"EARLY IDENTIFICATION PROCEDURES FOR HEARING LOSS"

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INDEPENDENT PROJECT SUBMITTED IN PART FULFILMENT

FOR *THE* DEGREE OF MASTER OF SCIENCE

(SPEECH AND HEARING)

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1982

Dedicated to

My Dearest Parents.

C E R T I F I C A T E

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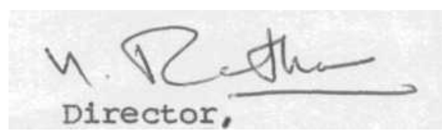

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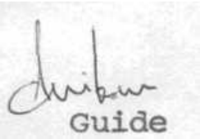

Dr(Miss) Shailaja Nikam
Professor & Head of the Dept. of Audiology,
All India Institute of
Speech and Hearing,
MYSORE 570 006.

D E C L A R A T I O N

This Independant Project is my 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.

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Date:

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C O N T E N T S

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CHAPTER I

INTRODUCTION

Hearing is the most expediant basis for normal language acquisition, and language is the key-stone of modern society Hearing loss must he identified as early as possible in the first 2 years of life so that its effects may be diminished to a certain degree and that he may mature to a full role in the society.

"The ability to speak and the precious gift of language is peculiar to man, and it is this wonderful faculty which, by enabling him to speak and to listen to other's thoughts and ideas, has made him supreme in the kingdom of living creatures. It is not certainly his ability to swim, run, climb or exert his strength that has earned him this superiority. If one could imagine an Olympic contest for all living creatures, man would not even gain a bronze medal in any event. But if there were a contest for oratory, man would be the only entrant, for only he can voice his thoughts; it is true that certain birds, notably parrots can imitate human speech sounds, but they have no appreciation of language"- Sir Terrance Cawthorne (1956). He continues....................one of the loveliest events of which every parent of a normal child is an entranced witness, is the gradual change from babbling into words which may occur after a year.

By far the commonest cause of any delay in the development of speech is an imperfection in the organ of hearing which prevents the infant from hearing properly the words and sentences.

Auditory competence, that is, the ability to code and organize acoustic information cannot be measured solely in terms of threshold acuity. Connections must be made between the functions being measured at different age levels and status of underlying mechanisms at those age levels.

The audiologist's inquiry starts with the very beginnings of deafness at birth and proceeds to continued identification of hearing status following birth. The three lines of inquiry being — detection of suspected hearing loss, follow-up, identification of hearing status, and prediction of best direction, habilitation might take are of deep concern to the paedeatric audiologist.

Response is a criterion to be looked into while testing of the paedeatric population. overt responses or their lack may not mean anything - Not every child who fails to respond to sounds is deaf. Lack of direct relationship between poor responsiveness to sound and pathology of organ of hearing is frequently encountered in children. The younger the child, the greater is the possibility of such a discrepancy being present. Therefore, the diagnostician of auditory disorders in young children is confronted with the additional obligation of ascertaining not only whether impaired hearing, acuity is present but also, whether other types of auditory disorders which summate deafness are present. This creates an additional problem for differential diagnosis.

Hearing can be evaluated adequately only when it is considered in relation to the child's total development and behaviour. This emphasizes the rationale and the basis of the concept of auditory disorders in children.

The diagnostician who over-simplifies auditory functioning and assumes a direct relationship between inadequate response to sound and impaired acuity, will erroneously diagnose certain children as deaf. Such a diagnosis can be made with assurance, only after other conditions which simulate deaf-ness have been carefully considered and differentially eli-minated. Likewise, it assumes that hearing is not evaluated only in terms of responses to intensity. Auditory behaviour is evaluated in relation to general behaviour and specifically in relation to the child's physical, mental and emotional development. The diagnostician of auditory disorders in children with the paradox of children making no obvious response to sound although having normal hearing, and of children responding normally to certain sounds although they have a significant loss of hearing.

The purpose of the present report is to review extensively the tests which have been carried out for new-born and neo-natal testing; their limitations and scope. It will also plead the necessity and relevance of such problems in early rehabilitative efforts.

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C H A P T E R II

DEVELOPMENT OF HEARING

"The Infant Learns to Listen In order That He May Listen To Learn" (Zigmond and Cicci, 1968).

All normal infants grow first into children and then into adults which is no surprise. This sequence implies several characteristics about development.

1) It is an orderly change.
2) It is directional.
3) It is cumulative to a large extent.
4) It is characterized by an increased differentiation and complex organisation.

Sequences of development often proceed from simpler more global behaviours to increasingly differentiated but integrated sets of behaviours.

DEVELOPMENT OF AUDITORY BEHAVIOUR:

Our language system is a spoken system and although hearing alone is not sufficient to account for language development, there is a great importance of audition in the total communication process. Just as language is a developmental process, so also the audition follows a developmental sequence. "In every day life, the ability to perceive different sounds in different ways at the same time are taken for granted the different kinds and levels of auditory behaviour. They testify to man's extra-ordinary auditory competence and reflect at the fact that hearing is not an unitary function

Most of the study of auditory behaviour is in relation to chronological age, which makes good sense to the clinician who must judge the children's responses at all ages. Thus a review of literature from any discipline specific, naturally starts from the prenatal stage.

PRENATAL HEARING:

The phenomenon of prenatal hearing useful in predicting psychologic attributes of later responses to various sound patterns. It would be of great interest to know if a foetus that carries known recessive genes for deafness, has normal hearing before birth.

Elliott and Elliot (1964) confirmed physiologically that the human cochlea had normal adult function after 20th week of gestation.

Johnannson (1964) reported of prenatal hearing, by using high frequency puretones presented by means of a microphone placed on the mother's abdomen, increase in fetal heart rate was taken as response. They reported of this after 20th week of gestation; thus contradicting the popular belief that the child is born in a tabula rasa. Upto 4 months the foetus xesponds to fluid borne sounds. According to Bench (1968) the foetus was surrounded by noise of about 72 dBSL, which may be considered as a too loud environment; yet the foetus listens to this noise for 4 months.

Foetal labyrinths are so uniform as to suggest the size of end organ receptors may be, pre-adjusted for reproduction of the human frequency range, (Eisenberg,). The cochlea is functional by the 5th month of gestation, and the auditory apparatus of the 20 week foetus is structurally comparable with that of an adult. The 6 months foetus responds automatically to puretones, but the question is how these sensory speciality and hearing abilities relate to mature auditory functions. The firsts "differential tuning" to the carrier frequencies of language may be made in the intra uterine life.

NEWBORN HEARING:

The development of auditory function, inter relates with all other sensory functions. Audition facilitates an unique combination of expressive as well as receptive operations which have social significance of utmost importance. Auditory function promotes the social well being of the infant and the rest of the immediate social community.

Murphy (19) reports of certain interesting changes on responsiveness where there is an obvious maturation of information storage which produces two aspects of the same phenomenon. These are:

1. The phenomenon of selectivity where in the normal infant at the 3rd week after birth ceases to respond to sounds

consistantly present in the environment while responding often with startle or distress to uncommon sounds, even though these are present at lower intensities.

2. The phenomenon of patterning as a basis for psychosocial security is clearly demonstrated when the auditory environment is radically changed in the first week of life. The premature infant produces a gradual modification of the auditory function.when testing this immature infant, one faces the problem of the extent to which their hyper responsiveness is heightened by the pattern of domestic careful exclusion of noise.

According to Ewing, the development of auditory behaviour is considered as one of the total aspect of the experience of the child. They found that domestic noises were related to general experience and used such noise to provoke the child into social response relevant to the social situation.

The stages of development of auditory responses involves DETECTION, DISCRIMINATION and RECOGNITION of sounds (Bernett). The progression starts at detection level, where the sound is responded to simply as a totality by the the child; indicating only the awareness of the presence of the sound. When a child learns to differentiate sounds as familiar or unfamiliar, discrimination is occurring. Localization of a sound source occurs next. A sound then comes to be associated with a specific situation or stimulus - a reference making process which can be verbal or nonverbal but which basically indicates that the child has the concept of sound. The succeeding stages of auditory usage involves differentiating various sounds, and finally imitating and understanding spoken language.

Stecher (1964) found that if analgesics or anesthetics were given to the mother during delivery, CNS depression would occur for a period as long as 4 days. Eisenberg(1970) indicated that newborns with CNS dysfunction could discriminate sounds at birth thus indicating that their neural systems were intact at birth.

Murphy defines an auditory response as a response occuring when stimuli have been transmitted to the brainstem via the auditory mechanism. Responses are described as any change in state or activity which is significantly related to a stimulus; thus making heart rate, excretion of adrenalin, modification of EDR, impedence, etc as responses when it is certain that Audio frequency stimuli have been detected by the peripheral auditory mechanism.

According to Bench, there is a relationship between the infant's state and the type of response. The lower the initial or prestimulus state, the greater the increase in the level of activity and viceversa.

RESPONSES

Downs (1967) has listed the following:

(a) Eyeblink/Eyelid activity - rapid stricture of eyelids which beings them together. Range of responses including (1) Definite eyeblink, (2) Fluttering of the eyes (3) Contraction of the eyes and eyebrows, which is followed by a grimace.

(b) Moro - violent startle reaction, jerking of the entire body, shaking or shuddering of arms or legs.

(c) Cessation of activity - Marked quitening of crying; and of arm and limb movements.

Range of response (1) Stopping crying momentarily (2) Stopping of playing of limbs for a moment (3) Stilting of mild ongoing activity.

(d) Limb Movement - When the infant is resting quietly, the sound provokes movement of limbs, arms, shoulder movements.

Range of responses (1) Limb or hand movement (2) Flutter (3) A definitely strong movement.

(e) Head turning Towards or Away from Sound - Head may turn towards the sound source or it may turn away from the sound source. Head turn may be direct toward either side, or of streching of the neck, raising the head upwards.

Range of responses (1) Movement of the head toward sound source (2) Movement away from it. (3) Any up and Down movement.

(**f) Grimacing** - face wrinkles up as a protest against hearing.

(g) Sucking - this should be specified whether it occurs

- before or after a response.
- does it occur along with the response (with limb movement and head turn)

(h) Arousal - An awakening of the whole body; it is when sleeping quitely or when awake, but quiet.

Range of responses 1. eye movement with slight to strong movement through out the body. 2. slight shudder of entire body.

(i) Breathing changes - are recorded only by very experienced observers who are certain of the pretest breathing pattern.

(j) Widening of eyes - When the baby is sleeping, his eyes may open wider.

a) widening of eyes from open state.

b) widening of eyes from closed state.

c) maising of eye brows with almost imperceptable widening of eyes.

* Eisenberg ( ) listed the following responses using

a stimulus of 90 dBSPL signal of 300 Hz.

Overt reactions	wide eyed look
Arousal	Pupillary dilatation
Gross body movements	Motor reflexes
Orienting behaviour	Facial grimaces
Turning of head	Displacement of a single Digit

Cardiac reactions:- disphasic decrease and increase or the reverse.

Eisenberg was the first one to describe differences in habituation to sound as an index of central Nervous System integrity. Normal infants habituated to stimuli in a short time. The neonate responds grossly to loud sudden sounds. With time, responses occur to more subtle stimuli which occur in the baby's environment.

In the newborn life as in later infancy, the responses are so distinct that naive observers can detect response reliably - arousals, orienting quits, motor reflexes, facial grimacing, cardiac reactions, etc. The average new born responds to atleast 3 consecutive trials, even in deep sleep; and the quiet wakeful infant may respond to 8 out of 10 trials. Thus it seems likely that pattern bound behaviour reflects plastic and fairly high level auditory mechanism.

The human newborn is perceptually mature in a greats many ways and better organized than casual inspection would suggest. His auditory behaviour depends both on central and sensory phenomena and it follows orderly rules; Frequency bound behaviour, which in the newborn periods has correlates in the performance of lower animals; bears upon qualitative judgements of sound in adult life. Intensity bound behaviour seems to have a species specific characteristic that are independant of developmental status. Patter bound behaviour which is uniquely selective in the newborn life may reflect fairly high level auditory mechanism.

THE OLDER INFANT

At 4 weeks of age the infant can descriminate phonemic contrast in sound signals, as measured by heart rate changes (Mc Caffery, Moffit, 1969). Fredlander (1970) reported that these responses represent some aspect of hearing. Attending, even in the infant, becomes a constructive active process rather than an analytic and passive response.

2 months - he is quietened when exposed to familiar sounds (Benett, 1976).

3 ptonths - babies attend better to mother's voice on a tape recording than to stranger's voice (Turnet, 1969). He learns to anticipate familiar activity (Benett, 1976).

4 months - Most infants cease motor activity, smile and attempt to search for the sound (Benett, 1976).

5-6 months - can distinguish friendly from angry talking and will smile or cry in response to that stimuli. They may respond to voice and may turn right or left.

7-9 months - Infants look up, cease activity, listen intently. They turn their eyes and head in the direction of the sound (Benett, 1976).

10 months - Responds to name, can locate their parents when named and responds to simple commands. They attempt to imitate vocalizations (Benett, 1976),

10-15 months - children begin to respond to language as environmental auditory stimuli.

18 months - locates facial parts.

Freedlander (197O) concluded that the babies show a wide range of discriminative listening to a wide variety of natural, disguised and synthetic language as well as to auditory stimuli. Thus these young babies use some cognitive processes to make their listening skills; formulating internal linguistic models against which to compare the recurrent input.

2 years - Given pictures or objects as referents, they can select the object named.

2½ years - Identifies objects by usage and action in pictures.

2-3 years - Able to perform voluntary actions in response to sound primarily by following simple and then, complex instructions.

Summary:

The present chapter has dealt with the development of the auditory function - both anatomical and functional. The stages of the development of hearing is of utmost importance to the clinician who works with the pediatric population. The ultimate goal in hearing assessment is eatablishment of threshold responses. The clinical goal is to seperate children into those whose behaviour suggest essentially normal hearing and those whose behaviour suggests need for further audiologic evaluation. Clinicians here should take into account the child's chronological age and maturational age in various areas such as motor, social and language behaviour.

In essence, these stages of development, provide the clinician the milestones of hearing and thus channel him what to look for in children as responses. A thorough examination of them will try to remove the questionability and variability of the response; which is debated by many authors.

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CHAPTER III

HISTORICAL BACKGROUND

In the development of audiology from the earliest beginnings to the present time; there is a continuous thread representing a logical sequence. As early as 1867, Lucae measured the impedance of the middle ear in models, but also in patients with various middle ear disorders. These are various pieces of evidence in the form of documents going back to the earliest recorded history and attesting the facts that hearing disorders and deafness were recognised entities and that therapeutic efforst were being made. The oldest made by the Egyptian papyros Eber(1550 BC) which dealt with the management of hearing loss. Hippocrates (460-377 BC) reported about hearing loss and tried to account for the possible etiology. Celeus after 500 years presented a clear differentiation in etiology-occlusion of the external auditory meatus due to cerumen, ulCeration, etc. Deafness was mentioned in the New Testament (Mark 7.31; Mathew 11,5). Emperor Hadrian made his handicap famous by holding his hand behind his cat. During the middle ages, no real progress concerning the functional diagnosis of hearing disorders was made. New concepts were not developed until 16th Century, the time of the Renessaince.

NEONATAL HEARING TESTING

Early investigators examined a variety of sensory systems, including the auditory system because of an interest in instincts, development of the "mind"and learning. Later they focussed on the infant's psychological and neurological development to plot normal growth curves to permit detection of impairment. Specific attention to assessing neonate's response to sound did not start until the later part of the 19th century. Determining the infant's auditory sensitivity or lack of it, has received attention because of the importance of initiating early educational programs and fitting of hearing aids. Upto now, assessement of newborns has been restricted to screening techniques only.

Determination of a hearing loss by the end of the first year of life is considered by some persons to be adequate to initiate special training programs. Most of the early reports of infant's responses to sound stimuli consisted of biographies of individual children by their fathers. Forty such biographies were received by Dennis and Dennis who tabulated appearing items of behaviour made by Tideman 1789. According to him 13 days after birth one could see continued attention given to those who speak to him, and, be instead when spoken to. Charles Darwin (1870) in a observation reported that during the first fortnight his son started blinking his eyes to sound stimuli.

The first collective investigation into mental life of newborns in a maternity hospital was made by Kaussmal, 1859 who was of the opinion that the capacity to hear was dormament in the personality. Preyer (1882) indicated that his son was 'deaf' for the first 3 days of life but responded to hand clapping sounds on 3rd and 4th days; on the 11th and 12th day could be quietened by sounds. This finding was supplemented by Benjamin Spock who reported the newborn to be deaf due to the fluid in the inner ear which may take long to absorb. Pratt summarised that the apparent insensitivity of the neonate seems to be the presence of amniotic fluid in the middle ear.

Prenatal and neonatal auditory sensitivity to gross sounds have been substantiated by many investigators. Movements of foetus in a pregnant woman were noticed, after sounding horn - Peeper (1924). Forbes and Forbes reported of prenatal movements one month before delivery when the metal bathtub in which the woman was lying was struck by a rod.

Fetal movements to 20Hz - 500HZ have been reported by Bernard, Peterson and Parley produced body movements in premature infants 3-4 weeks after birth. Genzer(l873) repeated Kausmall's experiments and concluded that newborn infants hear only on 2nd day of life. Kroner(1881) found neonatal responses to sound and found a variety of responses He reported that they respond better when half awake and that "repetition dulls the senses". Molden Hault and VonTrotlsch tested neonates and reported of responses as quivering of the eyelids, wrinkling of the forehead, arms, etc.

Miller and Genzmer(1834) established the Auro-palpebral reflex at supra threshold levels. Froding elicited the same reflex at 126 dB - 132 dB 1½ hours after birth.

Wedenberg observed the auropalpebral reflex at 500Hz-4KHz. He noted that 70dB-77dB wakes a neonate from deep sleep and 55dB wakes them from light sleep. It was thus concluded that normal hearing can be inferred at these levels of sound when the reflex is elicited or the neonate awakens.

Investigations on pavlovian conditioning have been made since the 1920's. Aldrich demonstrated a conditioned response to a bell with a child. Marquis (1931) established a response to the sound of a buzzer in 7 - 8 neonates during first 10 days of life. Kaye and Levin, Solomens et al, Wickens and Witchens concluded that conditioning could not be done for children under 12 days of life. Kasatkin and Levebova (1940) in a study found that 3 infants could not be conditioned for sucking responses within the first half of the 2nd month of life.

Pratt and Nelson and Sun used a stabelimeter polygraph technique to record body movement changes of infants under 10 days of age as responses to sound. Calibration of the stimuli(can, shapper, bell and tuning fork) was not sufficient for accurate determination of auditory sensitivity. Haller controlled the stimulus presentation with tones developed by 2B Western Electric audiometer; and found that responses such as discomforting and comforting were elicited for 7 frequencies in 4 intensity units. Comforting responses were(flexion and extension) and discomforting were squirming, writhing and crying.

Rosenblith found that neonatal responses to rattle (70 dB), bicycle bell(76 dB). There is little if any relationship between the newborn auditory scores and hearing responses at 4 months of age. Eisenberg writes "Auditory screening tests for newborns involve nothing more than gross observation and afford merely yes/no judgements about whether an infant responds to sounds, on the basis of which the examiner can say nothing about the integrity of VIII nerve or any other system".

RESPIRATORY AUDIOMETRY	Cannestrini(1913) was the first one to use it in neonates which was based on the work of Mosso(1878). Czetney(1892) recorded sleep curves of respiration and concluded the newborn infant is deaf, although they were obtained with other infants. Alteration of respiratory curves in presence of sounds have been studied in limited way, since the early 1960s in Germany, Japan, South Africa, England and U.S.A.
SPEECH AUDIOMETRY	Concept of using speech in testing hearing sensitivity was suggested by Wolfe(1874).Sander(1978) reported that as early as the first day of life, movements of newborns are synchronized with the rhythm of speech in the environment. Eimas(1971) reported that 1 month infants could differentiate /p/ from /b/ which indicates the ability to discriminate based on the feature of voicing. Eisenberg reports that speech is extremely effective in producing responses in newborns especially synthetic vowels. Franklin(1979) recommends the use of natural speech. Cannestreni(1913) noted that newborns responded even to their own mother's whispered speech.

ELECTROENCEPHALIC TESTS	BuBois Reymond(1848) demonstrated that the activity in the peripheral nerve was accompanied by an electrical change. The cerebral counterpart of DuBoise action potential was reported first by Caton in 1875. Marcus, Gibbs and Gibbs(1949) were the first to report the use of Electroencephalography to measure reaction to sound of young children during barbiturate induced sleep. Gidoll(1952) attempted for measure the puretone audiogram using Electroencephalography. Winthrow and Goldstein(1958) found that the thresholds were within 10 dB of the behavioural tests for school children.
ELECTROCOCHLEOGRAPHY	Application of Electrocochleography to labs was first done by Portman and Aran(1971). Berlin and Callen (1976) and Feinmesser and Tell(1972). All the three groups recorded Electrocochleography from different sites. .
Electro Cardiography	Initially the monitoring cardiac responses to sound stimulation was done by SONTAG and RICHARDS(1936). In 1950s application of this technique to other older groups were sought. Mennargia was the first to use this kind of evaluation in children.

C H A P T E R IV

INSTRUMENTATION IN EARLY IDENTIFICATION PROCEDURES

The field of Paediatric Audiology has been cluttered with uncalibrated toys(Weisenberg, 1971). This statement clearly implies the fact that various techniques which havebeen asked by the enthusiastic audiologist were not necessarily standardized, such gross measures do not lead us to a very accurate diagnosis - only to a very broad classification as hearing loss and no hearing loss. Thus it is evident that the main intention in testing infants, means actually only gross screening not leading to different degrees of hearing loss.

Basically, the equipment used for testing the pediatric population can be divided into 2 categories - Informal testing and formal testing. With the advancement of computer technology, evaluation techniques has improved and have become more sophisticated. Instrumentation used to identify deafness can be used prenatally or postnatally will be discussed in this chapter.

Noisemakers:- They have been most commonly used in assessing the neonates hearing status right from the anxious mother to the experienced paedeo-Audiologists. We classify the noisemakers into those that produce high frequency sounds to those which produce low frequency sounds - bells, clackers, gongs, squeakers, jingles,-etc.

Noise makers were found useful in identifying deafness in the peadiatric population. This has been reported by Bove and Flugrath (1971), Barr 1955, etc. Noise makers seem to be the most accessable tool available to test the hearing and so even we must try to emphasize the importances of determining the frequency components of the toys frequently used . 'Some tests like the Boel's test utilise a special type of noise maker like silver bells fastened to a ring producing frequencies being distributed between 4K - 12.5 Hz.

Signals produced from an Audiometer for BOA:-

Puretones, Noise and Speech are used to elicit responses. Puretones centered around 3kHz have been preferred by Downs and Sterrit 1964, who discuss its advantage in the following- greater accuracy of measurement and control in sound field- problem of standing wave is minimised. - can differentiate heriditary congenital from non heriditary congenital loss.

According to Fisch (1964) response of the child to rattles may be because they are inherently attractive sounds. A puretone according to him is as significant as any other naturally occuring sound.

Griffiths (1965) developed an Hearometer to present interrupted puretones at varied frequencies through a loudspeaker.

Cribogram - another technique for assessing the neonates hearing sensitivity utilises specialised instrumentation which consists of sensitive transducer attached to the cradle. A strip chart is present to record the activity of the child consequent to acoustic stimulation . A loud speaker is present to deliver the stimulus, an automatic timing equipment is also present for the delivery of the stimulus; the transducer consists of a piezo electric bimorph mounted on an aluminium disc; Depending on the force impressed on the bimorph, produces a voltage which is proportional to the voltage produced in the transducer.

Accelerometer recording system:-

It is developed by Altman (1975) comprised of a sound sources, cradle, Vibration pick, analyser system and recorder. A preamplifier amplified the voltage of the responses; and was passed through a Narrow Band Noise filter adjusted to 0.1 to 20Hz band width and was given to the accelerometer which generated voltage proportional to the acceleration of the vibration set up in the cradle.

Objective evlauations:-

(a) Reflex Inhibition Audiometry: (Marsh and Hoffman 1976)

Here the reflexive eye blink elicited by tactile stimulus is inhibited by the auditory stimulus preceded by 100 m.sec.

Tha apparatus consists of a device which generates the eye blink - air suspension acoustic speaker, to produce a highly reliable air puff. The diaphragm of the speaker is enclosed and the displacement on the diaphragm is forced in through a tube leading to the subject. An 8 attenuator permits the adjustment of the airpuff. The eye blink is measured with a modified d'Arsonaval meter fastened to the end of the air delivery tube. The point on the meter is extended with a length of polythene tubing which is taped to the eye lid. This unit translates the movements of the eye lid into rotation of the meter coil in a magnetic field, and generates a voltage nearly equal to the velocity of the motion, which is amplified, rectified and measured by a digital volt meter.

Impedance Measurements:-

Basic instrumentation of impedance measurements consists of a source, recording and comparing device. Thus here an oscillator is necessary to produce the 220 Hz tone which ia introduced to the external auditory canal through a loud-speaker. The reflected energy needs to be picked up by a microphone from which the reflected energy is compared with the reference voltage and is read out in the balance meter needle. An electronic manometer and air pump are connected to the probe tip to permit varying degrees of pressure, within the external auditory meatus.

ELECTRO ENCEPHALIC TESTS OF HEARING

Although the specific equipment used for recording the auditory evoked potentials varies among laboratories, the general needs are similar and may be summarised as follows: - Signal presentation system, Recording system, averaging system, and response storage system. A system could be used with appropriate electrodes, to record the evoked cortical potentials, brainstem potentials or cochlear potentials (Nendel, cited in Gerber, 1977).

SIGNAL PRESENTATION SYSTEM:

Signal generators are used in combination with appropriate electronic timers and switches, or alternatively electronic gates and filters. The generator produces the puretones that are shaped by appropriate gates into pulsed signals which can be phase locked into stimulus onset. Intensity can be controlled by an attenuator which precedes final application. Another important component is the pulse generator which serves as the master clock for the entire system. Trigger tubes from the pulse generator serve to control the timing of the acoustic stimuli - triggering channel on the FM tape recorder, (2) triggering of the calibrator, (3) onset of each sweep of the computor (4) the rate of signal presentation is thus set by the pulse generator.

RECORDING SYSTEM:

An electric potential can be measured at a given point only with reference to a second point. Thus 2 electrodes are used. The placement is important and varies with the type of potential you are measuring. The ongoing Electroencephalographic activity is picked up by the electrodes led through an electrode board to a calibration system which superimposes a reference signal of known voltage, and then amplified in 2 stages by the polygraph.

The amplifying system must also have extremely broad band frequency response characteristics from almost a DC range to an upper limit of about lO,OOOHz. Introduction of analog filters into the system may produce unwanted distortion of the evoked potentials.

AVERAGING SYSTEM :

Most of the computers are summing devices which through a process of algebraic addition, extract the time locked electrical activity and reduce the amplitude of the more random ongoing activity. To accomplish this, the computer descretely samples across time the voltage of the Electro—encephalographic trace and stores it in hundreds of continuous memory locations, called bins.

RESPONSE STORAGE SYSTEM :

It is displayed on an oscilloscope. Permanent storage of each response may be accomplished through the use of a plotter, or in the case of a general purpose computer, on digital magnetic tape.

RESPIRATORY AUDIOMETRY

Cannestrini (1913) recorded respiration curves from a pneumograph connected to a kymograph and assessed the respiratory alterations produced by various uncalibrated stimuli.

The crudest method consisted of an inflated girdle around the child's chest to measure air pressure causing change in breathing. Later the inflated girdle was supplemented by strain gauze system (Bradferd, 1972). Other methods were differences in temperature of inhalation and exhalation(Heron and Jacobs, 1967) Kankunen and Liden, 1977). Changes in impedence using electrodes on both the sides of the infants chest was done. After giving a weak high frequency current changes in breathing pattern were noted. Responses from electrodes are amplified and recorded on a micrograph - Impedence pleuthosography.

ELECTROCARDIOGRAPHY

The basic requirements to measure the changes in heart rate to stimulation are - stimulus generator, an amplifier, loudspeaker, cardio-tachometer to record the response. Stimulus generator is a calibrated audiometer The output from this is sent to an amplifier and loud-speaker. The amplifier is provided with switch to control the onset and offset of the tone. The cardio-tachometer is a beat measuring device, which is triggered by the prominent deflection in the cardiogram of the subject under test. An additional component, that is an averaging digital computer improves the efficiency of the recording system. The computer averages the time locked responses and stores them.

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C H A P T E RV

IDENTIFICATION AUDIOMETRY

"Today, there is one message that should be clear, concise and quite clear"

"IT IS POSSIBLE TO IDENTIFY AND DIAGNOSE HEARING LOSS IN THE NEWBORN"

- (Gerber and Mencher, 1974; In Early Identification of Rearing loss - Nova Scotia Conference, 1974)

Identification Audiometry refers to any of a variety of hearing testing procedures to persons of any age for the pupose of identifying those individuals with hearing sensitivity less than normal (Mencher, 1971). Identification of hearing loss is a long drawn out process which can even start before birth and can go on to later postnatal months. Ideally, the hearing loss should be detected as early as possible, for earliest possible rehabilitation. In our country "identification audiometry" most of the times refers only to postnatal identification. Literature gives us limited information about prenatal identification. Various tests have been developed by different audiologists, each test reflecting their own points of view.

Identification Audiometry is a term from the report of the committee on Identifaction audiometry of the ASHA and refers to "the application of any of a variety of hearing testing procedures to persons of any age for the purpose of identifying those individuals with hearing sensitivity less than that generally defined as within normal limits". Specific goals of identification audiometry are best specified by age groups, because of the differences in testing techniques and objectives which accompany maturation of the child and the environment of the adult (Mencher, 1971).

Smith(1972) writes on early identification as "In recent years there has been a new trend in the field of pediatric Audiology regarding screening of infants for hearing loss, within the first few hours of birth. This is typically carried out in the hospital nursery and is known as Identification Audiometry.

Brooks, D.N(1976) writes "Identification or screening audiometry is one of the fundamental methods at present employed for detecting a child with hearing impairment".

Downs(1967) specifies the goals in newborn infant screening programs as

(1) To identify newborn infants who have congenitally hearing losses serious enough to handicap their speechand language development. Such early identification will make it possible for medical or educational habilitation at an age that is early enough to take advantage of critical periods for the

development of auditory function.

(2) To add to medical sciences knowledge of the causes of hearing impairment by identifying the time of occurance of hearing disorder.

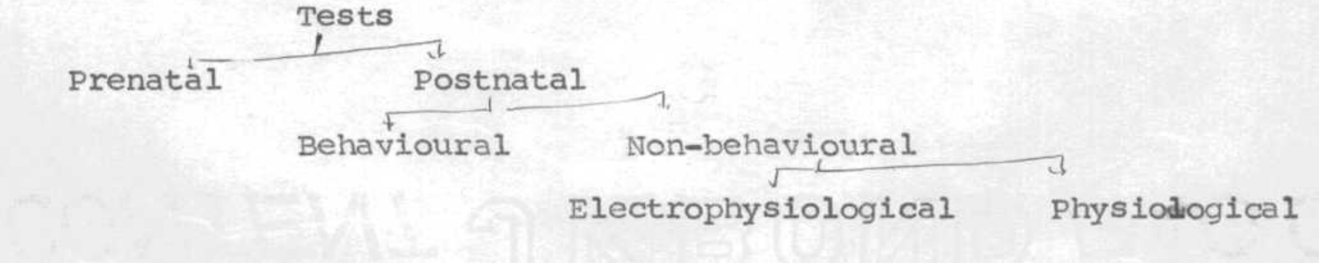
(3) To facilitate study of the development of hearing function in human infant.

According to Mencher(1972) early identification is divided into high risk registry, behavioural auditory screening.

Moncur and Wolfe (1975) suggest high risk registry babies should be first tested with behavioural auditory methods.

According to Urban(1977) identification of a hearing loss falls into 3 categories (1) Based on behaviour, (2) Based on high risk register, (3) Based on tests of hearing.

Broadly the tests for identification audiometry can be divided into



Identification of hearing loss has still remained in a twilight region because the 'response' in this field is still an enigma.

Young subjects behave like dynamic systems since they are continually changing their arousal state. This situation has two implications for infant audiometry (Bench, 1970).

Firstly, it is necessary to control for spontaneous changes in activity, which might otherwise be interpreted as a response to sound stimulation. Secondly, it is necessary to take into account the prestimulus or initial level of activity in assessing the magnitude of response change.

LAW OF INITIAL VALUE (Wilder, 1958): It states that the magnitude of response change, is influenced by the state of the individual before stimulation in such a way, that lower the initial or prestimulus state, the greater is the increase in level of activity on stimulation, the higher the initial state, the greater is the decrease in level of activity. This means that the response change is either positive or negative depending on the initial state; it also means that the intermediate state is zero. Thus it is to be expected that the subject will not respond, when tested at certain intermediate prestimulus state, when response is defined as change in activity, since in this instance.

prestimulus and post stimulus levels of activity will be the same. This is the CROSS OVER POINT described by Bridge and Reiser (1959) and was regarded as constant for any baby.

Law of Initial Value is explored over a wide range of prestimulus states from deep sleep to agitated state in a group of newborn babies. Neonates state of activity varies relatively quickly, enabling Law of Initial Value to be assessed over a wide range of behaviour in a relatively short time.

Bench(1967) did a study on 14 normal babies found that any given baby may show an increase of decrease in activity, or no change at all depending upon prestimulus state. Each baby was tested on 3 occasions for 60 minutes during which he was required to maintain his prestimulus state of activity(deep, light sleep) or wakefulness or mild or agitated crying. Heart rate was calculated from babies electrocardiogram recorded on a polygraph, which was taken as an objective measure of response pattern. This was highly correlated with subjective measures of activity (Bench and Synth, 1967).

Law of Initial Value effects must be borne in mind when testing infants, the absence of a response, or a negative change response may lead to the drawing of false conclusions. In practice, it is usually possible to avoid high or moderately high levels of activity, response change is always positive. However, it is usually impossible to control the state exactly so that prestimulus activity although low, is not invarient from trial to another, therefore unable to escape Law of Initial Value effects.

BEHAVIOURAL OBSERVATION AUDIOMETRY

Behavioural observation audiometry refers to the audiologist's attempt to elicit observable response to sound(Fultons, 1978). The responses may be either reflexive or voluntary which are temporarily related to the auditory stimulus. Stimuli used can either be speech or nonspeech stimuli. They can be presented as live voice or through a loudspeaker. Since behavioural audiometry requires extremely subtle manipulation of environment, there are naturally various variables to be controlled. They can be listed as the (1) behaviour of the child, (2) Environment, (3) Material, (4) Presentation of the stimulus and (5) Response.

Behaviour of the child:- The particular test in question must be geared to a particular child we are dealing with, from the mild docile cooperative infant to the aggressive hyperactive child.

Environment:- should be free from distractions especially visual ones. Temperature and humidity.

Test material:- must be capable of drawing the attention without being toodistracting.

Presentation of the stimulus:-must proceed from simple to complex and must be able to maintain motivation of the child and avoid adaptation.

Response:- The response criterion must be thought out and reliability must be maintained. This seems to be most uncertain point in the field of behavioural observation audiometry.

Preferences of test stimuli have been stated by many authors.

Galambos(1953) proposed the use of a click at 134 dB as the stimulus in behavioural audiometry. Ling and Doehring (1968) recommended the use of 1KHz NBN in detecting hard of hearing children. Docons and Sterrit(1967) recommended BBN as they report that all infants respond to BBN. Mendel (1968) recommended the use of NBN as stimuli since BBN may fail to identify an infant with congenital high frequency loss. Moncur(1968) noted that low intensity stimulus must be used so as to achieve control situations, calvert and Reddl(1969) recommended the use of BBN than 3KHz warble tone. Nikam and Dharmaraj recommended the use of an acoustically treated room for testing of infants rather than the hospital nursery. Berger(1971) says that Noise at 25-30dB elicited response. As the child matures, he locks around for the sound(7 months - 1 year) turns to voice, rattles, quiet meaningful sounds.

"Warbled tones have been recommended by many authors (Orchuk & Rintelmann, 1975; Swain and white, 1933; Hardy, 1958; Lagenback, 1965). It is supposed to provide a psychological advantage by reducing fatigue(Swain and White, 1933). Lagenback(1965) states that the warble tones attract the attention of the child, have excitable and awakening characteristics.

SUGGESTED PROTOCOL FOR A BEHAVIOURAL HEARING SCREENING TEST

(Recommendations of the SASKATOON Conference on Early Diagnosis of Hearing loss - Nova Scotia Conference, 1971)

Test Stimulus - A random noise having a low frequency attenuation of 30 dB/more per octave below 750HZ maximum of 90dB at the pinna, rise-decay time of 5 millisecs, duration of O.5 secs, 2 secs interstimulus interval of 15 seconds.

Infant Response:- Any generalized body movement, which involves more than one limb which is accompanied by eye-movement.

Scoring Criteria:- Controlled by one or two methods-

fa) Scorer does not know when stimulus is actually present.

(b) 2 observers score the responses independently. 2 stimulus responses should be positive to score as a pass and a failure should be retested atleast once.

Pretest State: This is important in the initiation of a response and must be controlled in specific terms. This protocol calls for an sleeping infant(eyes closed no observable body movement atleast 5 secs).

Test Environment: Ambient noise level should be measured.

EVALUATION PROCEDURES IN BEHAVIOURAL AUDIOMETRY

GALAMBOS (1953) described an EYEBLINK TEST for hearing. The usefulness of the cochleopalpebral reflex as an objective test of hearing was stressed. For this he produced a click sound through a gross stimulator it was produced at 134 dB. Infant should be seated in a high backed chair. Eyeblink responses were recorded and analysed. As intensity is decreased, eyeblinks decreased at 60 dB it disappeared. 50% of it occured at 95 dB. He concluded this level to be the threshold of hearing.

Peck, (1970) devised the BOTTLE FEED TEST for hearing screening. In this test, mother and child are placed in a sound treated test booth and the child is being fed normally. Examiner then presents various sound signals - monitored live voice and frequency modulated puretones. Consistent responses are got at 60-80 dB. Responses were taken as either

- interruption of rhythmical activity
- eye widening
- occular movements.

Advantages: (1) Random activity is reduced.

(2) Response easily identifiable.

(3) Crying is eliminated.

(4) Child is happy, alert, but not engrossed.

AWAKENING TEST - It was described by Wedenberg (1956). He suggested the presentation of tone pulses at 3KHz at 75dBSPL to awaken the child from light sleep. Criteria for responses are movement of eyelids, changes in heart rate, and general body movements. He states that by using a 3KHz tone, prediction of audibility to speech normally is present. Sleep can be 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.

MATTINGLY (1970) developed a SUCK TEST in infant screening. This depends upon cessation of sucking or nursing activity in response to pure tones or music. Mother is instructed to skip morning feed and bring the child to the test room. While the infant is nursing, testing with earphone at 3KHz and intensity level of 60dBHL. This is raised in 10 dB steps till cessation of sucking is observed. If there is failure in this test, then follow up is done after 6 weeks. Cessation of sucking and frequent eyeshifts from midline bo mother are taken as responses. In a quiet situation, it may not elicit rapid responses but a valid one.

GRIFFITHS (1965) devised the HEAROMETER which is an instrument used for neonatal hearing screening. Eoundspeaker is placed over the sleeping infant and interrupted pure tones of varied frequencies and intensities are delivered from it. Satisfactory responses ia the awakening of the infant from sleep.

SIMMONS (1976) developed the CRIBOGRAM. It is an instrument which records the responses in the form of a graph. One second narrow band noise stimulus at 92 dB is presented. Neonatal motor activity is monitored for 12 seconds before, during and 2.5 seconds after onset of the stimulus. Silent test is also administered. To avoid the startle response, a prestimulus is presented at 4OdB at 4KHz. About 20 tests can be done in a day.

Criteria for response is the largest peak to peak amplitude in a prestimulus interval of 3.5 secs is atleast two times or half the amplitude of the largest positive peak minimum negative peak in a 12 secs response then response is scored. If the number of changes in direction per seconds in the post-stimulus period is atleast 2 times less than half of the number of changes in direction per second in prestimulus period, then response is counted.

Random Vs Real responses - This is a function of duration after stimulus onset. Results indicate that random average response rate of 4.6% an average real response rate of 36% based on a study done on 2787 neonates.

The cribogram is a probalistic instrument with inherent inaccuracies - false positive and false negative error. The major value in rescreening is the initial screening fails is to clear newborns who might be scheduled unnecessarily for followup diagnostic testing. Improved cost effectiveness and diminished parental anxiety may be the positive consequence of subjecting a child to atleast two cribogram screenings. Thus a multiple screening strategy should have effect of substantially reducing positive error without increasing negative error.

According to Simmons, Jones(l976), the Cribogram seems to solve the problems usually associated with behavioural screening. The entire population can be screened using this simple, automated device. Transducer is sensitive enough that it can pick up heartbeats and very often monitors respirations. When crib activity is too much or when the baby is too active, it is taken as unscorable.

ALTMAN (1975) devised the Accelerometer Recording System The sound source is 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 accelerometer was attached to the wooden pillow. A preamplifier amplified the voltage of the responses and was passed through a narrow band filter adjusted to 0.1-20HZ band width and was given to the accelerometer. The voltage generated is proportional to the acceleration of vibration in the wooden pillow. Voltage of the signals are registered by the recorder. Here the stimuli is 3150Hz at 90dBSPL.

MARSH & HOFFMAN (1976) described the REFLEX INHIBITION AUDIOMETRY procedure. The reflexive eyeblink elicited by a tactile stimulus is in-hibited if the auditory stimulus precedes this stimulus by 100 msecs. in this method, the hearing acuity is assessed by determining whether the reflexive eyeblind(elicited by tactile stimulation of the face or cornea) is inhibited by an acoustic stimulus by a fraction of a second. This requires no conditioning. Origin of the Reflex inhibition audiometry in the startle reflex of a sound was found to be inhibited by a relatively weak pause of noise preceded the more intense startle stimulus by 20 - 500 msecs.

„ The apparatus used has been described extensively in the chapter Instrumentation. To review it, basically it consists of 2 apparatus - for generating eyeblinks, air suspension acoustic speaker to produce airpuff. The diaphragm of the speaker was enclosed so that displacement of the diaphragm forced in through a tube leading to the subject. The eyeblink is measured and modified by d'Arsonval meter.

Stimuli - tones served as antecedent stimuli, which were generated by controlling the output audiosounds. Interval can be controlled by tunes.

Procedure: Each subject was seated in a chamber fitted with earphones, thresholds were determined. Desired combinations of antecedent auditory stimulus and blink elicited airpuff were presented in 30 sec intervals. To combat boredom a 35 mm colour slides were used. Thresholds were found for 250, 500 and 1KHz and 4KHz. The stimulus had a risetime of 10 msec, 200 msec duration and an onset preceding the airpuff by 100 msec.

This procedure can be modified for the paediatric population. The subject is placed on the parent's lap, the emperimenter selects the stimulus configuration and the other experimenter puts the earphones on infant's head and airpuff delivery handpiece and initiate the trial. 10 airpuffs in silence interspersed with 1 KHz tone at 70dBHL having 100 Msec lead time, only one ear was tested, this procedure proved to be comfortable and gave no evidence of annoyance (Marsh, Hoffman, Stett, 1978).

In a study done by Hoffman, Marsh and Stitt on infants, they found that a prestimulus of 30dBHL strongly inhibits eyeblink reflex for all frequencies tested.

Advantages - (1) simple to administer, (2) safe, (3) no irritation to the infant and (4) inexpensive equipment.

cautions - No diagnosis of hearing loss should be based on reflex inhibition Audiometry. It only helps testing the child whose responses are inconsistent and adds confirmation to the audiogram.

MENCHER (1975) recommended the use of a PRETEST SENSITICER FOR NEONATAL TESTING. Broad band noise was used as an appropriate alerting signal to induce the neonate to focus attention to specific sensory modality so that responses will occur relevantly to stimuli following it. Broad band noise was selected because it was such that all infants respond to it. It was delivered at 90dB. In a study done by the same author, he found that in deepsleep it is found to be a useful PSA in newborns. In awake and quiet states, PSA was useful and increases response strength. It also might increase activity and hence may mask the response, speech signals are effective in eliciting arousal.

LOCALISATION AUDIOMETRY - In general it is applicable to infants of 3 - 4 months of age. Stimuli is presented through a loudspeaker. An assistant draws the attention of the infant, Toys are kept to distract the child. Localization to the source of the sound is taken as the response. Hut the information got is of the better ear, it may not elicit a response in an older child which may cause an erroneous diagnosis of hearing loss.

BOEL TEST - Programs for infant screening of communication disorders should cover the need for information about the development of attention functions - auditory, visual and tactile at an age when the child is on the doorstep of the speech acquisition, before 1 year of age (Junker, Basz, Malemem, Hockert, 1978).

BOEL (Blicker Orienterar Efter Ljud in Swedish) which may be translated as into look orients after sound. Named after an autistic child, who did not use the exquisite means of human exchange of speech but used to follow sounds with her eyes. Thus the BOEL test happened as a search for an alternative to the traditional 'wait and see' approach, and aimed at an early quick mental health check up(Stensland Junker, 1972).

Method - BOEL attention test is done to infants of age 7-9 months. Infants of this age have a short attention span, both with regard to space and with regard to time. The sounds are presented at limited distances, and should be small enough to be hidden in the clutched fist of the tester. 4 silver bells fastened to the ring, Visual stimuli consist of a red double band stick - the gripper and a silver mobile called the spinner. The tester, after having established a firm eye contact with the infant, checks that the eyes attentively follow the 'gripper' first horizontally to grasp it and examine vertically, before the infant is allowed to grasp it and examine it with the mouth. The mother is asked to remain passive. The sound sources are held about 20 cm behind the child's ear. As a final check visual attention and the capacity to follow a stimulus, the silver 'spinner' is held up in front of the infant and moved in the same way as was the gripper about half a meter to and fro, first horizontally and then vertically. The silver'bells' should be presented as the first of sounds and the 'bells' the last. The sounds should be presented fast. Presentations should not be reviewed.

The test protocol shows the results under the following items - steady back, firm look, wants to take gripper, holds firmly, contact smile, eyes follow, vocalizations, pats into mouth, searches ball, searches for bell. Eagerness to reach the red gripper depends greatly on an infant's personality and level of maturity. There are some infants more reserved than other; and there should be an understanding when evaluating any child. A lack of tactile curiosity should be considered as normal. An autistic child is characterized by loss of eye contact. A hearing impaired child does not search for the soundSy he cannot hear, and the infant who does not see cannot 'reach' for the spinner. The way of grasping in handling or holding objects is also informative.

If needed, the nurse retests the infant after a week. If the responses still deviate after 2 more retests then the nurse informs the paediatrician and other specialists.

SUMMARY:

Advances in Computer technology and electronic instrumentation coupled with dramatic inceeases in our understanding of behavioural and development have allowed us to present specific, reliable, realistic procedures which can be utilised in diagnosis of hearing loss in infancy. All this could have been only a dream(Gerber and Mencher, 1974 in Early Identification of Hearing Loss, Nova Scotia, 1974).

Early identification and subsequent audiological management of a child with hearing loss not only enhances the opportunity to develop adequate speech and language but also benefits the educational and sociological development(Horton and Sillon, 1970? Sustedt, 1974). No evaluation is an end in itself. Hence a combination of them should be used for testing and rechecking our diagnosis.

continually. The newborn nursery provides a setting in which the various test conditions can be controlled and results standardized. The fact still remains that the realm of behavioural audiometry has many variables which also depend largely on the audiologist's interpretation.

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CHAPTER VI

NON BEHAVIORAL TESTS'FOR IDENTIFYING DEAFNESS

Electro physiological audiometry employs responses to acoustic stimulation manifested by, observable changes of some physiological property of the subject, while behavioural audiometry requires an overt bodily reaction (Gerber 1977). One would choose this method of evaluation for the difficult to test patients, an infant, a multiply handicapped person, a severely retarded person. Electro physiological tests of auditory function should properly include the monitoring of any bodily change produced by the initiation of a stimulus in the ear. They can be seen as single or whole nerve activity in the auditory pathway, or central nervous system, or they can be recorded as visceral, glandular, or motar changes over a wide area of the body. This method is especially, useful with regard to the pediatric population.

Physiological tests for children have been employed for several reasons. (1) To determine sensitivity of the peripheral auditory system - an objective audiogram without the behavioural cooperation of the child. (2) To assess the integrity of various parts of the auditory system including neural pathways and central auditory function (Bess, 77).

Electro physiological tests currently used for children can be classified according to the system, including neural pathways and central auditory function into 2 categories (1) Those that monitor the affarent or auditory input pathway from tympanic membrane through cochlea, VIII nerve, brainstem to the central nervous system. The tests included are impedance tests, Ecog, brainstem audiometry, evoked cortical audiometry.

(2) A group of physiological tests of auditory function usually record responses from the autonomic nervous system they include measures such as skin resistance, heart rate respiration and pupillary dilation. The latter responses reflect not only input system, but also of numerous sympathetic and parasympathetic adjustments within the nervous system that respond to the auditory system. These should be done with great care because the response system normally should be maintained to obtain valid measures.

Impedance ECogh. Cortex EEG

External auditory   Middle ear   Inner ear cochlea   brain-stem (BSER)

The recording sites are the various evaluation procedures used.

Acoustic Impedance Measurements:

Acoustic impedance measurements provide, efficient, objective and illuminating information during the audiometric evaluation of children(Northern cited in Bess, 1977). It can provide diagnostic information regarding the site of lesion, nature of loss and acts as a supplement to behavioural observation audiometry. Impedence refers to the resistence to the motion and is expressed as a complex ration of force and volume velocity. While measuring impedance, we are actually measuring how much of resistance is present to sound waves at the ear. Impedance is influenced by 3 factors - Mass, stiffness and Resistance. Mass isrelated to the ossicular chain, stiffness is related to the movement of stapes, resistance is related to ligaments and muscles. Any pathology in the middle ear mechanism will thus alter the impedance of the middle ear and so influence the flow of energy reaching the cochlea. Midddle ear pathology is frequently present in paediatric population(Holon and Kunze, 1969; Lebby, 1974; Rock, 1974; Schwartz and Redfield, 1975). Thus such a loss of hearing can lead to speech and language retardation. This necessiates early identification from the view point of middle ear problems. The traditional method used is otoscopy but not all pathologies can be detected by this method.

Impedance measurement in babies is certainly not without problems(McCandless, 1977). Basically in impedance audiometry the following are done

- Tympanometry

- Static compliance
- Reflexometry.

Jaffe(1971) points out that conductive hearing loss has not received much attention in neonates because the ears of the neonates are not routinely examined in the newborn nursery, lack of concern mildmoderate conductive hearing loss and inability to identify it.

TYMPANOMETRY : It refers to the measurement of the compliance of the tympanic membrane at different pressures in the external auditory meatus. It is a dynamic measure. Tympanogram refers to the graph on which it is plotted and provides information about the following

- pressure status of the middle ear
- mobility of the drum and the ossicular chain
- resonance point of the middle ear.

Interpretation of the tympanogram should be based on the following facts (1) Peak (2) Amplitude (3) Shape. In adults the tympanograms have been classified into various groups by Jerger(1970) and Liden et al(1974), but the question is whether this calssification holds good for the pediatric population as well. Similarities between the tympanograms obtained in adults and children have been found(Fulton and Lamb, 1972; Jerger, 197O; Keith, 1973) cited in Northern and Downs, 1975. According to Cannon, Keith, 1975, the main difference between the 2 groups of patient population was that the presence of a W shaped tympanogram which aprroximated to the adult pattern with age. Bennet(1973) in his study noted that double notched tympanograms in some neonates(5-18 years) which later became a single notched with age. He classified them as

Single notched S_1 — Normal
S_2
S_3

Double notched D_1 - similar to S_1 but with double notch
D_2 - similar to S_3 but with double notch

Difficulty in obtaining hermetic seals have been reported, is is easier in the neonatal period. Deep sleep seems to be the optimal time for testing.

STATIC COMPLIANCE : It is the reciprocal of impedance. If a system is more mobile it is more compleant, if is immobile, it is stiff. Stiffness of the drum depends upon the middle ear condition,if middle ear contains fluids then tympanic membrane remains stiff. Normal compliance values vary from O.3 to 1.6(in adults). Below 0.3 is considered stiff and above 1.6 is considered as excessive mobility. Literature reveals that in the peadiatric population, the value of static compliance varies from that of the adults. Many hypotheses have been put forward to explain this.

(1) Hypermobility of the tympanic membrane or soft walls of the external auditory meatus.

(2) Development of norms in the neonatal period have been influenced by high incidence of middle ear pathology. Keith(1973) found median compliance of 1.2cc in a group of neonates 2½ - 20 hours, and l.lcc in neonates of 36 -151 hours. Gerber and Cone from their study on infants(5 days-13 months) found median compliance value of 6.79 cc. Thus these studies show that there is a decrease of compliance with age.

ACOUSTIC REFLEX THRESHOLDS : The acoustic reflex refers to the contraction of stapedius muscle to sound. The lowest sound pressure level at which the stapedius muscle contracts is the Acoustic reflex threshold. For an acoustic reflex to be present, the following conditions must be met

(1) There must be sufficient residual hearing to induce a reflex.
(2) Cranial nerve VII should be functional on the monitored ear.
(3) Stapedial tendon must be intact and properly attached to the head of the stapes.
(4) Ossicular chain should be continuous through the point of stapedial tendon, insertion and sufficiently mobile to allow for stapedial contractions to change the impedance characteristics of the tympanic membrane.

In the very young since factors other than acoustic stimulus elicits the reflex, we must be able to isolate only the reflex consequent to acoustic stimulation. Allerd et al (1974) measured reflex in 97.3% of neonates 25-30 hours; Keith(1973) measured reflex in 30% of 36-18 hours. Presence of reflex in neonates have been reported by many investigators (Keith, 1973; Bennett, 1975; Bench, 1978). Incidence data obtained from the data of Keith(1973) and Allered reported an incidence of 30-33%. The lower incidence of that of Bennet (1978) was due to

(1) Mesenchyme in the middle ear which impedes movement of ossicular chain.

(2) Depth of sleep.

(3) The development of nervous system is not complete (Goldstein, Wolf, 1977).

An incidence of 42% of Acoustic Reflex Threshold has been found in infants(Megolis and Popelka, Stream, 1977). Similar to the other measures of impedance as age increases reflex thresholds are elicited at lower levels and at many frequencies(Habner, Synder, 1974; Robertson, Peterson, Lamb, 1978; Jerger, 1974). Variability in Acoustic Reflex Threshold are seen maximum in the age of 24-36 months. Acoustic Reflex Threshold was seen around 70-90dBHL for 25-50 hours which was similar to that obtained for adults.

One of the requirements for the presence of acoustic reflex is the complete reflect pathways; thus the immature development in the neonate interfered with Acoustic Reflex Threshold. The maturational process goes on until 3 months; which may explain the differences in Acoustic Reflex Threshold between adults and children.

CLINICAL APPLICATION : No doubt, Impedance Audiometry is an integral part of the test battery and its potential value increases when all the 3 namely - tympanometry, static compliance and reflexometry are used in combination.

Tympanometry: There are 3 points of focus which are eseential for interpretation in the clinical population - pressure peak, slope and Amplitude. Feldman(1977) classifies them as

(a) Pathologies with negative pressure - Blocked Eustachian Tube, Serous otitis media.

(b) Pathologies with nominal pressure - ossicular bony fixation, Adhesive fixation - ossicular discontinuity.

(c) Pathologies with positive peak - Early acute otitis media.

(d) Absence of peak - Open tympanic membrane, Artifact, middle ear effusion.

With respect to the pediatric population that of utmost value in tympanometry is the identification of middle ear disease, that is, negative pressure is an important indicator to middle ear pathology(Liden and Ranval,1977; Remall, Liden, Jungest, 1978 Brooks, 1975). Here the controversial points seems to be the cut off point between the normal and abnormal which should be clearly specified. Some consider -150 mm of water as the cut off point(Brooks, Liden and Renall) and so beyond -150 mm of Water is abnormal. Some investigators (Orchick, Moriff and Dunn, 1978) consider C_2 i.e.,(-15 to -20mm of Water) as being the best indicator of middle ear disease, whereas Fellan and Nicoka(1979) consider C_1 to be a better indicator. C = (-100 to 150 mm)

Amplitude :- Those with greater amplitude may indicate the following pathologies(eardrum abnormality, ossicular discontinuity)and those with decreased tymponogram amplitudes indicate ossicular fixation, serous otitis media, tumors. Another important fact to be noted is the identification of certain congenital abnormalities in the middle associated with various syndromes. For eg., in Osteogenesis imperfecta or Vander hoeve's syndrome these is a congenital fixation of the stapes.

Slope may be associated with pathologies which flatten or decrease the tympanogram slope - serous otitis media, ossicular fixation, tumors of the middle ear. Increased slope — eardrum abnormality, ossicular discontinuity, smoothness of the curve may be associated with tumors, eardrum abnormality.

Static Compliance : In neonates and infants the use of isolated static compliance measurements seems to be of limited value, with the adult population itself there seems to be an overlap between otosclerotics and normals, and ears with ossicular discontinuity(Alberti, Kristen, 1970). Static compliance values vary with age and sex and thus causes more variability and seems to be the least informative test of Impedance for the pediatric population.

Acoustic Reflex Measurements : For threshold determination the formula given by Seisterhan and Nieymeyer(1974) do not hold good for the pediatric population. The bivariate plot method advocated by Margolis and Popelka(1975) has been found to be useful in assessing hearing sensitivity in children. No specific application is found applicable to the neonatal population.

ELECTROENCEPHALIC TESTS

The electro encephalic tests of hearing are cortical responses to sound stimuli. When an auditory stimulation is given there are minute changes occuring within the brain These responses are summated by the averaging computer. The electrical responses are picked up between 2-8 millisec. which reflects the activity of the 8th nerve and successive brainstem auditory nuclei, came to be known as Early components. Middle responses are those which are picked up with in 8-56 millisecs, late responses are picked up between 50-500 msec, the latency greater than or equal to 300 msec is considered as contingent negative variation. Early components reflect activity of the 8th nerve and successive brainstem nuclei. Middle and late components reflect cochlear potentials.

Middle responses: They were first recorded by Gersler, Freshkopt and Rosenblith(1958). They are recorded maximum at the vertex with a reference on earlobe or mastoid. The discoverers of these potentials first attributed them to be cortical in origin whereas in 1964(Beckford, Jacobson and Cobly) attributed them to myogenic activity which can be enhanced or diminished by manipulating the tension on the positional muscles of head and neck.

The response is recorded from relaxed, sleeping adults or infants in response to stimuli. It consists of 3 negative peaks and 2 positive peaks. Feasibility of using middle components in neonates were studied by Mendel et al, 1975, Goldstein et al, 1967; McFantid, 1977). The waveforms of the neonates 1-3 days of age resemble those of adults. Amplitudes were smaller and latencies shorter in infants than adults.(Mendel, 19770) Infants less than 1 year are tested during sleep. The response was better in the ipsilateral ear in neonates when compared with adults. The responses are not affected by sedation thus seems to be an effective measure in children.

LATER RESPONSES: The responses coming from 50-300 msec are referred to as late responses by Davis who described them in 1939. According to him they are cortical responses which are essentially related to temporal auditory association cortex and frontal association areas and thus can be elicited by auditory, verbal or tactile stimuli(Picton et al, 1974)

Late responses are reported maximally from vertex and a reference on the mastoid. The waveform consists of two negative and 3 positive peaks. Presentation 30-56 per minute. The responses vary with intensity, as intensity increases, latency decreases, amplitude increases(Moore and Rose, 1969; Goodman and Bryce, 1970). The normal threshold in awake infants has been established at 30dBSPL(cited in Gerber, 1977). Consistent responses were got for infants (1-7 months) of age by Fatter and Gordon(1972). But in general, both infants and neonates this method of assessment is not feasible. The stage of sleep of the infant has been found to have an effect on response waveform. An increase in the latency during speech has been observed of all peaks except P_1 in infants 16 weeks to 3 months. While the infant is asleep, is the ideal time for testing. Using sedatives affects the responses. Deep anesthesia abolishes response. Drugs also affects responses - phenobarbital, Neurobital, etc. The middle responses are influenced more than late responses. During sleep latency of response in infants is 40-150msecs greater than in adults(wizner, Freshbein, Grazinun, 1965). Barnet and Goodwin(1965) say that the depth of sleep in newborn infants influenced the late component response.

Several studies have been reported which attempted to use the late components to diagnose hearing loss in infants (Bornet and Lodge, 1966).

EVOKED BRAINSTEM POTENTIALS

These potentials occur within the latency of 2-8 msecs, and reflects the activity of the auditory nuclei and tracts. They were first elicited by Sohmer and Feinmeeser(1967). Jewett(1979) observed these waveforms and associated them with respective firings of 8th nerve.

Brainstem evoked potentials can be grouped into distinct groups (1) Onset potentials (2) Frequency specific potentials. Onset potentials can be further classified as

- farfield potentials(Jewett & Wilteston, 1971)
- Farfied Ecog (Terkildsen et al, 1975)
- Surface recorded Ecog.

Onset potentials are more widely adopted in the clinical set ups. Jewett's observation revealed a wave form with 5-6 monophasic positive waves with latencies varying from 2-7 msecs. These potentials are obtained from the brainstem.

Wave 1 : VIII nerve action potential.
Wave 2 : Cochlear Nuclear potential.
Wave 3 : Superior Olivary Nucleus.
Wave IV: Nucleus of lateral lemniscus and inferior colliculus,
Wave V : Inferior colliculus.

Wave VI, VII - Higher brain centres.

Among the waves Jewett, 5th is the most stable. The negative peak at the vertex with characteristic latency for the following reasons

- independent of state of arousal and age of the subject.
- less time consuming
- easily accessible
- can be obtained near the behavioural threshold.

Some other investigators argue that Wave 1 is more stable because of less inter-subject variability.

STIMULUS: High frequency tone bursts or clicks are used (Live and Sohmer, 1972), Lickeman et al, 1973; Martin and coats, 1973; Terkildsen et al, 1973; Thornton & Coleman, 1975; Goldenberg & Derbyshire, 1975).

RESPONSE: Davis and Hirsh(1976) distinguish between 2 types of responses.

(1) Onset arising from multiple locations in the brainstem It is characterised by wave pattern of 5-7 waves.

(2) At slow repetition rates at moderate intestities.

ELECTRODE PLACEMENT

Terkildsen et al(1974) recorded from active electrodes placed on vertex, nose, ipsilateral and contralateral mastoids, and homolateral positions of the neck.

Reference electrode - Left 3rd sternocostal joint of the thorax, other investigators kept the active electrode attached to the vertex, while reference electrodes were attched to both neck positions. Wave 1, II, IV, v, VI were higher in amplitude than with homolateral vertex records than with contralateral vertex recording. When Wave 1 has to be elicited, then we record the onset brain-stem potentials with an active electrode on the vertex with a reference on the ipsilateral mastoid.

Infant should usually be sleeping and the elctrodes are placed. The stimulus is presented at an average of 1024 times. Initially they are presented at a moderately high level. Once the characteristic wave is elicited the intensity is decreased. The lowest intensity at which the characteristic wave is obtained is taken as the threshold of hearing. Basically in a response waveform, we look for the following - the wave form, latency of V and I, difference of latency between V and I, amplitude of each waveform.

This is essentially taken as a n response. This wave-form reflect information primarily from 2K region. Variations can occur due to many factors - maturation is necessary for the occurance of the characteristic response.

Various investigators(Hecox and Galambos, 1974)(Hecox, 1975; Salamyctal, 1975) agree that newborns exhibit 3 waves

(I, III, V) in contrast the adult findings who mostly show(VI and VII). Contradictory findings are revealed by Hecox, 1975 who identified I, IV, v. Another finding was similar to those found in the adults was that with the use of repetition rate, individual wave clarity decreases. Wave forms similar to adults were found during the 1st year of life(Salany and Mckean, 1976) indicating that maturation is necessary for the elicitation of these potentials.

Libermann, Sohmer, Szabo(1973) observed shortening of the latency of wave with advancement of age in infants. Studies reveal that the latency of V wave decreases progressively with age(Hecox and Galambos, 1977).

Galambos(1975) stated that thresholds can be obtained even in premature babies at 30 dB above threshold of adults, and that the latency shortened systematically with increase in gestational age.

Thus the review of literature shows that there is a systematic shortening of I and V with age, this may be due to progressive mylenisation in infants.

Response can vary with stimulus intensity and it can be obtained at a low SL as 0 dBSPL when the subject is in a relaxed state(for neonates) and infants they must be asleep. Hecox and Galambos(1974). This procedure with the neonatal population is usually not used for differential diagnosis but only for screening.

ELECTROCOCHLEOGRAPHY

Ecog measures the peripheral activity of and thus proving a reliable diagnostic tool for assessment of hearing loss in children. Ecog is a test which notes, records and measures the averaged electrical signals between the promontary of the cochlea and the lobe of the ear in response of very short acoustic stimuli of alternating phase(Portman and Aran, 1971).

Ecog is the recording of stimulus related potentials generated in the cochlea, including the first order neuron namely the cochlear microphonic, the comound action potential and summating potential. Electrocochleagraphy needs assistance of personnel like a medical engineer, ENT specialist, anestheliogist.

The evoked potential generated at the level of the cochlea can be divided into 3 categories - the cochlear michrophonic, summating potential and action potential. The cochlear microphonic being related to the amplitude of displacement of the cochlear partition over a considerable frequency and intensity range. The waveform reflects the waveform of the acoustic stimulus being in phase with the amplitude of the movement of the cochlear partition occuring instantaneously after stimulus onset.

Summating potential is a direct current shift that continues through out the presentation of a stimulus. The magnitude and polarity of this are dependent upon the recording site, stimulus frequency and stimulus intensity.

Action potential results from simultaneous discharge of many individual nerve fibres. Action potential reflects both the transmission energy of the hair cell and also the transduction of this energy in the 8th nerve while the cochlear microphonic and summating potential reflect activity at the level of the hair cell.

Procedure: Recording sites at promontary(Portman, Lebert and Aran, 1967). At the external Auditory meatus(Coats Dicbey, 1970, 1972; Coats, 1974; Cullen, 1972). Promontary site is preferred because as the recording site is nearer the cochlea good, distinguishable responses are available. The promontary recording involves the transtympanic approach which needs general anesthesia. The infant is placed on the cradle, general anesthesia is given and the guaze needle is passed throuthe tympanic membrane till it comes in contact with the promontary. This can be done even with neonates a few hours old. Reference electrodes are placed on forehead and mastoid separately and respectively.

Action potential can be recorded from either promontary, external meatus or earlobe. Even here the promontary recording is prefered. The ear is then stimulated with sound stimuli of short tone bursts of alternate polarity - clicks which generates the cochlear microphonic and action potentials which in turn are picked up by the electrodes and are sent to the Averaging computer. This cancels the Cochlear Microphonic and adds the Action potential, which is the final waveform.

RESPONSE ANALYSIS : Diagnosis is made with respect to

- amplitude and Latency of response to click at each intensity level
- the latency of response near threshold.
- the absolute amplitude of maximum response.

The latency of the waveform is considered most stable because the other two are influenced by auditory and non-auditory constraints. The abnormal response should be compared with the normal one. In neonates, the normal response itself is found to have a prolonged latency, diminished amplitude and elevated threshold compared to adults. Normal thresholds in neonates 35-45dBHL compared with 28dBHL of normal hearing adults. Waveforms can vary with respect to intensity, interstimulus interval, type of stimulu, recording site and anesthetic agent.

Intensity - As intensity increases, the latency decreased upto a certain point. The amplitude of response also increases upto gradually at intensities upto 50-60 dBHL. At high intensities amplitudes increases upto 80dB above which it forms a plateau.

Type of stimulus: High frequency elicits specific responses because, the travelling wave of Bekesy takes 3 msecs-7msecs to move from base to apex and discharges more haircells and nervefibres at the basal turn. Here Acoustic potential response latency is 1.5-3 msecs, thus stimulation is mainly of the basal turn of the cochlea and therefore high frequencies are represented here, and therefore elicits clear Action Potential response. Thus Mendel(1977) states low frequencies to be ineffective.

Anesthesia - This can also affect responses which is a result of excessive swallowing action which produces electrical and mechanical artifacts in recording; so other forms are recommended such as inhalation methods(Zoman et al, 1974).

Electrode placement - Responses are recommended and are dependent upon active electrode. Eggermont and Odenthal (1974) give the following values(cited in Gerber, 1977)

Round Window - 2 dBSPL. Promontary - 5 dBSPL.

Annulus tympanicua - 10 dBSPL. External ear - 30 dBSPL.

The round window gives best recording and the external ear the poorest. But all time, promontary recordings cannot be done and hence must resort to the earlobe recording taking precautions. In neonates studies have not been done with regard to threshold determination only with respect to abnormal variation or not as any other behavioural method. But various studies have been done with children for adequate threshold determination without masking and good correlation with behavioural methods was obtained (Aran, 1978; Spoor, Eggermount, 1958).

RESPIRATORY AUDIOMETRY

This is another non-behavioural measure of hearing assessment. It has been known long that the newborn infants respond to loud, sudden and brief acoustic stimulation with changes of response. It refers to the assessment of auditory sensitivity in terms of alterations in respiratory cycle consequent to acoustic stimulation. Bradford(1968) suggested that respiratory audiometry may be employed for determining neonatal and infant hearing sensitivity.

Respiration in infants change right from the infant's first breath to later ages. Neonatal respiration is rapid and shallow. By 1 hour of age, there is a barelling of the chest and increase in the antero-posterior diameter. By 2 hrs - 6hrs of age, respiration is variable and related to activity. This is essential to our study in Respiratory audiometry because it is necessary to know what a change in response means consequent to acoustic stimulation. A median of 82 breaths per minute in an neonate of 15-30 minutes, 50-108 in infants(cited in Gerber, 1977). The infants upto 6 months display abdominal and diaphragmatic respiration compared to thoracic breathing of adults.

Pre-requisites of the Test

(**a) State of the infant** - Bodily movement can affect the infant's audiometric assessment. The input is usually taken as sleep - light shallow sleep(Bradford, 1975, Cannestrin, 1913). Suzuki et al(1964) recommended testing when the child is awake.

(b) Stimulus - The optimal stimulus for bringing about respiratory changes is yet to be assessed. Stimulus relevant are those related to infant hearing screening in general i.e., puretones, noise, warble tones.

Stubbs(1934) found changes in respiration asresponses to variations in duration and intensity of stimulus tone. The variety of the acoustic stimuli that has been used for testing neonate's hearing leaves the audiologist in a dilemma, thus also the stimulus for respiratory audiometry. Heran and Jacobs(1967, 1968) recommend the use of puretones of low frequency; Kumf and his associates advocated the use of subjects own breathing as a response both to white noise and puretone acoustic stimulus. Heron and Jacobs(1969) recommended the use of 4sec warble tone, Bradford(1975) used pure tone stimuli at 1KHz and 2KHz. so now the audiologist has a multitude of alternatives to choose from.

Intensity of the Stimulus : Suzuki(1964) used 30, 40, 50, 60, 70, 80 dB presentation level. Heron and Jacobs(19691 used warble tones at 40, 60 and l00dB which was similar to the intensity levels used by Gilchert and Gerber in their study. In general, some investigators indicate difference in response with respect to intensity level and some others indicate no difference in response between intensity of the signal and response(Heron and Jacobs, 1967, 1968; Mecean, 1976; Geens Maglions, 1978). Some indicate maximum response at threshold level, because at that level sound will be very faint and the infant strains to hear it. Thus literature shows no agreement between the various studies done and the intensity of the stimulus used.

Responses: significant stowing of respiratory cycle of adults, greater slowing for lower intensity sounds. Ronsey et al(1964) found that respiratory rates slow down as the threshold of hearing is approached. Suzuki et al(1964) investigated changes in respiration asthe following (1) changes in rate or depth of respiration, (2) Decreases in regularity of response. (3) Appearence of sudden respiration. According to Heron and Jacobs(1968) two important parameters affect maximum neonatal response timing i.e., the optimal time for recording responses(lig hours before feeding). They also observed the gasp reflex.

Basically the rate of response refers to the frequency of the expiratory and inspiratory cycles. This is computed by counting the number of respiratory cycles per minute.

If respiratory rate is taken as the pattern of response, then, it can be easily converted into ration or whole number integer to make intra or inter-subject data comparable using an oscilloscope, change in respiratory pattern can be seen here graphically. Heron and Jacobs also considered breath holding or prolonged inspiration as a respiratory response. Bradford found jaming of a curve or an M shaped pattern as a response.

Respiratory analysis - It can be done in 2 ways.

(**a) Measurement method** - It involves the measurement of rate and amplitude of cycles following stimulation. Number of cycles per unit time is taken. A computer is used to count the number of cycles instead of doing it manually. After this, mean and median are calculated and these values are compared with those initial values prior to acoustic stimulation.

(b) Visual Identification - Bradford (1977) visually displayed the respiratory curves and judgement of the response is made. Some investigators prefer the first method(Hogan, 1972) but Hartley and Hetrick(1973) prefer the second method.

Environment plays an important role (variable) since noises in the immediate environment can produce a startel reflex. Tnter stimulus interval as in any other test is important, since a definite time should be present at which the response behaviour may be observed before the next stimulus is presented. In summary it can be said that this kind of evaluation is useful in about 92% of the infants and correlation was found to be consistent with that of Behavioural observation Audiometry. Studies have also been conducted about the reliability and validity of the test and the results of these studies were positive(Heron and Jacobs, 1968; Kankunnen and Liden, 1971).

CARDIO VASCULAR MEASURES

Like other autonomic responses, the cardiovascular measures do not require subjects to make operant responses. Cardiovascular measures traditionally have taken the form of heart rate that is, number of beats per minute. Cardiovascular audiometry is preferable because it does not employ noxious stimuli nor does it necessarily need an intact Nervous system, thus it is not an invasive method. A definition is needed which accounts for the differences in cardiovascular behaviour between stimulus and nonstimulus conditions. Electro-cardiography with respect to acoustic stimulation is the electrical changes resulting from the contractions of the heart consequent to acoustic stimulation. These can be picked by electrodes placed on either side of the heart. A cardiogram is obtained prior to acoustic stimulation and another consequent to it and they are compared.

PROCEDURE : Electrodes are placed beneath the clavicle to prevent interference of head motion. Placement on leg is advocated by some investigators to minimise the noise in the signal due to the interference. Essentially, the placement site is at the discretion of the tester. The infant is swallded and made to lie quietly and placed in the stabilimeter. Initial measurement of the heart rate is done. Later stimulus is delivered and the hear rate gain is measured.

STIMULUS PARAMETERS - 3 aspects of the stimulus must be considered - Spectrum, Sound pressure level and duration. Studies done by Schok and Schatter(1942), Graham and Clefton (1966) fail to notice any relation between spectrum and heart rate measures.

Sound Pressure level may or may not affect cardiovascular measures. Lewis(1971) used 65 dB; Moreau(1970) used stimulus at 9OdB; Graham and Clifton used 75dB. Stimulus duration - This area has not been yet investigated. Whether the cardiovascular response varies as a function of energy is not known. Schater(1971) used stimulus for 0.3 msec; Clifton and Meyer(1969) used stimuli for 40-60secs. Clifton and Graham, Halton(1968) concluded that 10sec signal is preferable. Other investigators (Terkildson et al) failed to find differential responses to stimuli of varying duration of 1, 2, 4 or 8 secs.

STIMULI - The stimulus which is most commonly used - puretone(Beadle Trowell, 1962; Barloschuk, 1964; Jansenka, 1967). Broad band noise was used by Schulman and Kreeter, (1970). Eisenberg(1974) advocated the use of synthetic speech stimuli.

RESPONSE - The electrocardiagram consists of a series of waves with one prominent 'R' wave. Distance between two consecutive R waves is a heart rate. Response here is essentially a all or none phenomena. Eisenberg(1974) defines a response as a consistent 5-8 shift in the direction of lower heart rate during stimulus band intervals.

Disagreement between the nature of the heart rate response and its management has resulted in different findings regarding the form of response(Gerber, 1979). Davis et al(1955) measured pressure pulse, volume pulse and inter-pulse interval as responses to acoustic and tactile stimuli and found a biphasic response consisting of an initial decrease of interval(increase of rate), with an accompanying decrease of pressure followed by increases of pressure and interval which exceeded the prestimulus values.

The heart rate of a newborn increases during a period of 2-6 seconds following acoustic stimulus, a decelerative response in later infancy, this is a function of age(Graham and Clifton, 1966; Schulonan et al, 1970;). Eisenberg (1974) in a study states that when synthetic vowel is used as a stimulus, the response essentially takes its form as bradycardia, a long latency deceleration appears during the newborn period. Heart rate changes bear upon attentive mechanisms even in earliest of life. Mostly the response is of a declerative type of considerable magnitude with a peak latency of 6 secs or more(Eisenberg, 1970). This is followed by later accelerative response(Suzuki, 1978).

In the neonatal population, one fails to find a definite type of response which may be attributable to the lack of specific pattern of response, and patterning of the response itself(Beadle, Govell, 1962). A physiological view holds that the regulation of the heart rate is not under the voluntary content and is immature with respect to adult system. As age improves, regulation of heart rate improves. We see a variety of idiosyncratic responses in early neonatal period.

ANALYSIS VARIABLES - It is important to note to view the effect of how close to the stimulus onset cardiac response measurement is begun. Even in the absence of stimuli, heart rate sometimes increases and somtines decreases thus forming pseudoresponse. The importance of analysis duration is emphasized by the results of the studies conducted by Graham, Clifton and Halton(1968) who indicated that "acceleration began with in the first second and reached a peak by the 4th second after which there was a decrease to approximately the post stimulus level. Schulman and Kreter(1971) Schulman(1970), Schafter(1970), Clifton(1968, 1969) did investigations on prestimulus measurement. The principle which underlies these measurements is that judgement of presence of response is based on the changes in response from the prestimulus level.

Some prefer post stimulus measurementsfclifton, Graham, 1968). Studies have not yet been adequate enough to come to a definite conclusion about period for analyses. Gerber (1973) considers 15 beats after stimulus onset as the optimal period of measurement. But, we cannot make a standard period of measurement specified and an interval must be selected wherein there is a marked difference between prestimulus and post stimulus condition.

Prestimulus state in accordance with the Law of Initial Value by Wilder(1950) is an important variable which affects response. Decrease in heart rate with increase in prestimulus level is found similar to that found in Behavioural observation Audiometry.

Respiration is yet another variable affecting response, acceleration of heart rate during inspiration and deceleration during expiration is seen.

In short, the advantages of this evaluation can be summarized as that it is an objective test, thus it can be used in the younger population, it does not employ noxious stimuli, is not an invasive method. These advantages can be weighed out by the fact that the idiosyncrasy of responses got especially in the neonatal population. Extensive studies need to be done to make us definite of the "normal expected response". Control of variables must be done as far as possible to avoid pseudoresponses.

SUMMARY

We have in this chapter discussed the various non-behavioural methods of hearing assessment for the pediatric population. Essentially all these methods have one fact in common, that is they do not require the active cooperation of the subject. This is a salient feature to be noted while testing the newborn for early Identification. With the infant it seems to be ideal since the infant is not psycho logically mature to perform conditioning techniques which can be performed by children of 3 and above. But as any other tests of hearing, they have their own inherent draw-backs restricting themselves to a certain portion of the auditory system as in Electrocochleagraphy, Brain Stem Evoked response, etc. Measures such as respiratory audiometry and cardiovascular measures essentially reflect the effect of acoustic stimulation and the autonomic responses.

They are considered as indirect measures of hearing that is assessing hearing sensitivity through heart rate, respiratory rate. These are also called physiological measures since consequent to acoustic stimulation physiological changes are produced in the body such as alteration of the heart rate - deceleration or change in respiratory rate.

No test is an end in itself. It is best used in combination with other behavioural measures. Since informal screening or behavioural audiometry can be easily done with minimum of sophisticated equipment, correlation between an objective measure and the behavioural measure must be done. Most of the centres in our country where early identification is only developing, where early identification is only developing, only Impedance at the most is available. So our diagnosis is made with the available equipment and Behavioural Observation Audiometry.

Another point to be noted is the use of sedatives. Usually for the administration of electrophysiological tests use of sedatives is essential because the prestimulus state necessary is sleep. Evoked responses are affected by the use of sedatives and thus the responses obtained after the use of Sedatives may not be valid. Moreover for most of the electrophysiologica measures much of work has not been done with the neonatal population and hence establishment of norms have not been done. Without the establishment of norms, evaluation of responses are invalid.

In cardiac Audiometry we obtain a multiplicity of responses and among the neonates the responses vary to such a degree, that no clear cut response is obtainable. This idiosyncracy of responses deters the use of this measure in evaluation of hearing in the newborn and the infant. The responses are also a function of maturation and thus this mustclearly be kept in mind when evaluating responses especially in BSER.

The conclusion we must emphasize that a compromise between the behavioural and non-behavioural approach is necessary to come to an accurate diagnosis of hearing loss. Since in the newborn it is only a question of identification, maximum possible clues must ascertain it, and for this as many methods as possible must be used to evidence the fact.

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CHAPTER VII

RESPONSES

Webster's dictionary defines a response as "the activity or inhibition of previous activity of an organism or any of its parts resulting from stimulation". Logically it is impossible to accurately differentiate normal from abnormal auditory systems among children, if one is uncertain as to what auditory response behaviour is typical of a child with a normal auditory response system(David C. Shepard, 1971).

The child is viewed as a complex of systems not only capable of producing responses to auditory stimuli, but also to other sensory stimuli. The human organism, regardless of age is generally under constant bombardment by external and internal stimuli of differing sources and magnitudes. Thus many a time the response to an auditory stimulus might overlap with the response that is occuring to other sensory stimuli, thus producing erroneous responses and wrong diagnosis. Especially while testing neonates and infants the audiologist will have to (1) set criteria which defines an auditory response, (2) set up an imaginative measurement procedure which can evaluate the auditory response (3) set up response criteria that differentiates normal hearing children from auditory defective children.

The Auditory Response:- In audiological terms it is some distinctive activity following the auditory stimulus. In its simplest form, this post-stimulus activity in some way differs from the prestimulus activity. The type of activity the audiologist is seeking and the criteria are variable. Responses depend upon - response system chosen for the production of auditory response, prestimulus activity, age of the child and magnitude of response.

Auditory Response System - It involves a complex neuro-anatomic and neurophysiologic structure that mediate the final auditory response. Specific auditory response systems include the cochlea and neural pathways and are those only which respond to acoustic stimulation.

Non specific response systems - arethose that include a large number of components and not specifically responding to auditory stimulation. They include those components that lie within the CNS and those that leave the CNS and go to the point where the response is produced.

Broadly response systems can be calssified as

- Behavioural response systems
- Electrophysiological response systems.

Behavioural Response System - Auditory responses produced through behavioural response systems are characterized by some level of neuromuscular activity of the child under test.

This response is either visually observed or audibly heard by the audiologist; it can range to, speech utterances which are coctically controlled from archaic muscle reflexes subcortically controlled. The response of the child can be geared through the pretest instructions, training and by using appropriate conditioning principles.

Electrophysiologic Response System - They manifest themselves as recorded changes in the electrical properties of body structures as an indirect result of auditory stimulation centres of responses here are found at many levels of the nervous system.

Auditory Responses systems which are specific areonly slightly influenced by neural inpulses descending from the cortex. The responses can be elicited from cochlea, VIII nerve and brainstem.

Cochlear response - It is an electrical response generated in the hair cells occuring within 0.5 msec after stimulus onset.
8th nerve response - The Action potential occurs 1.5 msec after stimulus onset depending upon stimulus intensity.
Brainstem - An electrical waveform originating from the superior olivary complex consists of a series of 5 peaks which occurs approximately 2-7 msec after stimulus onset.

Non-specific auditory response systems

(a) Electrodermal response system terminates with recordable changes in the electrical properties of the skin. The nerve supply to the sweat glands have been found to be composed exclusively of the sympathetic nerve fibres of the Autonomic nervous system. An auditory stimulus of sufficient magnitude can cause alteration of the sweat gland activity.

(b) Electroencephalic response - The response is recorded by placing an needle electrode on certain areas of the cortex and the electricil activity that occurs after each stimulus of a series of repeated stimuli are given to an averager and the averaged response is recorded. The wave form is divided into Middle components(20-50msec) and late components(80-200msecs) depending upon latency from stimulus onset. Middle responses reflect acitivity of the Heschle's gyrus and are to be stable in functionfGoldstein and Mendel). According to Vaiglin and Ritter the late components emunate from primary auditory cortex.

(c) Electro cardiac response - Here the responses reflects electrical changes in the muscles of the heart consequent to auditory stimulation.

(d) Sonomotor Responses - When intense auditory stimulus is presented to the ear several motor reflexes are possible. They are Auropalpebral reflex, startle, Acoustic reflex, cochleomyogenic, vestibulo-myogenic, cochleo-neurogenic.

These responses can be affected by psychophysiological states of the child, level of ambient noise, spectrum of the stimulus. The sonomotor responses axe present at birth; their inherent drawback was the inability to plot thresholds.

Integrative - Associative Responses-

This response system presupposes that an external stimulus reaches the brain where certain amount of processing occurs; as a result of this cortical processing, pulses are transmitted to various pants of the body causing changes in motor, glandular, etc. In these sort of responses there is a process of sorting, selection, association, inhibition and the end process is reflected in both internal and motor activity of the body. An auditory stimulus would result in changes in the electrical activity of the cortex, (EEG), an orienting reflex will follow, as well as changes in heart rate, respiration, galvanic skin response, etc. The major strength of these function tests is extremely soft stimuli can be used even in children. These responses are useful only in testing infants above 6 months where orienting reflex has not yet been established.

Mendel (1968) reported that the type of stimulus used is important to responses got, and that they occured more frequently to broad band stimuli than to narrow band stimuli.

Moncur(1968) states that the random movements exhibited by the infant might look like response behaviour which can give rise to a number of false positives. Robson(1970) found that infant's respond better to conventional tests (high frequency rattle, variate) than to puretones by nearly 30dB. Samples(1978) reported responses more to speech stimuli indicating its effectiveness, especially to natural speech. She also found a greater number of responses to right ear which may suggest a left hemisphere localization for speech in girls around 7 months.

George Mencher(1971) recommends that results should be further classified to include - A clear response, Delayed response and Doubtful response.

This again depends upon the audiologist who is testing the child, his familiarity with the response. It is always better to have 2 judges atleast while testing an infant so that, there can be reliability as to what a response is, and when it occurs.

There are other questions which are relevant how much change matters in which direction and how soon after stimulus onset? This especially with reference to cardiac audiometry. Studies done by Gerber(1973), Schater et al (1971) Swain(1973) showed that the cardio vascular response to sound may be better revealed by measuring the absolute amount of change without regard to direction of change.

To summarise, the following table provides us with information on various kinds of responses.

Response	Recording Site	Measures
(1) Auditory Input System		
(a) Compliance	Tympanic membrane	Acoustic impedance
(b) Cochlear potentials	External auditory canal/ Promontary	Ecog.
(c) brainstem	Extracramial - vertex of the skull	Brainstem audiometry
(d) Encephalic responses - Middle - Late	Extracranial	Electroencephalic audiometry.
(2) Sonomotor system		
(a) Auropalpebral reflex	Eyes and surrounding musculature	Observed motor response
(b) Moro/Startle	Generalized motor reflex	observed motor response
(c) Stapedius muscle response	Tympanic membrane	Acoustic impedance change
(d) Cochleomyogenic response	Post auricular	Myogenic evoked potential
(e) Vestibulo myogenic	Post auricular	Myogenic evoked potential
(3) Autonomic(startle responses)		
(a) Pupillary changes (- contraction/dilation	Eye	Observation
(b) Heart rate	Chest	Cardiac Audiometry
(c) Respiration	Chest	Respiration Audiometry
(d) Psychogalvonometry	Hands or feet	Large, unconditioned change in skin resistence.

Response	Recording Site	Measures
(4) Integration-Association System		
(a) Alerting response	Eye and generalised bodily response.	Observed eye widening
(b) orienting response	Head/generalized bodily response	Observed turning toward source.
(c) Encephalic response	Extra cranial electrodes	Electroneurogenic response.

One cannot find agreement in literature as to when to expect the response after stimulus onset. Some investigators counted seconds or beats after the stimulus onset.

Since there are so many variations in the choice of analysis time, it is no wonder that so many different 'responses' have been reported. There must be some interval within which it does not matter how large or small the analysis period is and beyond which it does make a difference.

In conclusion it needs to be emphasized that the 'response' in the field of pediatric Audiology is a very nebulous, it may be overt or covert and hence chances are there for the audiologist to miss it. A counter check should always be done if possible by using a nonbehavioural method and supplement it with the parent's observation of child at home. At this stage, the most important recommendation seems to be a 'follow up' which may confirm the presence of a suspected hearing loss.

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