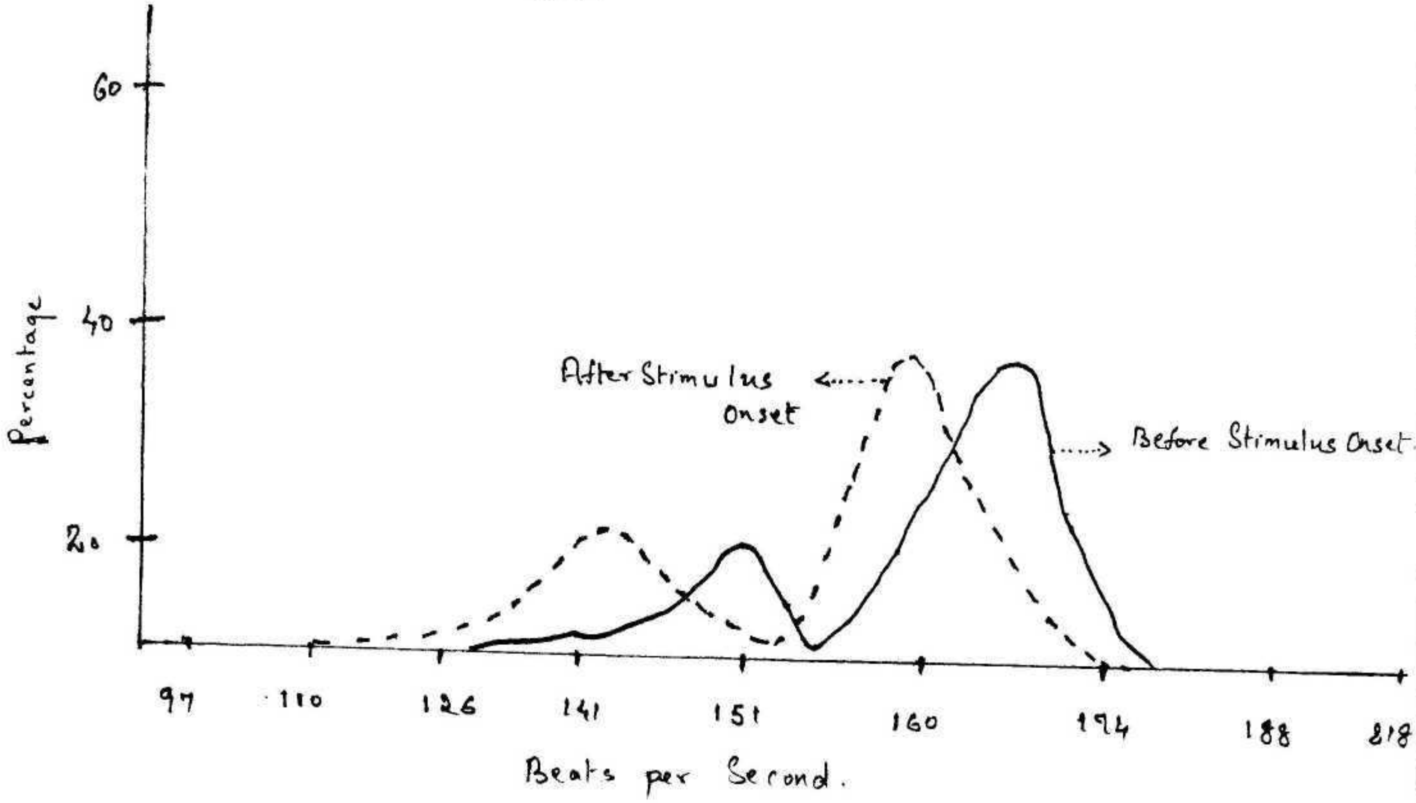
An aduitional component, that is an averaging digital computer improves the efficiency of the recording system. The computer averages the time locked responses, and stores them. The Streeing of data, aid in the statistical analysis and in the time display of primary heart rate data.

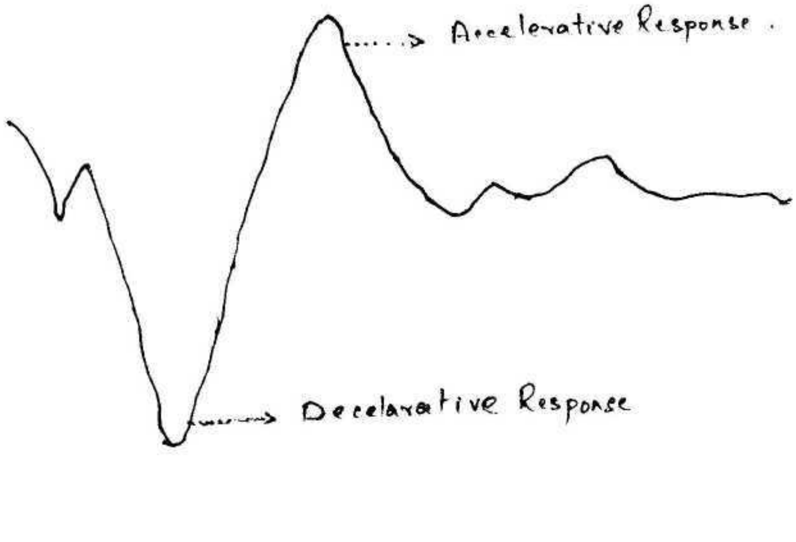
Response:

The electrocardiogram reveals a number of deflections which are refered to as P,Q,R, S and T waves (Ref). Among these Waves, the R wave appears as a prominent peak. The time in ervals between the scucessive R waves is connected into heart rate measures. Thus the existence of a response is based on these R wve time in ervals.

The exiteria for the presence of response is, 1. that the distribution of heart rates during some sample of time subsequent to stimules onset should difer from the pre stimules condition. 2. The diferences between the conditions should be significant in degree or in kind from differences that characterise the contigeons as a stimules conditions (Cited in Sisenberg 1976).

The response expected in normal infants is a shift in the epoch of the post stimulus condition oy an internal of 5-6beats, from the pre stimulea condition. Mostly the response is of decelerative tyre of considerable magnitude with a peak latency of 6 seconds or more(cited in Elsenberg 1976) depicting a normal diceleratine response in infants. An initial decelerative followed by an accelarative response (Suzuki 1978) in infants.


60
40
20
Percentage
After Stimulus Onset
Before Stimulus Onset.
97
110
126
141
151
160
174
188
218
Beats per Second.


Accelerative Response.
Decelarative Response

A typical response is not obtainable always because of the influence of a number of factors, such as (i) stimulus variables (2) response variables (3) analysis variables and (4) Miscellaneous.

Stimulees variables:

The three main aspects of the stimulus which has a bearing on the re3ponse;spectrum of the signal;sound pressure and decration of the signal.

The spectrum of the signal refers to the spectral characterstics, mainly to the frequency characteristics of the signal. Based on the spectral charaterstics, the signal can be classified into the following types; pure tone, beoad bound noise and speech.

Pure tone had been used in most of the carlice studies (Butterfield 1962) Beadle and Crowell 1962, Bartoshuk 1964 and Jasienka 1967). But some of later studies proposed the use of land linuted noi3es instead of pure tones. The contention for supplmenting beoad band noise was that the sensitivenes of the auditory system is dependent upon the signal energy, which is more in board band noise signals than in pure tones (Schulman and Kreiter 1970).

Turkewitz et.al (1972) have also opined that pure tones alone are inefficient and these in combination with other tones, at the same intensity would be mare efficient. Thus according to thes€ studies pure tones are considered leas sensitive compared to broad band noises in testing children.

An experiment conducted by Gerber, Mular and Surain (1976) in neonates revealed for tracy to the above findings The spectrum of the signal was found to have no effect on the response, as no differences were observed between the effectiveness of narrow band noise and pure tones. Thus the superiority of one stimule over the other has not been confirmed. Present day studies have made use of both stimuli.

The other tupe of stimule which is claimed to be more sensitive compared to pure tones and broad band noise is speech, Eisenberg et.al (1974 a) studied the response to synthetic vowel /ah/ in infants 10-25 days old. They observed a long latency deceleration on stimulation. This response was seen to occur irrespective of the age of the infant and the state of acousal. Many others have the charactereristic declarative response to this stimuli with a shift in the peak by 5 to 3 beuts, but not to pure tones or noisebands(Eisenberg et.al 1975 a, 1975 b) . Thus they have concluded that cordial declerative response is a special fun tional property of speech like stimuli,that is complex stimuli. This synthetic speech stimuli were found to be useful in differential diagnosis as well. Elsenberg et.al(l974) study in normals and high risk infants revealed a systematic decline in heart rate over trails in high risk infants but not in normals. Tney also observed lees variability in normals compared to high risk infants. This stimuli is also claimed to be present in the repectoine of infants(Eisenb€rg et.al 1974).

From the data available on the relative effectiveness of diferent types of stimuli, speech stimuli seems to be more efective than others. But more data is desirable before any conclusions can be drawn.

Sound pressure level of the signal:

Intensity of the signal has been claimed to have a significan effect on cardial response(Ref). The efect of intensity on response is two fold:- (a) It brings about a change in the magnitude of response and (b)it brings about a change in the pattern of response.

The change in the magnitude of response as a function of intensity in children has been reported by many invest-igators (Bartoshuck 1964, Graham and Clifton 1966 Steinb cheider and Richmond 1966). Leaman and Wegner 1956 have also reported an increase in the detectibility of response with an incease in intensity.

Contrary to the above findings have been reported by Barnet and Goodwin (1967), Davis, Buchwald and Frankaran (1955). They report of an obsence of significant co-re-lation between response magnitude and signal level. Eisenberg, Marmaron and Gionachino (1974) have consider the cardial response to be an Allor none phenomenon. They did not observe any efect of intensity on response magnitude in iniants(cited in Gerber et.al 1977). Gerber et.al (1977) in their study in infants.

Thus majority of the studies report an absence of significant co-relation between the response magnitude and stimulus intensity.

The influence of intensity on the pattern of response has been reported by Zeaman and Wegner (1956) and Huatrow (1962). They have reported of an increase in the initial decelerative and secondary anelerative response with an increase in intensity. As not many studies have been reported in relation to the effect of intensity on pattern of response, no conclusion can be drawn at this stage.

The effect of intensity on the latency of the response has been given by some investigators, Stelnschneider, Lipton and Ricnwood (1966) have reported a systematic shortening of latency with increasing intensity of the signal.

By combining all the data available, one can refer that intensity of the signal has an influence on atleast some aspects of response.

Duration of the signal:

The general observation is a variation in the signal energy as a function of the stimulus duration. Whether a variation in the response also occurs as a function of duration of signal,still remains debated. In the literature one comes across studies which suport and reject the hypothesis, that duration has a significant effect on the response (Ref).

Clifton, Graham and Hatton (1968) has opine that the duration a significant influence on the response. They report the optimal duration to be a 10 seconds signal in comparisonto 2, 16, 18 and 30 seconds signal durations.

Schateran et.al (l971) recommened 3 seconds clicks as optimal, where as schachte et.al (1971) propose the use of 0.3 m/seconds clicks. Though all the studies agree that, the duration has an effect on intensity, there exists difference of opinion regarding the optical duration of the signal.

In contrast to the above studies, several investigators have reported of an absence of a significant co-relation between stimulus duration and response. Tunkemitz et.al (1377) observed that different durations of stimulus, like 1, 2, 4 and 3 seconds did not result in a different effect on the heart rate in infants. Derber, Mulac anc Sumaen (1976) have also reported of similar results in infants. Gerber et.al (1977) in their series of experiments in neonates, did not observe any effect of stimulus deration on the response.

Hence again the data available is equivocal, therefore, no clear cut conclusion can be drawn regarding the influence of duration of response.

In general, from the presently available data on the influence of several stimulus variables on the response in children, one can infect that time aspects.

of the stimulus seems to have a significant effect upon the response, but more research is needed to make any positive statements.

Response Variables:

Three types of response occur subsequent to the stimulation of the auditory system of necnates and infants. these are; (a) an initial decelerative response followed by an accelerative response (b) a decclerative response (c) an arcelerative response (Schachter et.al (l97l).

Among the above three types of response, the probability of occurence cf aryone or a ccmbination of them is dependent upon the age of the subject, the duration of analysis and the pre stimulus state of the subject.

In neonates, one fails to obtain a consistent or specific pattern of response(Beadle and Growell (l962) Gerbe , Mular and Surain (1976) and others). The absence of the specific pattern of response have been attributed to an inherent lack of patterning in neonatal heart beats (Beadle and Crowell 1962). Another explanation given for such a lack cf specificity of response has been on the physiologica1 process in neonates. According to this view, the heart rate of the neonates undergoes both physiological and morphelogical changes due to the cardio circulatory transition from utero to exteautesive existence. During this period of transition, the regulation of the heart rate is not under the voluntary control and is also immature compared to the adult's regulatory system. This lack cf regulation considered responsible for the vicasious response seen in neonates on auditory stimulation. Ferrer(1977) has also reported of ucide fluctuations in the heart rate changes of about more that 30 beats/minute in neonates. this observation of Ferrer(l977) supports the physiological explanation given for the 1ack of specificity in the response of neonates to acconstic stimulus. Thus all these studies point to the idiosyueracy of the neonates response, and recommended against the use cf changes in the pattern of waveform as an index of response on stimulation. Therefore, while testing neonates, the response should be judged on the basis of the variation in the magnitude of the response following auditory stimulation. Therefore the type ofwaveform as an index of response is of little value while evaluating the responses of neonates to aconstic stimulation. But as age advances the regulation of the heart rate improves.

Therefore the patern or the waveform of the cardiogram can becomes more regularised and will thereafter manifest specific changes on stimulation. Thus in infants, a specific type of response can be elicited on auditory stimulation. Most of the studies have reported of a decelerative response on stimulating the auditory system (Sechulmao and wade (1970, Grifittes and Eiaenberg (1974), Gerber, Mulac and Latp. (1977) and Sazuki (1973). The decelecative response seen in these subjects have been attributed to an increase in the nazal inhibitory activity which reduces the heart rate within 3mseconds latency(Suzaki 1978), Graham, Clifton 1966, and Sokolor 1963), have attributed this response to the cortical aconsal of the subject, that is thia response is send to be having an bearing on the alternative mechanism of the infant. On this basis one can easily reason out the absence of decelerative response in neonates, as in the latter, the crienting system will not have achieved matenity.

Therefore while inalercting theresponae of neonates, change in the Magnitude of response following stimulature should be taken as an indication for the presnece of response. But in infants, the presence of a prominent deceleration should be taken to indication for the presence of response.

Analysis variables:

As already mentioned, the period of analysis of response following stimulation effects the judgement of tne response. Therefore quite an extensive research has been conducted to investlgate the optimal duration, analysis, but no consensus has been reached regarding the optimel during for which the mmeasurement should be made. The period of analysis of resource has a bearing on the pattern of response available. Two schools of thought are prevalant as regards the choice of the technique for the analysis of response. One proposes to inititue the measurement prior to stimulus onset where as the othr propose the measurement to begin after onset of stimulus.

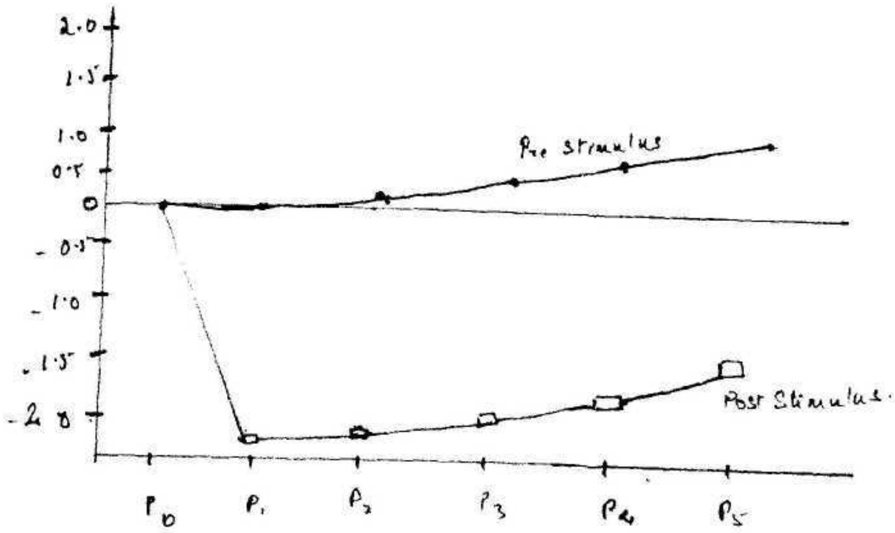
The proponents of the pre stimulus mesurement are schafter et.ai 1970, Clifton and his accociates (1963, 1969) and lewis 1971. The contracation/stand for advocating the prestinmlus measurement is, that the judgement of presence of response is based on the changes in response from the prestimulus level. Therefore, the measurement prior to stimulus onset provides the reference. Though a11 the investigators propose the measurement to begin prior to stimulus onset, the period given be each difers. Schaftcrtigal(1976)has recommended to start measurement - 3 seconds prior to onset. Lewis (l97l) has recommended to commence measurement 3 heart treats prior to onset, where as Clifton and his associates (1963, 1969) have suggested 1 second prior to onset. Thus there exists a lack of agreement regarding the period of measurement.

Some prefer the poststimulus measurement. Even here there is no consensus regarding the duration for which the measurement should be made. Beadle ana Crowel (1962) to Measure immmediately after the onset cf stimulus. Clifton and his asociates (1968, 1969) for 30 seconds after the onset cf stimulus. (Schulman and Krtity (l31l) have advised 16.6 seconds past stimulus, schulman et.al (1974) has advised to begin the measurement at stimulus onset. Thus one panrot predict an optimal duration of measurement from the data available presently. More systematic studies are required to make such a prediction.

The duration of measurement has been reported to have a significant effect on the magnitude of response and the pattern of response. Bartoshuck (1962 a.b) Clifton and Meyers (l969) have reported of an increase in the response as a function time from 2 to 6 seconds following onset in neonates.

The changes in the pattern of response with a variation in post stimulus duration has been given by Grahag et.al (1363), Gesber (1973) and ValinaW? (1970), Graham Bt.al (1963) aave reported, that nither 1 second after onset, the acceleration starts which reaches peak by 4 seconds and then decreases-Valmaki (1970) has observed a biphasic psendo response when the period of measurement is for a long time. Conversely if it is for a very short time then only a neonophasic response is obtained. Gerber(l973) considers 15 beats after stimulus onset as the optimal period of measurement. The variation of response as a function of post stimulus time interval is given in Figure(

As there is no standard period of measurement specified in the literature, one would do well a select an internal cohere in the response significantly differs from the pre stimulus condition.



Miscellaneous variables:

The two main parameters that wil1 be taken up for discussion will be the influence of prestimulus level and respiration on the cardiac response to stimulation.

The prestimulus level is sold to have a significant influence on the response. Wilders (1950) has given the to law of initial, valves which emphasis importance of prestimulos level. The law states that "the relative level of autonomic function:previous to stimulation of a perceptual system, affects any response that an autonomic mechanism may demonstrate following such stiumlation". Iacey(l956) Bridger und Reisee (1953) have reported of a decrease in the chance of heart rate with an increase in the prestimulute level Gerber, Kulac and Surain (1976) have also agreed that pre stiumlus has a significant effect on the response in their study on infants.

The effect of prestimulus level on response has been agreed upon quite unequivocally. Therefore to counteract the influence, an analysis of covariance has been suggested.

The effect of respiration on cardiac responoe has been reported way back in Zoneff et al. (l902) and by Billing and Shepard(l910). Howaell et a1. (193l) have reported of an acceleration of heart rate during inspiration and a deceleration during expiration. Gerber Mulac and Swain (1976) conducted an experiment to study the effects of respiration on response in infants, 1 to 10 months old. A narrow band noise was presented under three condition a of respiration that is, peak of inhalations peak of exhalation, are randomly with respect to respiratory cycle. They observed a monophasic decelerative response in the first condition. In the second a monophaaic and slightly accelerative response was obtained where as in the thivd condition a biphasic response with slight deceleration followed by an aocelerative response was observed. All these studies draw one's attention to the effect of respiration on the cardiac response.

In general one can coaclude that the cardiac response to acoustic stimulation may vary withthe spectrum of signal, sound presence and deration af signal, period of measurement, prestimulus 1evel and respiration. Therefore while judging the response one should be aware of these parameters acting on the response to make a correct judgement .

The advantages of cardiac audiometry are (a) This requires only a standard, commercially built apparatus like an audiometer, electrocardiograph, (b) Does not employ any kind of intense or noxious stimuli, (c) No treecing needed for the subject (a) Adaptation is minimal, (e) Hard to disguise or suppress by voluntary means. Therefore aids in diagonis of funcational loss.(f) The probabilities of false postive response is considered to be less(Schulman et al (197O) cited in Gerber et al. 1976) (g) has teen found to be usefu1 to list all agrees from neonates to crelulte.

The limitation of this are few. One is large variability is seen between subjects especially in neonates. Secondaly the response to susceptible to vary with the influence of a number of factors (listed previously) Therefore unless one controls all these variables, one would be liable to make wrong interpretations.

CHAPTER 11

SPECIAL TESTS FOR DIFFERENTIAL DIAGNOSIS OF AUDITORY IMPAIRMENTS

For the differential diagnosis, a number of lists, have been developed like ABIB, SISI, Brief tone audiometry, M & I etc. But the norms have been developed for the adlt population and therefore its validity in children should be checked. Some have recommended the use of these lists in childern also (Lloyd 1966; Fowler 1963; Acfreese and Stank 1977; Rentleman and Howford 1963; Price and Flach l963). Some of these lists are modified to be applied to young and difficult to test population. The modifications are made along the following line.

1. Simplify the vocabulary and the coaplexity of the instruction,
2. Modify tha list procedure,
3. Change tha type of response, the patient must make,
4. To provide supplementary training,
5. Repeatation of test measures,
6. Raduce the dipgnostic significence of the test if modifications are rnade.

The diagnostic tests useful for detecting cochles, retro-cochlea and central auditcry disorders in children will be discusaed.

Cochlear assessment:

The tests which have been developed for this are ABIB,SISI brief tone audiometry etc. For ratrccechlear loss detection, Bakely, tone decary etc. pre employed.

First the cochlear teste will be taken up far discussion, these are namely SISI, ABIB and a brief tone audiometry.

Short increment sensitivity india

The main proponent of SISI pre K Jeeger, shedd and Harford 1959). In this teat, the test frequencies ia cho-aen pnd than the 1% increment are superimposed on the con-tinuous tone. The presentation level of the tone is 20dBHL initially. Then they pre decreased first in 5dBHL steps, then lower and easier. The number of correct identification of increments pre computed.According to Jeeper et al 1959 SISI was a device of the cochlear impairment, but according to the modification by young and habbits. This is test of retrocochlephesion. The norms given by the latter pre: 70-90dBSL to the cochlea can discriminations. 1% increments their ccchlear functioning said to be normal.

SISI has been advocated for use in children (Deffness and Stark 1971, Spreen 1973, and Maikides)

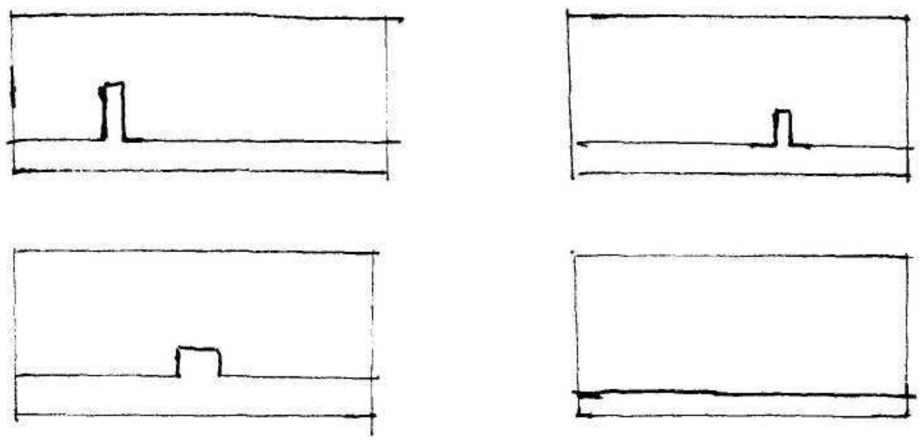
Screen 1973 tested children of 5 to 13 years of age with a 4KHz tone and did not obtain, any failures but the Value obtained was higher, so they recommended to use the 0-30% (negative) creteria for children.

Deffeese and Stark 1977 administerad SISI to children of 5 to 7 years and 8 to 10 years of age. Their results showed greater failure in the younger age group. In the older age group 72% success was achieved. Therefore

They concluded that SISI was useful in childern older than 7 years of age. The criteria used was the same as in adults, that is 0-30% scores for normal.

Fulton and Lloyd (1975) have recommended to introduce large inrements to check on and combat in altertiveness after training with large increments, several tuals were given with 1 db increment. Another way is to have a large increment which shakes or weakens the individual and then conditoning withlower increments later with control tuals. This has been suggested for the older children and adults.

Fulton and Lloyd (1968) Fultn and Lloyd Sprectbin 1968 have recommended the use of operant tracing procedure with childern while administering SISI. In SISI the child is trained to differentiate between nosie plus continous (pedestal tone) and nosise plus contious tone 5 dB increment initially and later on with 1dB increment candy is provided as reinforcement for corrrect response. To avoid habituation the conditiong can be done with another moditity. A light blub with an appropriate alteration can be used with for a visual SISI or to use. SISI slips of varying sizez fro large to no slip to be used as this stimulate the auditory SISI scroes. The Fig......... illustrates the Viksal SISI test for young childern and difficult to test population. The instruction to the children are point to tha step (orbox) in these pictures, if there ia one.



(Courtsey; Fulton & Lloyd 1975)

Contesy; Pulton and Lloyd (1975) one other modification is to use 75dBHL to compare performance between the two ears (Thompson 1963). This is to make the listening task easier and to maintain the attention.

Fulton end Lloyd (1975) administered SISI to mentally, retorded. The results were not diagnostically significant but study showed that even severely raferred childern could the teamed to carry out the SISI task.

Thus using operant pradigan SISI list can be adminis-tered to childern as well as difficult to list population.

<u>ALTERNATE LOUDNESS BALANCE LIST</u>

Londacie balance list was first given by Fowler 1936 as a measure of cochelear pathology. Fowler (1936) reported that even childern could be listed with this procedure.

that even children could be listed with this procedure. In BIB, that the listner has to indicate whether the tone is both the ears are equal in loudness or not (Jeeger and Harford 1961).

usually words like alternating loudness, tone freqae-ncies etc are used when giving instructions. But this voca-bulary and the need to make differential response will not be understood by children and difficult to list population. Thus to administer this test to children, the clinician will have to modify his vocablulary and language and rely heavily on gestures and demonstration. Pentmime instructions also be useful in making childern understand the task. Repetations and rephasings of instruction ia needed.

Fulton and Lloyd have recommended the following steps to be followed:-

1. should start with gross intensity difference
2. should have the child identify the loader one,
3. should gradually decrease the level of the tone,
4. should establish test testt reliability,
5. ahould start with high frequency tones aa, they are more effecting and therefore better balanced by children. According to Fulton and Lloyd, emphasis should be placed on the fraquencices 4KHz to 6KHz as this shows the cochlear patho-logy even in the prescribe of retrococalear pathology.

6. If the child finds difficulty in indicating then visual ears can bo provided, like two pictures protraying different loudness level can be provided to make the task easier.

Eg: On one card can pictures a large exploding firecracaker and on the other card a smaller are- this is for the unequal conditions. When they are equal, then two cards of same size cracker explode can be plepicted.

Another method is to use small waeights and train there. later transfer this tracing to the loudness problem. Thus by employing these modifications the ABLB list can be reliably administered to childern. One posture point, towards the applicability of this list to children and difficult to list is this does not depend upon the accuracy of measurement of threshold. Thus a 20dB administration of the threshold will act affect the outcome of the ABLB test.

BRIEF TONE AUDIOMETRY(BTA):

BTA measures the diffennces in threshold among short tones and aids in the indentification of vacione pathologies of the auditory system.

In BTA the threshold for 500, 200, 100, 50 and 20, lOm.seconds tones at a single frequency is trucked at an alternation rate of 2.5dB/seconds over successive/min intervals. All tones are presented at a repetation rate of l/sec with a rise-fall time of lOsecond.

From BTA trackings, the threshold is emstimated for each durng tone from the midpoints of the tracng . The instruction to the subject is as soon as be hears some tones he is to push down the response button, and when he no longer hears the tone, the button must be realesed. He is also told that the tone may become shorter and shorter but ha has to continue to respond in the same way.

The results of BTA in differant pathologies is in normals, ccnducture and retrocochlear loss cases the difference between the threshold for 500 m.seconds pn6 2Om.seconds is around 8dB where as in cochlear loss cases it is around 3dB, Thus this aids in differentiating various pathological conditions.

Barry and Larson (1974) employed BTA in normal and deaf school age children of age ranging from 6 to 14 years. The deaf childern presented a distrinctly different pattern from that of normal childern at 500 Hz. The results of deaf children was similar to that of cochlar loss cases. Thus this shows that BTA may be employed in childern also for difficultally diagnosing various pathological conditions.

TONE DECAY:

Tone decay ia a symptom associated with retrocochear lesion, tone decay may occur at threshold or at supatthreshold levels. "Threshold tone decay may be defined as the decrease in threshold sensitivity resulting from the presence of a barley auible sound". Sypathreshold tone decay may be defined as "a decrease in theshold resulting from a sound well above threshold(Green 1978). different procedure have been given for the administration of tone decay test (Hood 1956; Rosenberg 1958; Greene 1960 Owens 1965 ; Olsen and Nottsinger 1974; Jarger 1975).

Fulton and Waryas 1974 modified the owens tone decay test to make it applicable for mentally retarded. The owens tone decay test is as follows:

The tone ia presented at 20dBHL for that frequency for 1 whole min. If the aubject ia instructed to keep his finger up, as lon as be hears the tone. If before the If before the completion of 1 min. the subjects drops hia finger. there a 20 sec rest period ia provided and the listing started at 5dB above the presentation level. Tone decay upto 20dBSL is measured and depending upon the rate and amount of decay different types aredescribed type I and II are considered characaterstic of disease. Type III characaterstic of 8t nerve lecion.

The ownes method has been considered best suited for mentally ratardeds as the list period for any one signal does not exceed 1 min. This meeuces in attention and thereby aids in maintaining the attention through out the list administration. This test provides,both intensity and duration information which is a further clue to differential diagnosis.

Fulton and Waryas (1974) trained the mentally retardeds to respond. When the tone iks on and when the tone is limited off. Signals were then presented at 15,30,45 ,dBSL for 20,40,60seconds in a counterbalanced order at each of the frequencies, 500, 4000 and 8000 Hz. This procedure was found tobe successful with mentally retarded. Therefore one can infer that normal children can be tested for tone decay using Fulton and Wary ps (1974).

Bekesy Audiometry:

Bekesy audiometry is an automatic technique which aids in threshold determination as well as in differential diagnosis. This comprises of a beat frequency oscillation with a frequency range of 100 to 10,000 Hz with the provision for full sweep across all frequencies or to list at specific frequencies. Depending upon the procedure used, it is called sweep frequency or fixed requencying tracing. Two types of list signals are provided, one is continous tone and the other ia a interrupted tone. The other provision is the frequencies may be presented either in an ascending or deaceding order. The tone is interrupted at a rate of 2.5/sec with a 50% duty cycle. An inatantly revisible motor drive controlled by the patient's hand switch is geared to alternate the signal at the rate of 2.5 dB/sec or 5dB/ sec. total intenaity of the audiometer is approximately 12OdB. For masking bread hand and narrow hand noise is audiable.

A pen that is coupled to the alternator, traces and con- tinous recording of the subjects response on a specially prepared graph, which is placed on a mounting table (Hughes and Johnson 1978)

The interpretation of the result is based on the re- lation between continous and interreupted tracings. Thus on the basis of tha relation between the two tracings, Jarger 1970, has deacribed 5 types of bekesy tracings. Type I is associated with normals and conducture - Type II ia associ- ated with cochlear pathology Type III and IV with retrocochlear pathology and type V with functional loss.

In type I tracin, the two tracings develop. In type II the continous tracings drops from interrupted tracing at the region of 1KHz and nerves parallel.across other freque- ncies, In type III, the continous tracing executes a rapid and marked decture in threshold sensitiviy. The contious tracing drops to the output limits of the audiometer within 1KHz region. Type IV the continous tracing declines from interrupted tracings but is not so rapid as in type III and neither will it reach the output limits of audiometer, instead maintains the initial differnece between the two tracings across all tha frequencies. Type V tracing in this the continous tracing would be better than the interrupted tracings.

The tracings given above were established in the adult population. Therefor emany investigatnions were carried out to check the application of Bekesy audiometry in childern (Rintelmann and Harford 1963, kprice and Falch 1963, Stark 1965, and Peterson 1963 ; Swisher and Stephana 1968).

Rontelmann and Harford 1963 observed type V Bekeay tracng in childern of age ranging from 9 to 19 years with psendohypocusis. Peterson (1963) has also reported of type V in children within organic loss of age ranging from 9 to 13 years.

Price and Falch 1963, Swisher and Stephens 1968, have reported of the applicability of Bekeay auiometry in children.

Price and Falch 1963, found bakesy audiometry to be reliable in childern older than 7 years. They observed an increment in the response with age uptil 7 years but after 7 years, no significant improvement was noticed. Thus they concluded that Bekesy audiometry is applicable to childern with normal intelligence and deonological age of 7 years. It may be applicable kto younger childern with slight modification like children found preesing of button difficult, therefore in such cases by substituting the spring of the button the task was easier. They have also reported that hgihter the intelligence better is the performance on bekeay audiometry. Price and Falch have stressed the importance of maintaining eye contact between lister and the subject to keep up the motivation and attention of the child.

harfeley, have reported that bekesy audiometry is applciable for childern of 8 years of age of more, and Stark 1965, Seingethaler 1964, have observed conventional threshold tobe better than belesy audiometry by 10dB in children.

Saiaher end Stephana 1968, *lao observed conventional thieshoiaa tobe better thmn bekeay thresholds in children pge ranging from 7 to*l5 ye^ra by 86B. They h^ve reported of the typee of behaay trpcin^a commonly, aeen in children pa type i, II, ^nd they plao observed p high correlation between bekeay and conventional padit metric reaulta. Ihua from pll these atudy reporta, one can conclude thpt be&ay pudioaatry apy be reliably employed to paaeaa the hairing function in children.

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