AN INVESTIGATION INTO LOW COST HEARING SCREENING DEVICES

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Independent Project submitted as part fulfilment for the first year M.Sc, (Speech and Hearing), Mysore.

All India Institute of Speech and Hearing
Mysore 570006
1998

CERTIFICATE

This is to certify that this Independent Project entitled *AN INVESTICATION INTO LOW COST HEARING SCREENING DEVICES* is the bonafide work in part fulfilment for the degree of Master of Science (Speech and Hearing) of the student with Register No.M9712

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May, 1998

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CERTIFICATE

This is to certify that this Independent Project entitled **AN INVESTIGATION INTO LOW COST HEARING SCREENING DEVICES** has been prepared under my supervision and guidance.

Mysore

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DECLARATION

This Independent Project entitled *AN INVESTIGATION IN TO LOW COST HEARING SCREENING DEVICES* in the result of my own study under the guidance of **Mrs. P.MANJULA,** Lecturer in Audiology, All India Institute of Speech and Hearing, Mysore and has not been submitted earlier at any University for any other diploma or degree.

Mysore

May, 1998 *REG. No. M9712*

TO MY PARENTS

DIDI, JIJAJI & TUNU

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CHAPTER I

INTRODUCTION

Children have,at birth, the potential to walk and to talk. They are genetically endowed with the appropriate neurophysical systems, but time is needed for these systems to develop and mature.

The auditory channel is the route through which speech and language development normally takes place. The development of speech and language appears to be based on innate, biologically programmed factors (Lenneberg, 1967) which can be exploited most effectively through an auditory input (Liberman, 1964). The use of other approaches for teaching initial language and speech skills to hearing-impaired children must be considered inadequate though frequently necessary.

For normal language acquisition in the child he/she requires an adequate sensory input with rich and abundant speech stimulation and adequate processing abilities. Hindrance to any of these at ah early stage will have a devastating effect to normal language acquisition. Language delay can be caused due to many reasons like mental retardation, organic structural defects, functional problems, etc. But of these, hearing loss is one of the most commonest cause for delayed speech and language.

There is a direct relationship between the age of occurrence of deafness and the degree of language skills. Early the deafness occurs the poorer the language development. Hearing-impairment in a child restricts the attainment of his best potentials for language, limits personal development, gives rise to aberrant emotional behaviour and poor educational achievement. This is because there exists a critical period for the development of language function and deprivation of auditory input, especially in the critical period, would impede the acquisition of sounds of all aspects of language (Young and McConnel, 1957).

This emphasizes the need for early identification of hearing loss, so that it's adverse effects may be restricted to a certain degree through rehabilitation.

Assessment of hearing is the corner stone of the field of audiology. The challenge of accurately determining the hearing status of an infant or young child is met through specialized training and extensive clinical expertise. Establishing the precise degree, type and configuration of hearing loss in each ear is critical to initiate medical treatment as well as individualized intervention services for children (ASHA, 1991).

Auditory screening is an attempt to identify persons who have significant hearing defects from a population of predominantly people with normal or adequate hearing (Hedgcock, Miller and Rose, 1973).

The purpose of hearing screening procedures, which generally are an integral part of hearing conservation programs, is to identify these individuals as early as possible (Anderson, 1972). Early detection of hearing loss results ideally in early diagnosis, treatment, early rehabilitation and education of persons with communication disorder.

Identification audiometry in screening refers to case finding aspects of a hearing conservation program (Meinick, et al. 1964).

There are two stages of an ideal hearing screening program. The first stage eliminates those who have normal hearing. The second stage eliminates those who did not follow instructions in the first stage of those who are poor respondees for some reason (Anderson, 1972, Darley, 1961).

Hearing screening tests are administered in either individual or group settings, the stimuli used in these test range from pure tones and speech to noise produced by various noise makers, squeakers and environmental sounds (Anderson, 1972; Meyerson, 1956; Anderson, 1972; Anderson, 1972).

Glorig (1965) related the period from birth to 3 years of age the most critical for hearing-impairment diagnosis. Two important aspects of testing were stressed (1) that the quality of the sound is known by the tester (2) that lack of response is not confused with lack of hearing.

O'Neill and Oyer (1966) emphasised that the determination of spectral components is desirable since some frequencies are more prominent in complex sounds. Responses were more to broad band stimuli (Mendel, 1968)$_3$ But definitive assessment of normal-mild-moderate-severe-profound categorization, low vs. high frequency involvement and monaural vs. binaural involvement is difficult.

In the literature there are reports of numerous ways of hearing screening of children. These include the use of fetal audiometry, respiratory audiometry, behaviour observation audiometry, conditioned audiometry, brainstem audiometry, measurement of otoacoustic emissions, etc.

Recent changes in the health services have forced constructive re-appraisals of how resource can best be developed to maximise health gain preventive health measures, such as screening, particularly, requires the appraisals of cost benefits and risks because they lack the element of an obligatory response to the expressed need.

The aim of an ideal hearing screening programme should be to locate all the persons with hearing-impairment.

In order to achieve this, screening should be carried out at a number of places and be able to cover wide population.

The accuracy of identification audiometry is stated in terms of the number of correct identifications. Incorrect identifications take two forms : children who fail the procedure, but actually have normal hearing (False positives); children who pass the procedure, but have educationally significant hearing losses (False negatives). Reduction of positives or false negatives depend on the setting of validity criterion. Eg. Incase of puretone screening (1) The threshold test occurs in close proximity to screen test (2) Independent testers accomplish each test without knowledge of other results. To determine the number of both false positives and false negatives it is necessary to threshold test a substantial number of children including both, those who have passed and those who have failed. Determination of false positives is easy (by rescreening) but that of false negatives is difficult.

Most of the hearing screening methods available are not suited to screen the school children in the Indian population because of the high cost, non-availability of proper resources, lack of trained personnel, time, cost per child, maintenance and proper follow-up.

In order to overcome the above mentioned short comings of available screening procedures, there is a need to develop less expensive, easily available, easy-to-use materials to screen the huge population. Some items like bell, drum, rattles have been tried. But these items lack frequency- and intensity- specific information, standardization, distance of presentation of stimuli, etc.

Keeping such things in mind items need to be developed which are less expensive, easily available and can be standardized to have good sensitivity (ability to detect the correct number of individuals having the disorder) and specificity (correctly identify those without the disorder), stable over a relative time, needs little training.

The present effort is with an intention of investigating the use of the easily available materials as auditory stimuli for the purpose of hearing screening.

WHY HEARING SCREENING

There is a need to develop a screening kit for hearing because the frequency of problem is high in population. This depends upon prevalence (no. of diseased patient per 100,000 persons in the general population at the time of investigation) and incidence (frequency of new out break of a disease condition in a population for a given time period}

National Speech and Hearing Survey team is U.S. tested hearing of 38,000 school children in U.S. in (1968-69). Their results indicated that first graders showed highest prevalence rate of hearing loss, sharply lower in second grade and a progressive decline through the elementary school years. After the seventh grade, the rate dropped and remained constant. An overall of 2.63% had pure tone average greater than 25 dB HL. Unilateral hearing loss was more commonly seen and first graders showed an incidence of 1.8% and decreased to 0.22% in the ninth grade.

The *'Pittsburg Study"* (Eagles, Wishik, Doerfler, Melnick and Levine, 1963) compiled data of 4,000 children in the age range of 0 to 14 years. The study showed a bilateral hearing loss in 1.7% of population studied and 5% had significant hearing-impairment in one ear. Also stated that best estimation of hearing loss was 5% of school children having hearing loss at least in one ear.

Northen and Downs (1970) stated that 13% of children in 2 to 3 years of age group had hearing problems. Approximately one out often pre-school children had hearing loss. At 3 to 4 years, the incidence is 12% and 9.2% of the 4 to 5 years olds had hearing loss.

The study by Nikam (1970) regarding the incidence of hearing loss in various age groups (from 2 to 14 years) showed that highest percentage of hearing loss was found among 3 year old accounting for 26.66%, 14 year old coming next with 12.5%. Among 2086 children screened, 64 had bilateral conductive loss, 14 with unilateral conductive loss and 4 unilateral and bilateral sensory-neural hearing loss.

Survey of National Speech and Hearing funded by U.S. Office of Education, Hull et al. (1971) provided preliminary results, by frequency of children with hearing levels exceeding 25 dB (ISO-1964). Among first graders, 4.3% of children failed at 25 dB in 500 Hz in left ear and 4.9% in right ear. For 4 KHz it was 5.5% in the left ear and 5.6% in the right ear.

Eagles et al. (1963) reported that 5% of school children have hearing loss in one or both ears at one or more frequencies beyond normal range of hearing.

Study of those fitted with hearing aid showed that 90.5% had sensory-neural hearing loss, 9.5% had conductive hearing loss (Karikoski and Marthila, 1995).

Eagles et al. (1967) in an epidemiologic study of otitis media in Pittsburg found 15.2% of entire school population to have otologic abnormalities in one or both ears, indicative of past or present ear disease. In a 5 year follow-up study, 1200 children were tested and about 30% had otoscopic abnormalities prior to study or developed during the 5 year period.

Misra et al. (1961) studied 1390 school children in Lucknow (North India). From his study the prevalence of hearing loss was 34% among the children studied. Majority of loss was conductive type.

Howie (1975) concluded that there is an evidence that approximately 2/3 rd of children under the age of 2 years have at least one significant bout of otitis media.

Studies in Indian context is limited to survey conducted by Kapur (1965), Nikam (1970), Maya (1988) and Misra et al. (1961). The number of subjects used, age range and instruments used in the above studies are found to be varied. This difference may be due to different test conditions, different signal level, use of different test frequency, different equipment , etc (Axelsson, et al. 1987).

CHAPTER II

REVIEW OF LITERATURE

HISTORICAL PERSPECTIVE OF HEARING SCREENING

Early Years (1955-70)

Infants hearing testing was not given much importance prior to a report from Sir Alexander and Lady Ewing of England (1944). The Ewings used various percussion sounds and pitch pipes to elicit *"aural reflex responses"'* in young children and reported that responses as reflexes are best elicited before six months, after which they decrease.

The origins of new born hearing screening can be traced to . Sweden. In 1956, Wedenberg reported that *"the most easily observable responses of an infant to sound is the auro-palpebral reflex i.e. rapid and distinctive closing of the eyelids when they are open and a screwing of them when they are closed"'.*

A few years later, Carl-Axel Froding (1960) of Eskilstuna, Sweden; evaluated the hearing of 2000 new boms using a small gong and mallet which produced sound of 126-133 dB SPL. His technique was to observe the auro-palpaberal reflex in quiet or sleeping infants. Also reported on fluctuation of responses.

The initial reports of new born hearing screening in the U.S. came from research projects conducted by Downs, an audiologist and Graham Sterrit, a psychologist (1964). They screened more than 17,000 new borns using a hand held infant hearing screener with a sudden onset stimulus of 90 dB SPL (a noise band centered at 3OO0 Hz). Required the observation of behaviour response to an auditory stimulus.

The lack of confidence in behaviourally based mass infant hearing screening led Bergtrom, Hemenway and Downs (1971) to recommend the use of high risk factors to identify through a high-risk register system which will reduce screening a large population.

In 1969 *"The Joint Committee on Infant Hearing"* was formed with members from the Academy of Ophthalmology and Otolaryngology, Academy of Pediatrics and ASHA to evaluate the status of new born hearing screening. The Committee met in 1970's to review new born hearing research reports using the auditory behavioural observation screening with calibrated noise-band stimuli as described by Downs and Sterrit (1964, 1967) also discussed the high risk register.

The Formative Years (1970-1980)

The Joint Committee on infant hearing prior to reaching a conclusion .about whether mass hearing screening of new borns should be indeed instituted, the Joint Committee recommended further study of a number of the many variables that might affect the results of infant hearing screening programs.

The Joint Committee concluded that routine mass screening of new born infants for hearing-impairment could not be recommended without additional data and should depend on extensive follow-up studies based on quantitative assessment of the hearing status.

In 1972 the Joint Committee issued a supplemental statement to their original 1970 position statement which listed five high risk alerting factors for congenital deafness :

1. History of hereditary childhood hearing-impairment.
2. Rubella or other non-bacterial intrauterine fetal infection (e.g. cytomegalo virus or herpes infection).
3. Defects of ear, nose or throat, malformed,low set or absent pinnae; cleft lip or plate (including submucous cleft) any residual abnormality of otorhinolaryngeal system.
4. Birth weight less than 1500 gms.
5. Bilirubin level greater than 20 gms/120 ml serum.

The 1972 position statement recommended that at-risk infants were to be referred for an in depth audiological evaluation of hearing during their first two months of life and even if hearing appeared to be normal, the infant showed receive regular hearing evaluations there after.

The 1972 Joint Committee divided the deafness risk categories into three sections (1) factors identifiable by interview or written . questionnaire with one parent (i.e. family history, rubella exposure or rash with fever during pregnancy or parental concern for the baby's hearing) (2) factors identifiable by physical examination (i.e. abnormalities of ears, nose or throat) and (3) factors identifiable by review of the medical records (i.e. low birth weight or excessive bilirubin level). Downs and Silver (1972) suggested the *"ABCDs"* alphabetic acronym for easy recall of the high risk register. Affected family; bilirubin level, congenital rubella syndrome, defects of the ear, nose and throat and small at birth.

In 1974 experts from various disciplines who had familiarity with infant screening were invited to participate in the International Conference in Nova Scotia (Mencher, 1976). The conference participants presented data to compare infant hearing screening techniques and reported there results. The conference proceedings stated that the high risk register approach should be supplemented with newborn behavioural observation hearing screening.

Participants at the Ohio Conference made supplementary suggestions which included (a) audiologic follow-up of the high-risk infants be made as soon as possible following identification, but certainly by 7 months of age; (b) the mother-child relationship be safeguarded by education; (c) informed consent from a parent be obtained; (d) information regarding normal child development be provided; and (e) development and implementation of identification and diagnostic procedures related to hearing-impairment be undertaken by public health agencies.

During the 1970s, objective, physiologically based hearing screening techniques, the Crib-O-Gram and Auditory Brainstem Response Audiometry, received attention as potentially powerful screening tools that could be used in mass infant hearing screening.

Tbe Development Years, 1980-1989

The 1982 position statement expanded the risk criteria from five to seven factors. The two additional risk factors associated with deafness that were added to the list were bacterial meningitis caused by Haemophilus influenzae and severe asphyxia demonstrated by Apgar scores of 3 to lower.

The 1982 Position Statement recommended that the hearing of infants who manifest any item on the list of risk criteria should be screened, under supervision of an audiologist, prior to 3 months of age, but no later than 6 months after birth. The initial screening was to be based on behavioral or electrophysiological response to sound. If consistent behavioral or electrophysiological responses were detected at appropriate sound levels, the screening process was to be considered complete except for infants who exhibited a risk factor related to late onset or progressive hearing loss. If results of the initial screening of an infant manifesting any risk criteria were equivocal, the infant was to be referred for full audiological assessment testing. The 1982 Position Statement also included, for the first time, procedures to be followed for the diagnostic work-up for infants failing the hearing screening, as well as management and habilitation recommendations for infants identified as hearing-impaired.

The Decade of the 1990s

The Joint Committee was well aware that advances in science and medical technology had increased the chance of survival in markedly premature and low birth-weight neonates and other severely compromised newborns. This improvement in survival rates was associated with a 2.5% to 5.0% incidence of significant sensori-neural hearing loss in at-risk infants. Accordingly, the 1990 Position Statement recommended that infants manifesting any of the previously noted risk criteria, warranted auditory screening.

The 1990 Joint Committee expanded the previous position statement considerably. The document was divided into risk.factors for neonates (defined as birth to 28 days) and for infants (age 29 days to 2 years). Detailed hearing screening recommendations for both groups were included. Optimally, the hearing screening was to be completed prior to the at-risk baby's discharge from the hospital, but no later than 3 months of age. Further, the Joint Committee stated that, because of the high false-positive and false-negative results related to behavioral observation screening, that the initial hearing screening should be based on the auditory brainstem response (ABR) test. With concern that the ABR technique could result in some false-positive results, ongoing assessment and observation of the infant's auditory behaviour was recommended during the early intervention stages.

The 1990 Joint Committee's recommendations included referral of the hearing-impaired infant to a number of specialists including a physician with expertise in the management of childhood otologic disorders, an audiologist experienced in pediatric hearing assessment techniques, and a speech-language pathologist, teacher of the hearing-impaired, or other professional with expertise in the assessment of communication skills in children with hearing-impairment. Family education, counselling and guidance, including home visits and parent support groups, represented the growing influence of the Joint Committee's concern for the adequate management of new borns with hearing loss.

Further, screening programs were urged to evaluate factors such as cost, availability of equipment, personnel, and follow-up services which are crucial in the development of infant hearing screening programs.

Indeed, since the mid 1960s, infant hearing screening techniques had matured from gross behavioral observation of reflex responses to the precise electrophysiological evaluation of infants identified to be at risk for deafness.

The 1994 Joint Committee Position Statement

Within the procedural and technical considerations of the statement, the 1994 Joint Committee indicated that auditory brainstem response (ABR) hearing screening and otoacoustic emissions (OAE) screening each had advantages and disadvantages. The statement indicates that both of these physiological screening procedures out perform behavioral assessment for accuracy in identifying hearing-impairment. In feet, the statement warns that behavioral measures cannot validly and reliably detect hearing loss of less than 30 dB HL in infants less than 6 months of age. The statement does not recommend any specific screening technique or program protocol, per se, but recognizes that infant hearing program protocols will likely vary by region allocation, individual needs, and administrative structure.

Additional research was suggested to provide systematic evaluation of techniques for identification, assessment, and intervention; refinement of the risk indicators; outcome studies to evaluate the impact of early identification of infants with hearing loss and their subsequent achievement of education and communication competence; as well as continued research in to the prevention of hearing loss in newborns and infants.

IMPLEMENTATION OF INFANT SCREENING

The High-Risk Register Approach

Several methods of implementation of the high-risk register for deafness have been used in the United States. Usually, the programs are directed or supervised by a qualified audiologist.

The risk registry identification program which generally incorporates three states: (a) face-to-face interviews with the mother of the baby; (b) visual observation of the infant specifically looking for defects such as malformation or abnormal location of the pinna, cleft lip or palate, or signs of syndromes associated with deafness; and (c) review of the medical records of the baby and the mother including the labor and delivery process.

Most of the early prevalence of hearing loss estimates were determined from high-risk register studies of newborns. By the early 1990s, however, evidence from numerous studies confirmed that use of the high-risk registry as the basis of infant hearing screening programs identified only 50% of infants with significant hearing loss (Elssman, Matkin, and Sabo, 1987; Mauk, White, Montenson, and Behrens, 1991).

Universal Hearing Screening Program

1. The Florida Universal Screening Program
2. The Colorado Program
3. The Rhode Island Project

Opposition to the Early Identification of Hearing Loss

It was suggested, in the 1994 Position Statement, that the parents and care providers of identified infants be made aware of all intervention options including hearing aids, personal FM systems, vibrotactile aids, and/or cochlear implants. This philosophy is in direct contrast to the Deaf Culture movement supported by the National Association of the Deaf (NAD). The deaf community holds that they are, in fact, an *"ethnic'"* minority with a specific cultural identity, and not a handicapped group of persons with disability (Dolnick, 1993).

Northen and Hayes (1994) concluded that, as advocates for children with hearing loss, professionals must improve strategies for early identification and intervention and continue open discussions and debates about the most effective protocol for screening hearing in infants.

Hearing Screening In Different Range

A review into the developmental history of identification audiometry provides an insight into the need for the development of screening test. Various tests designed for testing the hearing of infants, children and adults have been developed. Modifications in the tests have been made to compromise in time and expenditure unduly affect in the efficiency of the tests, a great deal.

FETAL AUDIOMETRY

Peifer (1938) was the first one to report fetal reactivity to acoustic stimulation. The technique has been of placing a vibrator on the mother's abdominal wall, to deliver auditory stimuli. The responses recorded were fetal heart beat and changes in the electrical activity of the fetal brain.

The advantages include early detection of severe to profound loss, helps in early rehabilitation and management.

Disadvantages are that the Fetus may respond to tactual stimulus, the reaction of the mother to the sound stimulation may stimulate the fetus, some researchers believe that myelinization of auditory nerve does not take place until after birth.

TESTING THE NEONATES
(Birth to two months)

In case of neonates, infants and children, screening techniques are varied and they require the careful skill of the examiner. The stimuli used are varied. The presentation of the stimuli is done in a controlled fashion and the responses are evaluated carefully.

The main aim of the early identification of hearing loss has been, to provide an opportunity for early rehabilitation at an age at which maximum benefit can be obtained (Downs and Sterritt, 1967).

However, Goodhill (1967) and Kimball (1967) took a conservative approach to screening programs for neonates and infants. False-positives can lead to many problems. Kimball suggested that responses to sound stimuli in infancy, are mediated at lower brainstem level, so hearing is not screened in these procedures.

During the first two months of life, the responses obtained are of all-or-none type. However, fairly intense sounds are required to elicit response (Spits, 1965). In normal hearing infants an average of 77 dB SPL and a range of 55 to 115 dB SPL of auditory stimuli have been able to evoke behavioral reflex responses (Shepherd, 1971). The responses elicited include the moro-refiex, listening attitude, diminished activity in the presence of sounds. A common test of hearing used with the neonates and very young infants is crumpling a sheet of onion-skin paper. The audiologist looks for a change in the child's ongoing activity and before the activity (Shepherd, 1971).

Hardy, et al. (1959) suggested the use of short peak of noise made by a clacker at about 55 to 60 dB for testing the hearing of neonates. The response was moro-reflex.

Froeschels and Beobe (1946) used whistle as a stimulus to test infants 10 days or less in age. Wedenberg "(1956) used a bell as a stimuli for testing 150 neonates ranging in age from one to seven days. The intensity of the stimulus was 125 dB SPL at 750 Hz.

Froding (1960) used gong as a stimulus to test 2000 new born children. Auropalpeboral responses were observed.

Aldrich (1928) made use of conditioning procedure for testing hearing in the neonates. Bell sound and scratching of foot of the baby where the conditioned and unconditioned stimuli.

Hisenberg et al. (1964) used calibrated noise makers for testing the hearing of neonates. The testing situation involved three trained examiners who recorded the pre-test and post-test activities.

Northen and Downs (1974) reported expected startle responses in infantsto speech at level of about 80 dB SPL.

Nikam and Shyamala (1971) reported on a study conducted to screen infants. The stimuli used were squeaker noise and vocal sounds with frequency and intensity characteristics as 250 Hz to 500 Hz at *65* dB SPL,and,500 Hz to 1000 Hz at 65 dB SPL, respectively, presented from a distance of 18 inches from the ear. The response to these stimuli was in the form of reflexive behaviour.

Use of a sound treated crib to screen infants was reported (Ratna, 1972). The crib had two speakers on either side and an observation window. Puretones of frequencies 500 Hz, 1000 Hz and 3000 Hz at intensities ranging from 30 dB to 100 dB were used as stimuli. Each ear was tested separately and agreement among the observers was the criteria used.

Glorig (1965), while reviewing the literature on hearing screening, suggested for an ideal neonate screening program. The suggestions included the use of stimulus which differentiates between various frequency ranges that are important for identifying hearing losses; stimulus intensity of 90 to 100 dB SPL measured at a distance of 6 to 18 inches from the source for 1 to 2 msec, onset time of the stimulus; definition of responses in order to permit duplication of experiments.

NCNHS (National Conference of Newborn Hearing Screening) recommended use of high risk register and behaviour observation audiometry.

Another microprocessor controlled instrument called Body SPEK 2000 was used for fast,efficient neonatal hearing screening. It is a non-invasive technique.

VICON APRITON (A-Z Signal Generator) produced two acoustic signals on a filtered narrow band of white noise peak at 3000 cps with most energy in 2,800 cps to 3,800 cps, with outputs of 70, 80, 90 or 100 dB SPL, measured at 4" from the source. The second stimulus is a white noise stimulus covering the entire frequency range of 100 to 10,000 Hz also presented at 70, 80, 90 and 100 dB SPL.

"Rudmose Warblet 300 Single" signal generator provided 3000 Hz warble tone with an FM duration of+/- 150 cycles at 30 to 40 cycle rate at 80, 90, 100 dB SPL measured 10" from the source.

As can be seen many items were made use of as hearing screening kit. But each of them have some advantages and disadvantages.

A new technique Newborn hearing screening using Linco Bennett Auditory Response cradle was described by Shepard (1985) who described a modified mass new born hearing screening program, which was piloted using a combination of a simplified high-risk register and a newly developed automated screening device. The auditory response cradle. The program was designed to handle a total of 4000 babies per year. The auditory response cradle used a binaurally presented high-pass noise through a closed acoustic system at an level of 85 dB SPL +/-3 dB. Three independent motor and two respiratory response channels were monitored by the controlling microprocessor unit during a 5 sec. prestimulus interval and a 5 sec. post stimulus interval. Typical time for complete test was 5-10 min. The results indicated a false-positive rate at or below 1.5%.

Advantages of Neonatal Hearing Screening include earliest ways of studying the response of neonates to sounds, non-invasive - techniques where measurement is objective, less time consuming and items used were less expensive and early identification by these leads to early rehabilitation.

Disadvantages ofNeonatal Hearing Screening are neonates need a high level of signal to respond, the change of behaviour is rapid, the number of false-positives are high in case of neonates, interpretation of results are difficult, items used for screening were not specified in terms of frequency and intensity.

TESTING INFANTS
(From two months to twenty-four months)

Infants are more selective in stimuli to which they respond, and they require lower intensity levels as compared to neonates.

Ewing and Ewing (1944) found sounds more meaningful than voice for children with in the first three months, in the next three months of life, voice seemed to be a better stimulus. The responses change from reflexive to learned responses i.e. sound localization. Speech was found to be successful during 2nd and 3rd year of life.

Miller et al. (1963) found that stimuli familiar to the environment of the infant were the most effective stimuli.

Waldon (1963) believed that the pure tone stimuli are not appropriate to be used with infants and he suggested the use of baby cry. This method is called as audio-reflexometry.

However, Murphy disagreed with Walden and said that pure tones can be used effectively, provided they are made meaningful to the infant.meaningful source,like a lighted doll.

Hardy et al. (1959) used stimuli like a clacker, doorbell, xylophone, squeaker, low, middle and high frequency rattles, voiceless consonants, spoon stirring in a cup and crumpling of tissue paper. All the noise makers generated sound that averaged 40 dB SPL except squeaker that produced and bell and clacker 60 dB.

Suzuki and Ogiba (1961) designed a procedure which they called conditioned orientation reflex audiometry [CORA]. If properly conditioned the infant localises the tone. The response elicited is the head turn to different sound levels presented through loud speaker.

Mencher (1974) mentioned about two procedures which are under consideration for use in screening infants for hearing loss. The first one is arousal", which is any generalised body movement involving more than one limb and accompanied by eye movement of any form. The second procedure makes use of a device called as Crib-O-Gram in which a child's movement in a crib is detected for a particular intensity across the frequency.

Other techniques which can be used as screening devices for testing hearing includes the use of operant conditioning which principles involves Visual Reinforcement Operant Conditioned Audiometry (VROCA) and Tangible Reinforcement Operant Conditioned Audiometry (TROCA). Here, the use of reinforcement i.e. puppet or eatable is used to elicit the response after a period of conditioning. Threshold estimation can also be done.

Advantages of Infant Hearing Testing are - if conditioning between the stimulus and response is established threshold testing can be done, child responds actively because he expects a reinforcement, individual ear can be tested separately by the use of headphones, frequency specific hearing results can be identified because threshold testing is possible, and useful with difficult-to-test children like mentally retarded, cerebral palsy, etc.

Disadvantages of Infant Hearing Testing are - conditioning the children to a stimuli is difficult, there may be habituation of response after some time, the number of false-positives may be high, and Puretones do not elicit brisk responses.

TESTING YOUNG CHILDREN
(Between two to five years age)

Young children, after the age of two years, no longer give involuntary responses of the neonates with ill defined lateralization responses of infants. These responses tend to be more adult like. As the child grows older, he attains control over his responses to the various auditory stimuli. Conditioning can be made use of in testing. Most useful techniques make use of play situation and hence are called as play audiometric techniques.

Most of the procedures in this section deal not only with screening but also threshold estimation.

1) Conventional (Hand-Raising) Audiometry

Many children between three and five years of age can be auditorily assessed by instructing them to raise their hands when presented with a puretone signal. A variety of games have been devised to hold the attention and interest of this group of children. Example is the astronaut game where the child has to raise the finger in response to a coded message (Curry and Kurtzrock, 1951; Llyod, 1975). With some children a verbal response - *"yes", "I hear it",* or "now" is more reliable than hand raising verbal responses reduce false-negative responses.

Usually children at this age are easily distractible so the clinician has to become alert for the loss of stimulus control and for variability in response.

The use of control periods that is nonstimulus period sampling is one way to demonstrate response reliability, hand raising response may get extinguished after some time in this case social praise is to be used often.

(2) Play Audiometry

Most common procedure used in the pure tone assessment of young children. In this procedure the child is instructed to engage in some activity. Perhaps making him drop blocks in a box, putting rings on a peg, putting pegs in holes, stacking blocks, or hitting a drum each time he hears a signal. These activities are interesting to child and gives him reinforcement (Bender, 1964; Brown and Knepfler, 1962).

Barr (1955) credited with introducing play audiometry, indicated that youngest children tire easily and new games must be invented and therefore recommended that a variety of activities and toys be made available. Here there are two stages (1) conditioning or learning (2) threshold determination.

Play audiometry is probably often used because children who are initially shy and withdrawn can be more easily engaged in a play activity usually child gets more involved in play than responding.

Barr (1955) tested 135 children between the age of two and six years with the *"play procedure"*, and found that the percentage of success was directly related to age. Successful test was obtained with 16.6% of the two and two-and-a-half year olds, 55.5% of the two-and-a half to three year olds, 70.7% for three years olds, 88% for four year old and 92% for five year old. Results are more reliable under three years of age.

(3) Procedures Using Picture Consequation

Dix and Hallpike (1947) introduced the *"Peep show"* procedure which consequates responses to pure tone signals by presenting an illuminated picture. In this procedures the child was instruced to look through a window and press a button each time he heard a pure tone presented via the speaker. Correct responses were consequated with illuminating picture.

Statten and Wishart (1956) advanced the concept of picture consequation with the construction of an elaborate doll house.

Miller (1963) recommended slide sets that tells a story as opposed to unrelated pictures. Weaver (1965) used Walt Disney film strips. All of these used headphone to deliver the stimulus.

Reports by Keith and Smith (1987) have shown that automated peadiatric hearing assessment using interactive video images can be used for screening and threshold detection in three to seven year old children. The procedure involves animated video graphics which focuses the attention of the child and reinforce correct responses using microcomputer controlled automatic testing facility from play tone. In the screening mode, hearing is checked at pre-test levels (usually 20 to 25 dB HL) at four main frequency levels.

(4) Procedures Using Mechanical - Toy Consequation

Conditioned orientation reflex (COR) audiometry (Suzuki and Ogiba, 1960; Suzuki, Ogiba and Takei, 1972) involves signal presentation through speakers mounted at approximately 45 degree angles on both the sides of subject. Mechanical toys located immediately below the speakers are activated following a localization response. Results show 38.5% successes for one year, 83-87% for 3 to 4 years.

This procedure had undesirable features like (1) sound field stimulus presentation techniques do not permit bilateral measurement and measures only better ear (2) sound field stimuli are known to be unstable (3) localization responses are poorly defined and subjective.

Matkin and Thomas (1974) used a procedure similar to COR audiometry called as visual reinforcement audiometry (VRA) with children 6 to 35 months of age. This procedure involves reinforcing the correct behaviour by presenting a visual stimulus.

In a study by Gans regarding screening techniques in babies reported by Robson (1987), 22.8% of the babies who responded to conventional screening tests of hearing failed to respond at all to at least one pure tone, even at maximum intensities. The mean level at which the babies responded to the pure tones was significantly higher than the intensity of 35 decibels at which they responded to conventional procedure. Also the study showed that the conventional methods of screening are the most satisfactory provided that they are carried out carefully and efficiently.

Speech Screening Tests (SST)

1) Speech Detection Thresholds (SDT)

It is the level at which a listener may just detect the presence of an ongoing speech signal and identify it as speech (Martin, 1975). The advantages include thatit is the only available test which sometimes provides information similar to pure tone thresholds. Disadvantages include prediction of audiometric configuration from SDT is difficult.

Additional speech tests like speech reception thresholds using spondees and speech discrimination tests using-phonetically balanced words can be used (Keaster, 1947; Bangs and Bangs, 1952).

(5) **Behavioural Observation Procedures [BOA]**

In this procedure various stimuli are presented through speakers placed at an angle to the subject and responses are observed by the examiner.

Dicarlo and Bradley (1961) used music white noise and recorded pure tones from four speakers.

Thompson and Weber (1974) used both BOA and "Play *audiometry"* with 190 children three to fifty-nine months of age. Children over eighteen months were tested with play procedures. Their experiments indicated response level was related to age till two year and then reached a plateau. They concluded, BOA is best suited as screening assessment procedure.

BOA Responses are Highly Unreliable Measures (Bench et al. (1976 a, b) and Moncur (1968).

Wilson and Thompson (1985) have stated that "Even though BOA lacks precision as an indicator of hearing status because of limitations like (1) It is a test of responsiveness and not of threshold (2) Observer bias, but it is the only available behavioural procedure for some profoundly retarded children, or very young infants who cannot be conditioned to auditory signals. In order to overcome the above problems it has been established that (1) Observers need to be denied about the knowledge of the stimulus being presented (2) Sounds should be presented in a pre-defined order so that on-site decisions about stimulus presentations do not have to be made (3) Testing form should include a certainty scale and allow for listening of behaviours.

BOA

Advantages of testing young children with the above mentioned tests include the use of principles for conditioning to obtain thresholds, child does not get fatigued easily, child's thresholds is easy to find as he expects reinforcement, use of speech tests gives face validity to test. Speech is a more natural stimulus, using speech reduces false negative responses. Helps in correlating the scores with pure tone average thresholds.

Disadvantages include conditioning may not help for longer time, needs change of activity as child mayjoose interest, behavioural response is difficult to interpret, results with speech tests are difficult because cannot be used with mentally retarded or difficult-to-test children.

ASHA (1985) recommends individual sweep frequency check up at 1000, 2000 & 4000 Hz screening at 500 Hz be included in absence of acoustic reflex. All frequencies to be screened at 20dB HL(ANS1, 1989).

OBJECTIVE TESTS OF HEARING SCREENING

In these tests, a change in the physiologic activity of the body, as a function of auditory stimulation is measured with active co-operation from the subject. These procedures are also mainly used in threshold estimation. The responses obtained are called objective as these are not under voluntary control of the subject. The techniques are most useful with difficult-to-test cases and cases suspected of having functional hearing loss. Attempts have been made to use these as screening tests.

Santag and Wallace in 1934 and Santag and Richards in 1938 recorded fetal movement and acceleration of the pulse after supplying atone of 120 Hz.

Cody and Klaus (1968) pointed to the use of cortical audiometry in testing the hearing of infants children, mentally retarded persons, patients with central nervous system disorders and the patient with functional hearing loss.

Methods like heart rate response audiometry is reported as a method of hearing screening as a response to auditory stimuli. Zeaman and Wegner's (1960) studies confirmed that changes in heart rate are related to intensity.

Respiration audiometry was developed as a technique for predicting hearing sensitivity by monitoring change in respiration that occurs in response to auditory stimuli. Measurement is done by a thermistor placed near the nose.

IMMIANCE AUDIOMETRY

Another non-behavioural objective test is acoustic irnmittance audiometry which helps to differentiate conductive, cochlear, retrocochlear hearing loss. This determines middle ear pressure, tympanic membrane mobility, integrity and mobility of middle ear ossicles and stapedial reflex measurement.

The diagnostic power of the test is greatly enhanced when the procedures are utilized together and interpreted as a test battery. Immittance measurement include -

(1) Tympanometry - evaluates the integrityand compliance of the tympanic membrane and middle ear system.

(2) Equivalent ear canal volumes - a measure of the volume of air between the imittance probe tipand the tympanic membrane.

(3) Acoustic reflex measurement- measures the contraction of the stapedial muscle when the ear is stimulated with sufficiently loud sound.

The Guidelines for screening for Hearing-Impairment and Middle ear Disorders' (ASHA, 1990) recommen d three acoustic immittance measures :

(a) Compensated static acoustic admittance
(b) Equivalent ear canalvolume
(c) Tympanogram width

Failure Criteria[ASHA (1990)]are :

a) Flat tympanogram and equivalent earcanal volume exceeding the normal range 0.2 - 0.9 cm3.

b) Low compensated static admittance in two successive screenings within 4-6 weeks (0.4 to 1.0) cm3.

c) Tympanogram width exceeding the normal range - 60-150 dupa.

Advantages are.the technique is relatively simple to conduct, efficient, requires only passive cooperation from the child a provides multitude of information regarding the child.

There are controversy regarding the use of acoustic immittance measurement in infants as reviewed by Northen (1988).

Paradise, Smith and Bluestone (1976) screened 280 children showed a high positive correlation (86%) between tympanometry and otoscopy for patients older than 7 months of age but conflicting results less .than 7 months with confirmed otitis media.

Groothuis et al. (1979) found a 92% correlation between otoscopy and tympanometry in infants who were older and younger than 7 months of age.

Prevalence of acoustic reflex in infants increase as probe frequency increases (Northen and Downs, 1991). This may reduce false positive while sscreening.

Punlson and Tos (1978) reported a high incidence of 'B' type tympanogram during the first 6 months.

In general,the clinician has to be careful in interpreting results before 6 months of age.

2. Electrocochleograph (ECochG)

This is a method used to measure the VIII nerve action potential by placing the subject in a reclining position and target electrode placed closed to cochlear nerve. The stimulus elicits large number of synchronous nerve discharge.

Advantage include presence of ECochG rules out peripheral deafness, helps in selecting better ear for hearing aid, helps in surgical decision.

Disadvantages are-.it is invasive, both amplitude and waveform may be affected by auditory and non-auditory factors like tissue and electrode impedance.

3. Auditory Brain Stem Response (ABR)

ABR is an objective technique which algebraically sums the potentials that occur in a fixed time interval following stimulation while averaging out random physiologic noise. The physiologic activity is evoked with rapid click or filtered noise. There appears 5-7 wave peaks in a fixed time. Interpretation is based on latency intensity function, interpeak latency waveform etc. Each of these Jewett waves have a highly predictable post-stimulus latency. At high intensities 5 or 6 major waves arise at 1.5-2 msec, recurring at about 1 msec, intervals in first 10 msec, wave V is important.

In newborn hearing programs, the ABR typically is applied as a hearing screening procedure (ASHA, 1989). That is the infant either passes or fails the hearing screening based on the presence of an electrophysiologic response to click stimuli at some predefined intensity criteria usually 30, 40 and/or 60 dB nHL. ASHA recommended pass criterion is 40 dB nHL or less in bothle ars.

Study by Galambos et al. (1984), Hyde et al. (1984) found 80-90 % of infants pass the ABR screen at 30 to 40 dB nHL.

Peters (1986) described an automated infant screener, known as ALGO-I based on advanced evoked response technology. Reported 94% agreement of automated with conventional ABR testing.

Hyde et al. (1990) calcualted the performance of ABR screening and concludeo that 2000 and 4000 Hz in excess of 30 dB is excellent for detecting sensoryneural hearing loss.

Mauldin and Jerger (1979) suggested the use of bone conducted BAEPs in children with congenital atresia or closed head injury.

Advantages are - can be used children and neonates, to detect site of lesion, in neurodiagnosis, and difficult-to-test children.

Disadvantages include - ABR may be affected by maturation, temperature, sex, stimulus polarity, stimulus frequency, stimulus rate, electroconfiguration, no.of samples, interpretation.

4. Otoacoustic Emissions (OAE's)

These are low level acoustic signal leakage from the cochlea spontaneously as a response to acoustic stimulation (Kemp, 1978). These can be detected with specialized equipment placed in the external auditory canal. The stimuli used are clicks and the responses are recorded by another microphone placed in the external auditory canal. There are two types of OAEs (1) spontaneous OAES (2) Evoked OAEs,which include Transient Otoacoustic Emissions (TEOAE) and Distortion Product Otoacoustic emissions (DPOAE).

The presnce of evoked autoacoustic emissions has proven to be evidence of a normal functioning cochlea and peripheral hearing system. Otoacoustic emissions are absent in case of conductive hearing loss and significant sensorineural hearing loss (Anderson and Kemp, 1979).

Cope and Lutmanyshowed 80-90% normal people have OAEs. But mild loss of 20-30 dB will diminish OAE.

Kennedy et al. (1991) suggested that the discovery of OAE has opened new avenues to quick and reliable hearing screening.

Bonfils et al. (1988), Stevens et al. (1989, 1990) compared measurements from ABR and OAEs from more than 1000 infants in NICUS. They reported OAE showed sensitivity of 95% and specificity 84%.

Kennedy et al. (1991) reported OAES more accurately sorted out infants with conductive hearing loss than ABR screening.

Bergman et al. (1995) reported successful use of TEOAEs and DPOAEs for screening.

The most promising application of OAEs is the use of the evoked OAE as a screening device (Kemp, 1978).

The advantages of these tests are - these are non-invasive, objective and very accurate, detects the site of lesion, hearing evaluation can be done for difficuit-to-test, like mental retardation, cerebral palsy, etc, as May be done under sedation also, hearing screening can be done at an younger age with more accuracy.

The disadvantages include - the _ high cost, need of specialised trained personnels, difficulty of interpretation, the instrument is not easily available, needs special rooms (AC) and controlled environments.

FACTORS THAT MAY HELP TO REDUCE FALSE POSITIVE/FALSE NEGATIVE IN HEARING SCREENING

Goldstein and Charles (1971) analysed the commonly employed procedure for routine neonatal hearing screening. The procedure is, Downs and Sterritt (1967) procedure,of using 300 KHz warble tone level of 90 dB SPL, with a 100 dB SPL level to be used if no responses are elicited. According to them this procedure does not seem to accomplish its objectives adequately and has high false positive and false negative scores. Fails to do mass screening for children with deteriorating hearing loss, those with mild to moderate hearing loss proposed alternatives by these authors include (1) until routine screening procedure can be made more effective, hearing testing in the nursery should be limited to children in the high risk register (2) the high risk register should be expanded and refined (eg. Syndromes like Wardenberg be included (3) Neonatal hearing evaluation procedures should be improved to offer greater accuracy and precision (eg. While testing children use a quietist possible room, take to other babies of same age to compare the response, response to touch and light be evaluated) (4) paediatrician should give more care during routine examinations.

A study of 3857 pre-schools by Gardener (1988) from screening of hearing and speech showed variation of results due to change in weather conditions. The two groups were compared for effect of weather (Moderate/colder) and school placement (private/headstart). The study showed fewer failures would be picked up if hearing and tympanometric screening is carried out during moderate weather (April 11 to May 30 and September 15 to November 29). If speech, voice and language screening are done during colder months (November 21 to April 10), the incidence of ear and hearing problems among preschoolers, children incrases. •

Another study by Compagnone and Conners (1985) have found that pure tone"test used in isolation, resulted in many false positives. Tympanometry meanwhile was somewhat cumbersome and uncomfortable for the children, because it involved considerable time spent in test preparation. Acoustic reflexometry however provide fast, accurate results with a significant reduction of false positives.

EFFECT OF HEARING LOSS ON LANGUAGE DEVELOPMENT

The existence of middle ear disorder of early origin which apparently tends to encourage inefficient listening strategies may lead to poor language development and hence educational difficulties.

Eisen (1962) identified a child with auditory learning difficulties who had a history of otitis media in early childhood starting in infancy.

In a classic study by Holm and Kunze (1969) an experimental group of children five-and-a-half year to nine years old was identified who had had no other medical problems but middle ear diseases that had its onset before the age of two. A well matched control group of children with no history of ear disease was given a battery of tests, including the Illinois Test of psycholinguistic (ITPA), the Peabody Picture Vocabulary Test (PPVT), the Templin-Darley Picture Articulation Screening Test, and Mecham Verbal Language Development Scale. The otitis media group showed significant lowered scores in all tests requiring the receiving or processing of auditory stimuli or production of verbal response. All language skills were lower in experimental groups.

Study by Kaplan et al. (1973), of 489 Eskimo children, followed their development from birth to seven through ten years of age. Those children with a history of otitis media before age two and hearing levels of 26 dB HL or greater had statistically significant loss of verbal ability and were retarded in total reading, total mathematics and language tests like Wechsler Intelligence scale for Children (WISC), intelligence tests. Bender Gestalt Tests (BGT) and Draw-a-Person Test.

Kaplan's findings (1976) have shown that school achievement gap between the early otitis media group and the non-affected children showed a tendency to widen with increasing grade level, so the differences could become even greater at an older age.

A number of other investigators have pointed out the role of minimal auditory deficiencies in lowering school achievement. Goetzinger et al. (1964), Kodman (1963), Ling (1972), Wishik et al. (1958) and Quigley (1970) pointed to minor hearing losses as being responsible for educational problems in the developmental years.

OTHER SCREENING METHODS

Crude Tests of Sensitivity

1. Conversational Voice Test
2. Whisper
3. Coin Click
4. Watch tick

Self-Screening Methods

Schow and Nerbonne (1982) introduced a ten item Self-Assessment of Communication (SAC) questionnaire as a general purpose instrument for screening adults for hearing handicap. Also introduced was Significant Other Assessment of Communication (SOAC).

In this participants were required to fill out a form which contains several case history questions (Concerning ear pain, noise exposure, tinnitus and hearing aid use).

Several years ago a project entitled CHARGE (Changing Hearing Aid Rehabilitation for the Growing Elderly Population) was started. One of the tool used in this project was the Hearing Handicap Inventory for the Elderly (HHIE). The HHIE is a good, quick, simple, inexpensive, self-administered -test containing ten basic questions related to social and emotional problems associated with hearing loss.

Telephone hearing screening has also been reported in literature which was developed by occupational hearing services. The program is called "Dial A - Hearing Screening Test" where the patient has to dial a number if his hearing has to be screened.

Also reported in the literature is screening through mass media i.e. radio. On a particular day at a particular time on specified band signals of 75 Hz. were transmitted. The patient had toreport if he fails to listen it.

As reported for general screening a 512 Hz tuning fork can be used. The test includes (1) auditory acuity by air conduction (2) Weber Test.

The Rinne Test is good for screening but difficult to interpret in case of sensori-neural hearing loss.

The use of Rinne and Weber Tests help in quick screening but also have problems in case of false-positive responses or mixed hearing loss. But interpretation be confirmed after audiometry and otoscopy test.

AUDIOSCOPE-3

Is a hearing screener. This generates tones (500 Hz, 1 KHz, 2 KHz, 4 KHz) at either 20, 25 or 40 dB HL for screening purpose. In addition, the unit offers a pre-tone to allow the patient to practice listening before the screen begins.

Neonatal Hearing Screener

The noise stik is a free-field hearing screener, for use in early detection of infant hearing loss. At the press of button the screener emits a controlled burst of calibrated white noise whose shaped frequency spectrum is centered around 300 Hz, ranging from 2000 to 4000 Hz. Held like flash light, noise stik is directed at the infant's ear from a distance of six to eight inches and at a hearing level of 60 or 90 dB SPL.

As reported by Nagaraja (1996) a high-risk register, three hand held low cost auditory screeners, mass hearing screening technique through T.V, standardization of behavioural reflex patterns to different noise and sound stimulation, use of calibrated toys, scratch test, etc. are used by early identification of hearing impairment.

SIGNS OF HEARING-IMPAIRMENT IN YOUNG CHILDREN

Reported by Ferulld, there are certain guidelines given by Weiss and Lillywhite (1985) for early detection of hearing loss by describing some of the behavioural signs of hearing-impairment as opposed to medical signs.

1) Before six months of age, the child does not startle, blink eyes, change immediate activity in response to sudden, loud noises.

2) Before six months, the child is not soothed by or does not show other responses to mother's voice.

3) By six months, the child does not imitate gurgling and cooing sounds and show response to noise-making toys.

4) By six months, the child does not turn eyes and head in search of sound that comes from behind or from the side.

5) By ten months, the child does not make some kind of response to his own name.

6) By twelve months, the child does not show response to household sounds such as a spoon rattling in a cup, running water, or footsteps from behind.

7) By twelve months, the child engages in loud shrieking and sustained production of vowels.

8) By twelve months, the child does not respond to someone's voice by raising head and turning, if necessary, to look directly at the speaker.

9) By fifteen months, the child does not initiate sounds and simple words.

10) People consistently have to raise their voices to get the child's attention.

11) The child responds inconsistently to sound; sometimes hearing it and at other times not.

Weiss and Lillywhite also include behaviors such as (1) at any age the child watches the speaker's face carefully (2) at any age the child turns head so that one ear is facing direction of sound source (3) at any age the child prefers low pitched or high pitched sounds (4) at any age the child talks in a soft or loud voice.

NON-AUDIOLOGICAL TESTS

Screening tests for the deaf child consisted of an otorhinolaryngological, paediatric and neurological examination, which included (a) fundoscopic examination (b) vestibular testing, using the Hallpike Bithermal Test. All the children had audiometric testing and psychological and psychiatric examinations were done. The laboratory studies consisted of x-ray films, an electrocordiogram, Rubella antibody -iiter, hematocrit, white blood cell count, VDRL test for syphilis, urinalysis, algratio blood vrea nitrogen (BU N) and where indicated serum electrophoresis. This was an important study as it finds the link between organ system defects, microcephaily, visual impairment, renal diseases, MR etc. The cost may be high and facilities may not be available at all places. Reduces the risk of congenital and genetic deafness.

GROUP SCREENING TESTS OF HEARING

Group screening tests came into existence mainly to economise in terms of time and money spent on identification programs.

One of the earliest group tests used on a large scale was fadding numbers test. The test consisted of presentation of paired one digit numbers decreasing in intensity in 5 dB steps from 35 to 0 dB. The subjects were required to write down the numbers heard, in the score sheets (Alpiner, 1971; Anderson, 1972).

Johnston (1948) developed the Massechusetts Hearing Test a group pure tone test with this method, as with Fading Number Test, forty children can be screened simultaneously. The frequencies used were 500, 4000 and 8000 Hz. These are presented at hearing levels of 20, 25 and 30 dB respectively.

In Pulse Tone Group Test, as many as forty children can be tested, simultaneously. The frequencies tested are 500, 1000,2000, 4000 and 6000 Hz (Roger and Newby, 1947). The pure tones are presented, in descending order at levels of 50, 40, 30, 25, 20 and 15 dB above the normal thresholds. A loss of 20 dB at any of the test frequencies in either ear is considered to be failure of the test.

In 1939, at the World's Fair in New York and San Francisco, the Bell Telephone Company carried out tests with musical tones and speech (Steinberg, et al. 0940).

In 1952, Johnston described a pure tone test that could be administered to ten children at a time and did not demand a written response. When the sound was presented to the child, he was to raise his hand. This made use of earphones.

Anderson (1952) demonstrated a group pure tone test of hearing using 500, 1000,200O and 4000 Hz tones. The tones were given at a levelof 15 dB. The subjects were required to count the number of times they heard these tones in each ear. Anderson found that the pulse tone test was a good screening devices. He also demonstrated that a burst of white noise could be utilised as stimuli.

Webster in 1952, reported the development of a warble tone group screening test. The test was presented through loud speakers in a reverberant room. The tones were presented with decreasing intensity from 4O dB above threshold level.

Hedgecock, et al. (1975) used automatic screening audiometric technique testing for four persons at a time.

Griffing (1967) developed a procedure called verbal auditory screening for children. At a time, two children were tested. The first word is presented at a level of 51 dB and each subsequent word is attenuated by 4 dB. The lowest level is 15 dB where the last three words are presented. The child has to point to the pictures and the presenter records the responses and is considered pass if he responds at a lower level .

INDIVIDUAL SCREENING TESTS

These have been various approaches to the identification of hearing-impaired individuals. These include the subjective judgement made by the persons, parents, family members and teachers or use of special screening tests.

Study by Hallet (1975), teachers identification was found to be more reliable than pure tone audiometry in case of bilateral hearing loss of primary school children. However teacher's referral did not significantly match with parents.

Most of the audiometric procedures used in screening the hearing make use of pure tones usually delivered through the headsets. Each ear is tested separately across various frequencies.

National Conference on Identification Audiometry recommended that the testing should be done in sound treated rooms. The frequencies used in screening tests are 500, 1000, 2000, 4000 and 6000 Hz. The intensity level at which these frequencies are presented are 10 dB (ANSI-1951) for 500, 1000, 2000 and 6000 Hz tones and 20 dB for 4000 Hz tones. Criteria for fail is no response at any of these frequencies at the level they are presented.

Peterson (1944) also reported on the technique of Sweep Frequency Testing. In this test, frequencies are swept from low to high frequencies at a pre-determined intensity level.

Hirsh (1944) suggested that the pure tone should be presented at a level of 15 dB (ISO, 1964), that the pulsed tone is a more suitable stimulus than the continuous tone stimulus and that both automatic as well as manual methods be employed.

Istra and Barbaccia (1970) made use of four automatic Bekesy type audiometers to screen four subjects at a time. The total testing time taken was 10 minutes per test. The test was given at 500, 1000, 2000 and 4000 Hz.

Hildyard et al. (1963) suggested the use of tuning fork tests to increase the validity of current techniques. Crowley and Kaufman (1966) suggested the use of Rinne Tuning Fork Test for identification purpose.

Lawrence and Rubin (1959) suggested that a limited frequency test using 500 and 4000 Hz tone would best meet reasonable criteria for agreement with the standard sweep check.

The two frequency test is simpler, faster to administer, less fatiguing to the tester and is the one which requires less preparations and cheaper instruments (Siegenthaler, 1961; Norten and Lux, 1960).

Glorig and House (1957) proposed 4000 Hz single frequency screening.

Davis et al. (1958) stated that hearing is rarely poor for speech frequencies than it is for 4000 Hz. Ventry and Newby (1959) tested 1517 first, second and third grade children and found single frequency screening at 4 KHz is useful. Merklein and Fox (1957) found that single frequency screening at 4000 Hz correctly classified *91.3%* of the 220 industrial workers.

Lightfoot, et al (1959), Miller and Belle (1959); Siegenthaler and Somers (1959); Stevens and Davidson (1959) rejected the single frequency screening technique.

Frequencies 3000, 4000 and 6000 Hz are a sensitive indicator of the onset and progress of noise induced hearing loss (Glorig, 1967). These can be used in industrial settings for identification.

Mobile hearing units have been made use of to control the testing environment in crowded places or where the ambient noise levels are high (Osborn, 1951; Chase, 1949). Sound treated mobile units are present which have single or multiple audiometric test booths.

Computerised audiometry can be used in the evaluation of the hearing-impairments (Weiss, 1961; Wood, et al. 1971,1972; Sparks, 1973). This would save the audiologists time needed in the administration of the test.

According to Goldstein (1972) behavioural hearing screening detected bilateral hearing losses of even mild (> 20 dB HL) degree. Sensitivity to significant hearing losses was 82.6% and would have been improved if test frequencies > 3000 Hz were included in the study. The high frequency stimuli are more diagnostic of hearing loss.

Study by Wolf and Goldstein (1980) have observed selective masking with early components of brainstem responses to click in neonates suggest that the cochlear response mechanisms for high frequency may not be mature. If in complete maturation is indeed the case, it is ironic that 3000 Hz cannot be used for screening.

GROUP HEARING TEST PROCEDURE vs. INDIVIDUAL PROCEDURE

Some audiologists prefer to use the individual sweep frequency check rather than the group test. The National Conference on Identification Audiometry specified that for school age children the frequencies tested should be 500, 1000, 2000, 4000 and 6000 Hz (Darley, 1961).

The biggest advantage in giving a group test of hearing is that many persons can be tested in a relatively short period of time. A group test can be administered by an audiometrist who has minimum of training (Newby, 1964). The National Conference on Identification Audiometry stated that these are two stages in identification audiometry. The first stage involves testing of a large number of children resulting in the ready identification of those who may have no hearing problems. The second stage involves, a more detailed test by more highly trained personnel, with more elaborate equipment (Darley, 1961). This leads to final identification of those who should be referred for a complete diagnostic check-up, in such a program, a group screening test for the first stage and an individual test for second stage of identification can be employed.

The advantages include faster rate of screening, easy maintenance, is less expensive and less number of trained individuals needed.

The disadvantages of group hearing tests include the requirement of special, costly equipment, its maintenance and calibration, the necessity of ensuring against cheating and higher false-positive identification rate (Anderson, 1972). There will be a few subjects -who will not follow the test instructions (O'Neill and Over, 1966).

HEARING SCREENING IN INDIA

Incidence of hearing problem, of the Indian population living in six lakh villages in the country, eighty percent are afflicted with deafness, while one in thousand is pre-lingually deaf, one ten is affected by ear discharge. The degree of deafness varies from mild to profound (Rangasayee, 1985).

Most of the attempts made to identify persons with hearing loss in India have made use of crude test of hearing. The stimuli used are arbitrary and intensity level not specified. The studies were done in uncontrolled environment. This involved a lot of subjective criteria employed. Few examples, include Misra, et al. (1961) in a sample of 50,000 school children found that one in every 30 children required attention for hearing problem. Kapur (1965) tested school children from three schools in-and-around Vellore and concluded that prevalence of hearing loss in these children was between 16.3 and 18.66. The test given was pure tone type. Any child who failed to respond at 25 dB for any of the frequencies from 500 through 6000 Hz was considered to have failed the test.

Low Frequency Screener: Palm leaf or coconut rattle with four tamarind seeds make about 35 to 45 dB SPL around 500 *Hz* when rotated in hand. Healthy looking tamarind seeds are found to weigh an average of 700 mgs.

High frequency screener : Two soda lids are woven in a thread producing 35 to 45 dB SPL sound around 4000 Hz.

Hearing Aid-Cum-Hearing Screener

The T-coil circuit has been made to oscillate without disturbing the performance of the hearing aid. is used for a dual purpose. The cost involved is less than one United State dollar (Rangasayee, 1984).

According to a study by Harrison and Roush (1976) - A program was initiated to seek a nation wide perspective on the status of identification and intervention for infants and young children with hearing loss. The study included three hundred thirty one parents whose children ranged from infancy to five year of age had to return a mail survey that included respondents from thirty-five states. Parents were asked to report the approximate age of suspicion, diagnosis, hearing aid fitting and initiation of early intervention services. Demographic information, risk factors, if known and reasons for delay were also investigated.

Results have revealed substantial delays between parental suspicion, audiologic medical diagnosis, fitting of acoustic amplification and initiation of early intervention services; however, the pattern of delay was different for children with known risk factors because of additional health problems as compared to those without known risk factors. The median age of identification and intervention was lower than that reported by some previous investigators (Stein, Clark and Kraus, 1983; Stein, Jabaley, Spitz, Stoakley and McGee, 1990), although a considerable range was reported for each category. They concluded the study saying that median age of identification and intervention, although still higher than optimal, may be improving.

CHAPTER HI

METHODOLOGY

The project was carried out in two phases which included Phase-I - Selection of items as hearing screening devices and measuring their frequency and intensity characteristics. Phase-II Use of the selected screening devices to screen school-age children and to correlate the result with pure tone screening procedures.

Phase I: SELECTION OF SCREENING DEVICES

The items selected for the study were based on certain criteria. These criteria included (1) Low cost (2) Locally and easy availability (3) Easy to handle and use (4) Provide stimulus properties stable for a long-time. The items selected were :

(1) Toy trumpet (plastic)
(2) Plastic whistle
(3) Cardboard (Register cover)
(4) Chocolate paper
(5) Newspaper tearing
(6) Click tok
(7) Claps
(8) Matchbox with five match sticks
(9) Glass Bottle with six marbles
(10) Speech sounds.

Further specifications and details of the items are given in the Table-3.1 Specification of items for hearing-screening kit.

In order to check whether the same items would be selected from the market when their exact specifications were provided to different testers, ten speech and hearing trainees were given the specifications and requested to obtain these devices. The specifications provided included place of availability, approximate cost, size, etc. It was observed that the subjects brought the specified items except for the 'Click tok' for which the specifications needed to be supplemented by drawing and/or showing the item itself. As some items were difficult to be located, the final items of hearing screening kit included tapping on card board cover tearing of newspaper, vowel sounds /a/, /i/ and /u/, Chocolate paper, match box with five match sticks, plastic whistle;six marbles in a glass bottle.

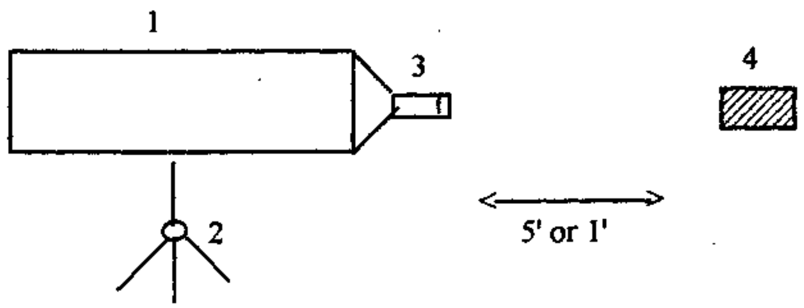
After the items were selected which were to be used for hearing screening, measurements were done to find their frequency and intensity composition. These measurements were carried out. using -

(1) For intensity measurement:

Sound Level Meter (- Bruel and Kjaer type 2209)with octave filter set(type 1613), Condenser Microphone of free field (type 4165) (Fig.3.1).were used.

PROCEDURE FOR SOUND INTENSITY MEASUREMENTS

The instrument used for the purpose of intensity measurement was sound level meter(type B&K 2209)with other accessories.



1. B&K SLM Type 2209
2. B&K Tripod Type UA0587
3. B&K Free Field Mic Type 4165
4. Screening Device

Fig. 3.1 Instrumental set-up for intensity measurement of the screening devices

PROCEDURE FOR SOUND INTENSITY MEASUREMENT

The sound level meter was checked for battery condition, calibration was checked and intensity measurement was carried out as follows :

Setting on SLM

' Slow'time weighting net work

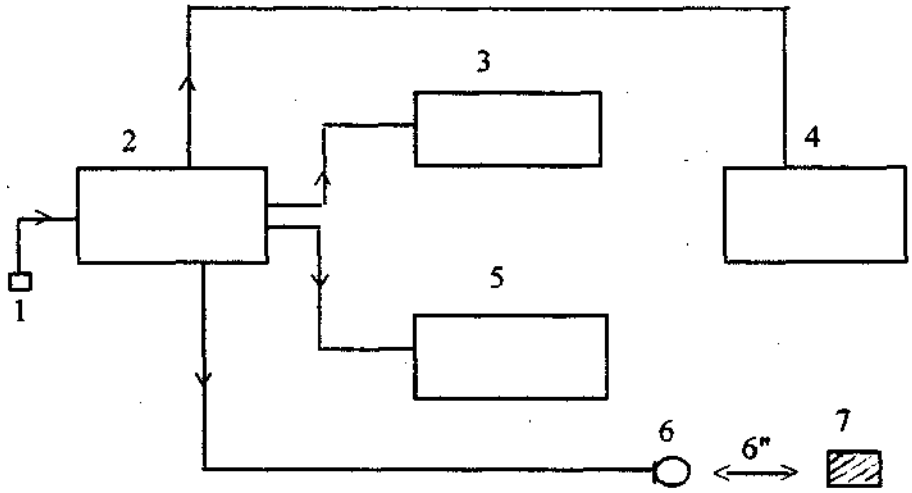
The frequency network set to 'linear'.

The input and output attenuators were adjusted such that the needle in the meter deflected between '0' and "10". The free-field microphone was directed in the correct orientation for measurement of the sound pressure level.

While writing down the intensity readings,the position of the meter, attenuator and weighting network switch was noted.

(2) For Frequency Analysis

D.S.P. Sciagrap } was used
Type 5500/5501 }
(Kay Elemejttrics) with Accessories (Fig.3.2)



1. MAINS.
2. Main Module
3. Monitor
4. Printer
5. Control Module
6. Mic
7. Noise Maker/ .screening device.

Fig.3.2 ..
Instrumentation set-up for frequency measurement

2. PROCEDURE FOR FREQUENCY MEASUREMENT

The instrument used was DSP-SONA GRAPH TM [Kay Elemetrics - Model 55OO/55O1]..

The instrument was turned 'on' for a minute and allowed to warm-up.

For measurements, microphone was connected to the input section of the main module.

The analysis menu of the instrument was set appropriately for measuring spectrograph and power spectrum in menu section of the panel.

For doing the measurement, a signal was given and input level was adjusted for correct recording.

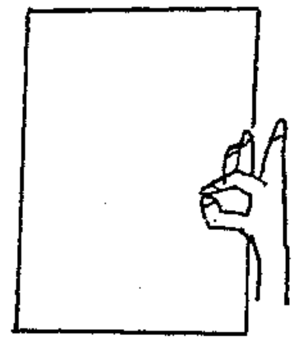
Time cursors were also used to measure the characteristics as a function of time.

After noting the frequencies at which energy concentration was highest, print outs of the screen were taken.

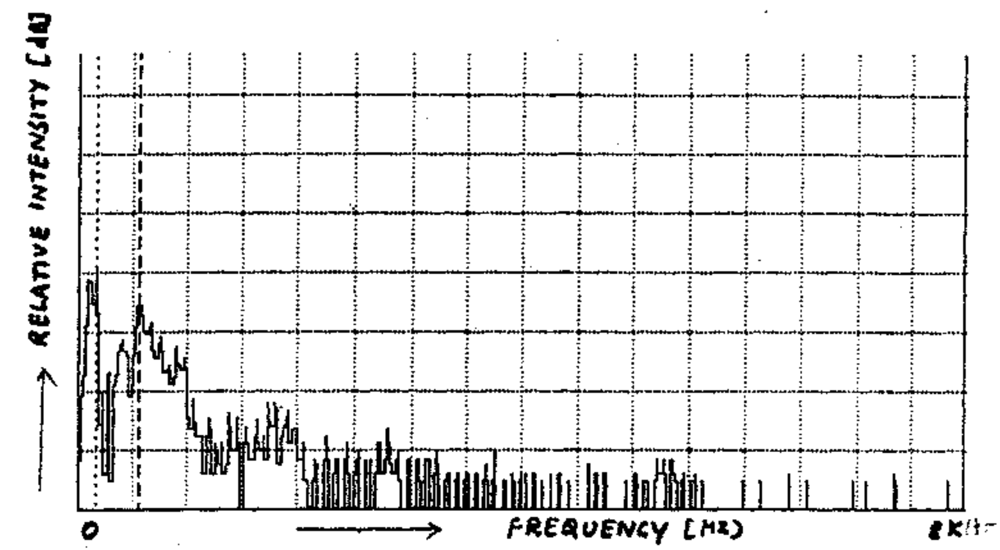
ITEMS SELECTED INITIALLY FOR HEARING SCREENING [FIG 3.3]

SPECTRUM OF ITEMS USED IN HEARING SCREENING

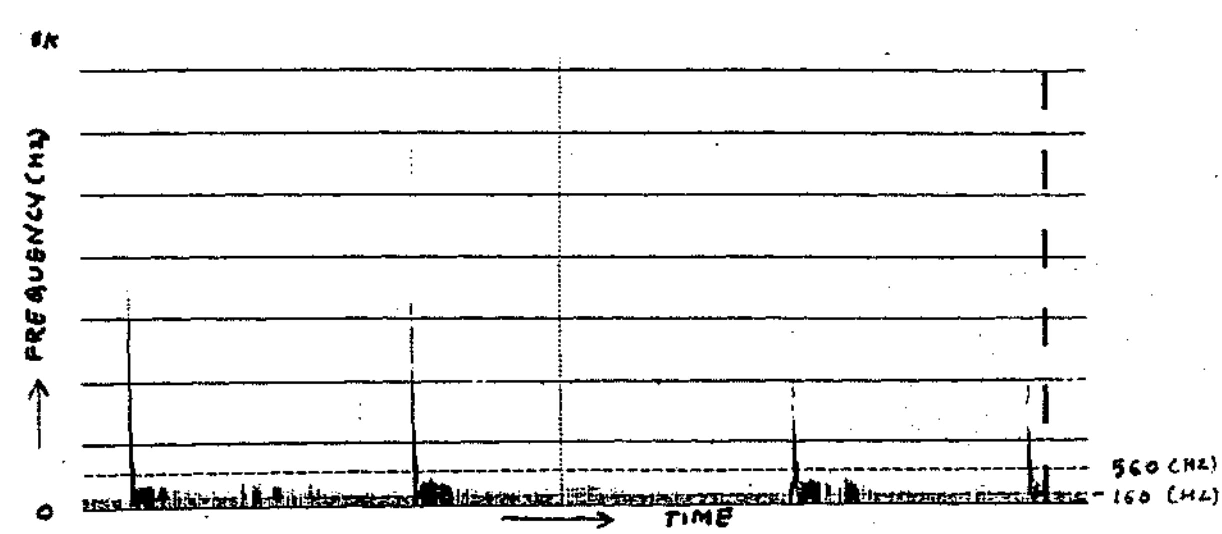
TAPPING AT THE CENTRE OF *CARDBOARD REGISTER* COVER *[FIG 3.4]*



POWER SPECTRUM

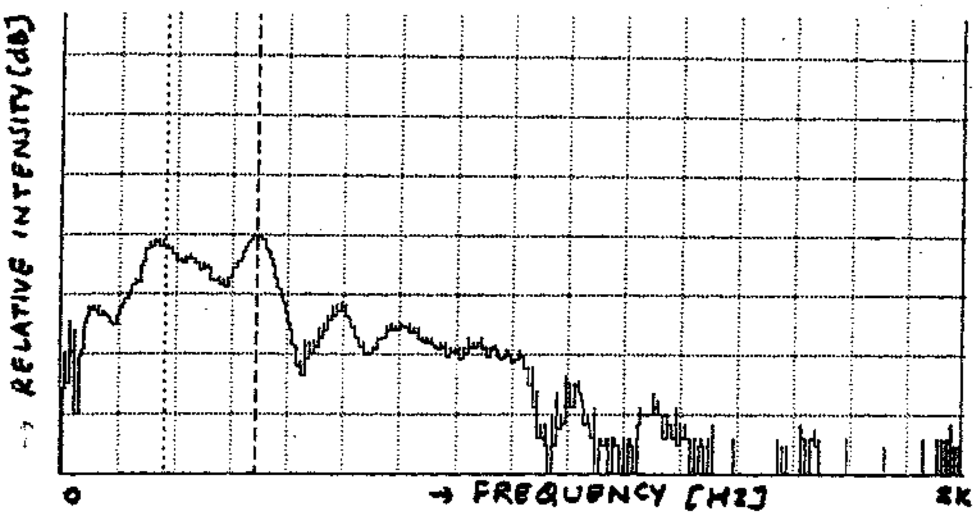


SPECTROGRAPH

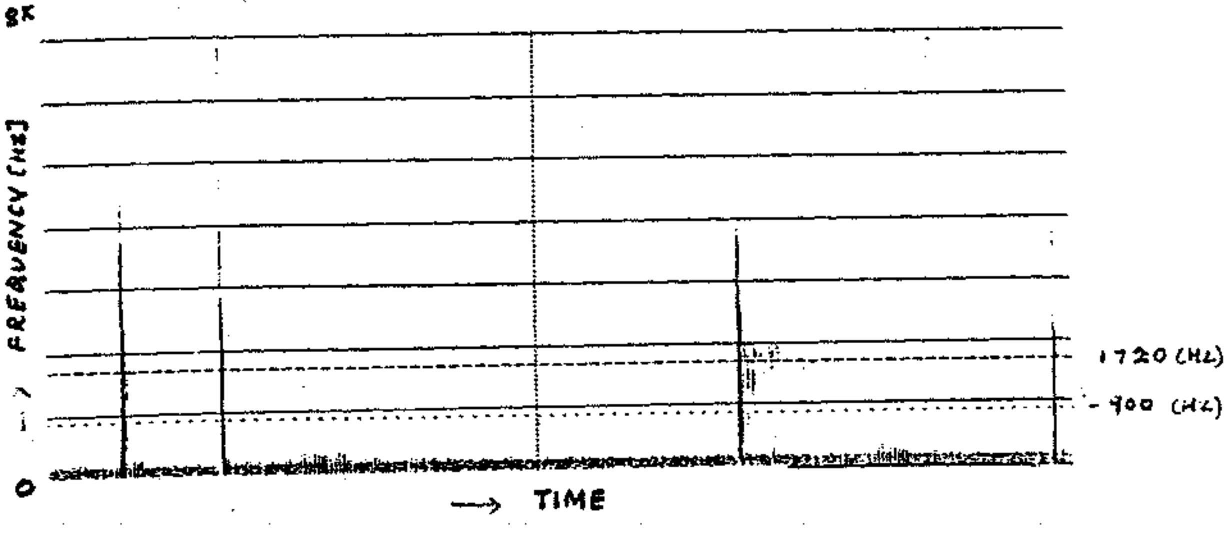


CLAPS (FIG-3.5)

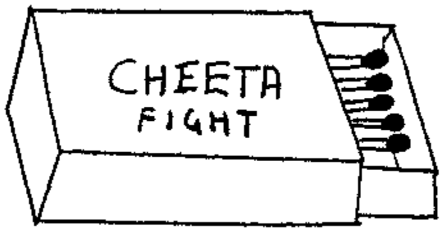
POWER SPECTRUM



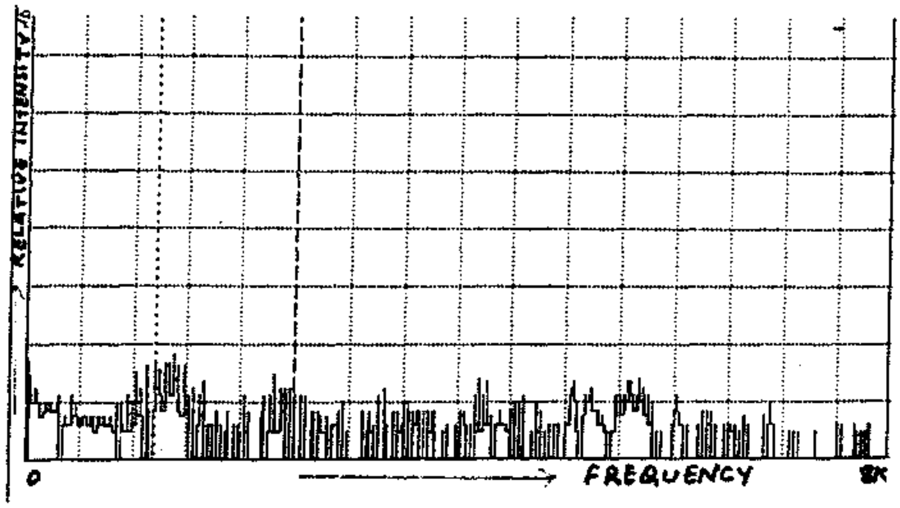
SEPCTROGRAPH



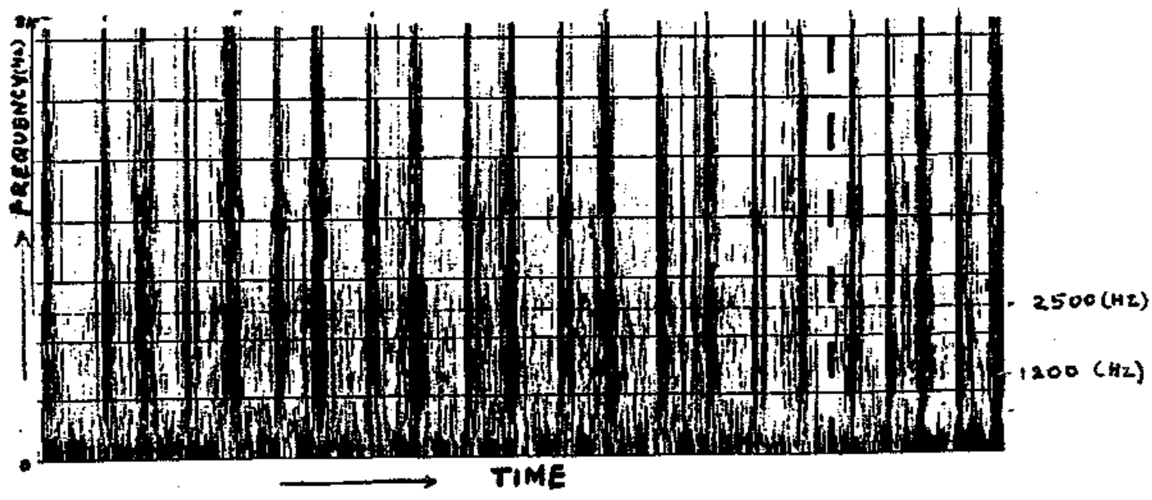
MATCH BOX WITH FIVE MATCH STICKS *[FIC3.6]*



POWER SPECTRUM

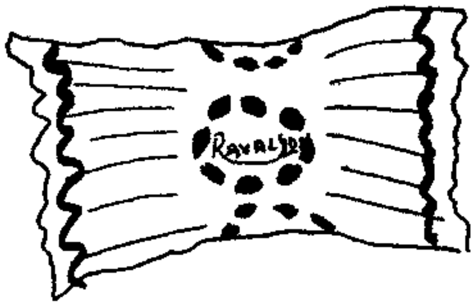


SPECTROGRAM

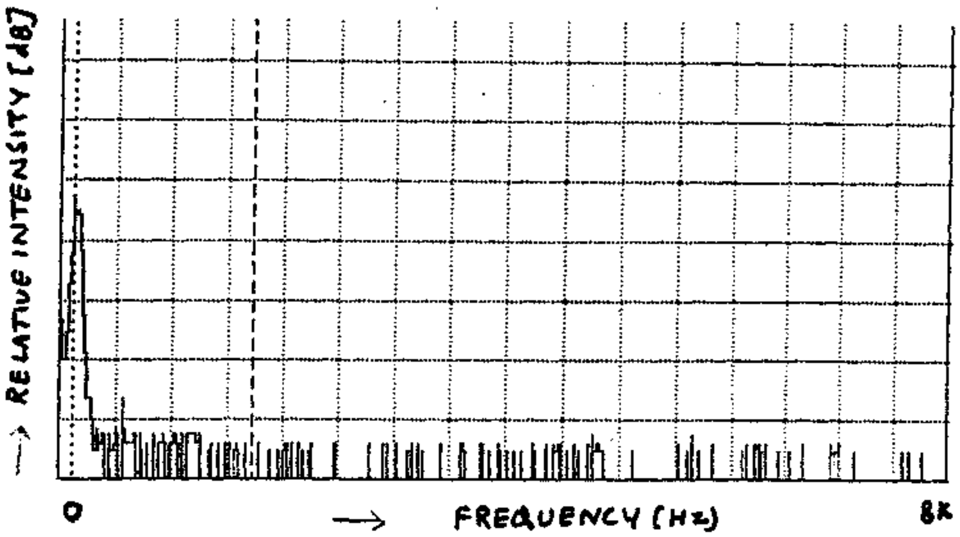


CRUMBLING Of CHOCOLATE PAPER

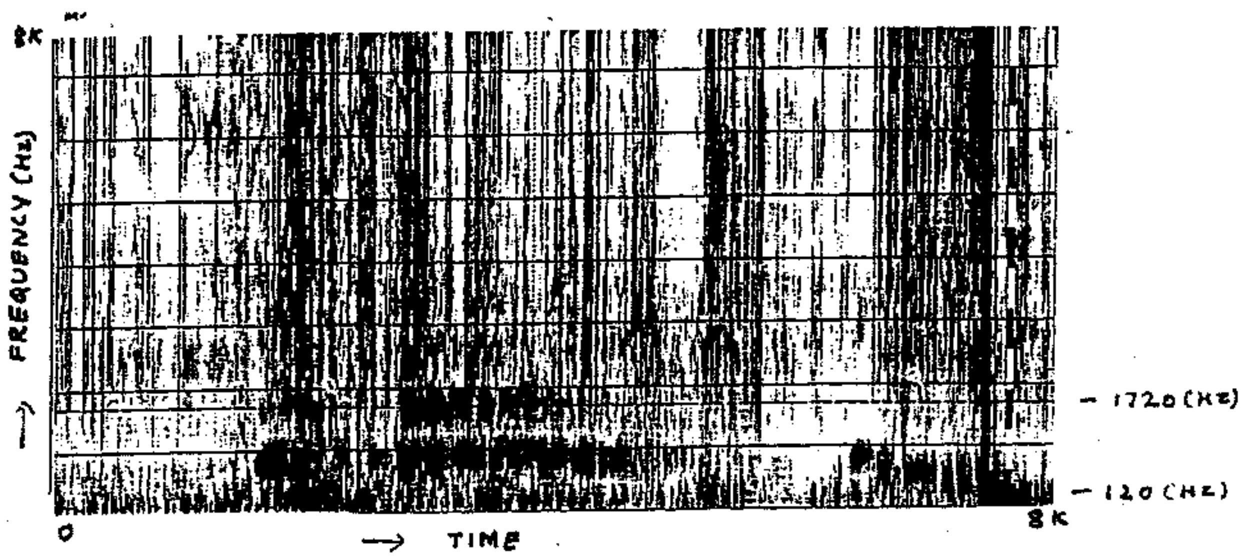
[FIG- 3.7]



POWER SPECTRUM



SPECTROGRAM



SI. No.	Item	Approx cost	Frequency Range and Peak Frequency	Level of Presentation	Intensity/distance	Duration of signal presentation
1	2	3	4	5	6	7
	Peak in High frequency region |> 2000 Hz]					
1.	Toy Trumpet	Rs. 2.5 0	500 Hz - 8 KHz	Moderate	1 feet - 70dB SPL	2SEC
			Peak at 3000 Hz	Moderate	5 feet - 30dB SPL	
2.	Plastic Whistle!	Rs.2.00	2 KHz-4 KHz	Moderate	1 feet - 70 dB SPL	2—3 sec
			Peak at 3000 Hz	Soft	5 f ppt 30 dB SPL	
3.	Speech Sound		125 KHz-8 KHz	Moderate	1 feet - 40 dB SPL	2 sec
	(without vowel /S/)		Peak at 3500 Hz	Soft	5 feet - 20 dB SPL	
4.	Speech Sound		125 KHz-8 KHz	Moderate	1 feet - 40 dB SPL	2sec
	(without vowel /£/)		Peak at 2500 Hz	Soft	5 feet-30dB SPL	
5.	Five glass marbles		125 - 8 KHz	Soft	1 feet - 40 dB SP1	
	put in a glass jar		Peak at 8 KHz	Soft	5 feet - 30 dB SP1	
6.	Chocolate paper	50 p	1 KHz - 4 KHz	Soft	1 feet - 35 dB SPL	
	crumbling		Peak at 2000 Hz	Soft	5feet - 30 dB SPL	

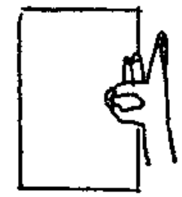
l	2	3	4	5		1
	Peak in Mid-frequency region [l 000-2500 Hz]					
1.	Match box with five match sticks (Cheeta Brand)	50 p.	1 KHz-4KHz Peak at 1000 KHz	Moderately loud - Moderate	1 feet - 40dB SPL 5 feet -30dB SPL	3 secs.
2.	Claps (fore fingers of right hand on the palm of left hand. Hands 1 foot apart)		250 Hz -4 KHz Peak,:l KHz	Moderate-Soft	1 feet - 40dB SPL 5 feet-30dB SPL	2-3 secs.
5.	/m/ nasal sound		125 Hz-4 KHz Peak-.l Hz	Moderate - Soft	1 feet - 40 dB SPL 5 feet-30dB SPL	2-3 sees.

1-	2	3		C	1
Peak in Low Frequency region [<1000Hz]					
1. Tapping the card board at the centre with middle finger	Rs. 10 for the register with card board cover	125 Hz-2 KHz Peak -500 Hz	Moderate Soft	1 feet -40dB SPL 5 feet-30dB SPL	2-3 secs.
2. Gradual tearing of NEWS paper [30 cm by 30 approxl .	Rs.2.50	500 Hz - 3 KHz Peak at 500 Hz	Moderate (Rapid) tearing Soft (slow) tearing	1 feet - 40 dBSPL 5 feet - 30dBSPL	1-2 secs.
3. Vowel/a/		125 Hz- 1 KHz Peak 500 Hz	Moderate - Soft	1 feet - 40 dB SPL 5 feet -30dB SPL	2-3 secs.
4. Vowel /i/		125 Hz- 1 KHz Peak 200 Hz	Moderate - Soft	1 feet - 40 dB SPL 5 feet -20dB SPL	2-3 secs.
5. Vowel /u/		125 Hz- 1 KHz Peak 400 Hz	Moderate - Soft	1 feet - 40 dB SPL 5 feet -3OdB SPL	2-3 secs.

- Order of availbility - easily available News paper, Matchbox;
- Need more specification - Chocolate paper, Plastic whistle, marbles in the glass jab, card board register.
- Difficult-to-locate - Click tok, (needs more specification).

As can be seen from Table 3. l,many of the items selected had overlapping frequency distribution and variability in stimulus presentation. Hence those items easily available and easy-to-use were selected. The items selected had frequencies in the range of 500 Hz to 2000 Hz.[*TABLE*- 3.2]

	Item	Peak Frequency	Intensity	Distance	Level of Presentation
1.	Tapping card board register cover in the centre with middle fingers	500 Hz	30 dB SPL	5 feet	Soft tapping
2.	Match box with five matchsticks or claps (Using fore fingers of right hand on palm of left hand)	1000 Hz	30 dBSPL	5 feet	Moderately Soft
3.	Chocolate paper-crtimnbling	2000 Hz	30 dB SPL	5 feet	Soft



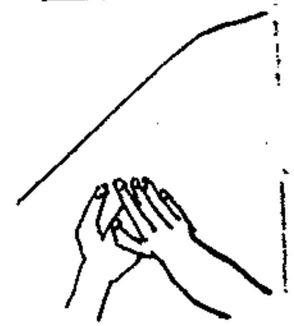


Table 3.2 : Showing the frequency and intensity concentration for items used in hearing screening

PHASE II
PROCEDURE FOR CHECKING RELIABILITY OF THE SCREENING KIT

SUBJECT SELECTION

A total of fourty subjects were selected for the study. The children were selected randomly to include both male and female subjects. The age range of the subjects was five to twelve years with a mean age of 6.8 years. All the subjects were studying in a local school from first standard to seventh standard.

HEARING SCREENING ENVIRONMENT

A classroom was selected which was relatively less noisy and where the ambient noise was maintained at minimum level during the screening.

PROCEDURE FOR HEARING SCREENING

The calibrated hearing screening kit that was developed in Phase - I of the study, and,a screening audiometer were taken to the school for hearing screening.

The subject -was seated comfortably at a distance of five feet from the tester and signals were presented exactly from the back of the subject.

The child was instructed to respond whenever he heard the sound.

INSTRUCTIONS

"You will be hearing a sound for 1-2 seconds of various items. After each sound is presented. There will be a gap of five seconds. You have to respond by raising your finger or by turning your head whenever you hear a sound. You can even imitate the sound heard. Make sure that you respond even if you her it softly. The child was verbally reinforced for every correct response ".

LEVEL OF PRESENTATION OF THE STIMULUS

The signals were presented from a distance of five feet so that the level was about 30 dB SPL for the stimulus items presented at moderate to soft levels. These were presented at the level of ear and exactly from behind the subject without giving any visual cues. The stimulus was presented twice for 1-2 seconds.

RESPONSES ELICITED

The responses elicited for the auditory stimuli included either (1) Head turning (2) Finger raising (3) Imitation of the sound (4) Repetition of sounds.

RECORDING AND CHECKING RELIABILITY OF RESPONSES

The responses were recorded. After this a re-screening was done to cross-check the results using a calibrated portable audiometer (Madsen Micromate 304).

CRITERIA FOR PASSING THE TEST

The child was considered to *"pass"* the hearing screening if he showed any of the above mentioned responses within the 2-4 seconds after the signal was presented.

CRITERIA FOR FAIL

The child was considered *"fail"* if he showed delayed or no response even after 3-4 seconds of the stimulus presentation.

PLOTTING OF RESULTS

As each ear could not be tested separately, the response of the child was assumed to be that of the better ear. The audiometric screening was done separately for each ear.

After the screening was completed i.e. by cross-checking using pure tones at 500, 1000, 200 Hz at 20 dB HL these were plotted in to 2 x 2 matrix indicating the true positive, true negative,false positive and false negative results. Then statistical analysis was applied on the data obtained.

CHAPTER IV

RESULTS AND DISCUSSIONS

After the hearing screening test was administered at a local school with the developed kit and a screening audiometer, raw scores were plotted in the matrix.

Fourty subjects were evaluated from the local school, out of which 72.5% (i.e. 29/40) were identified, with the new screening kit developed, to have normal hearing. When the reliability was cross-checked with the pure tone hearing screening 67.5%,(of the twentynine, twentyseven (27/29\were found to have normal hearing. The results were analysed to measure the false positives and false negatives. The results have been plotted in the following matrix.

New Hearing screening Kit

NEW HEARING SCREENING KIT

PURE TONE SCREENING	N=40	Pass	Fail
	PASS	27(A) (67.5)	2(B) (5%)
	FAIL	2(C) (5.1%)	9(E>) (22.5%)

A - True Positive

B - False Positive

C - False negative

D - True negative

Table 4.1: Comparison of new hearing screening kit with the pure tone hearing screening.

The results Of the new screening kit and pure tone screening tests were compared for the fourty subjects (N=40) and put in the form of a tetrachoric table as in Table 4.1. The table shows that twentynine subjects passed and eleven failed the new hearing screening.

In the pure tone screening test, twentynine subjects passed and eleven subjects failed . Out of the twenty nine subjects who passed the pure tone hearing screening test, twenty seven subjects passed the new hearing screening kit and two subjects failed. These two subjects constituted false positives in the study.

Out of eleven subjects who have failed the pure tone hearing screening kit, nine subjects also failed the new hearing screening kit. The remaining two subjects constituted false negative.

Cells A and B in Table 4.1 show an agreement between the new hearing screening kit and pure tone screening test. And the cells B and C show the disagreement between the two tests (Garret, 1966) . The total agreement (A + B) is thirty seven and disagreement in terms of false negative and false -positive score is two and two respectively. If there is 75-80% agreement between the two tests (A+D), and if the cell B contains less than or 5% of the total scores, then the new screening kit may be considered to be reasonably efficient.

In the Table 4.1, A + D is 90% and the value in the ceil B is 5% i.e. the total agreement value obtained is fairly satisfactory. When evaluated against the criteria as proposed by Newby (1948).

The data in table 4.1 is represented graphically in Figure 4.1, on the 'x' axis are the four cells, A,D,B and C and on the 'y' axis are plotted the number of individuals falling under each cell.

On comparison of the new screening test with the pure tone screening test, an agreement was revealed in the tetrachoriq, table as suggested by Newby (1948) i.e. the new screening test could be considered as reasonably efficient in identifying hearing loss.

Variables that might have affected the study

The frequency, intensity measurement which were obtained during laboratory measurements might get influenced by other factors like (1) signal reproducibility (2) variation of noise level in the room when screening was conducted.

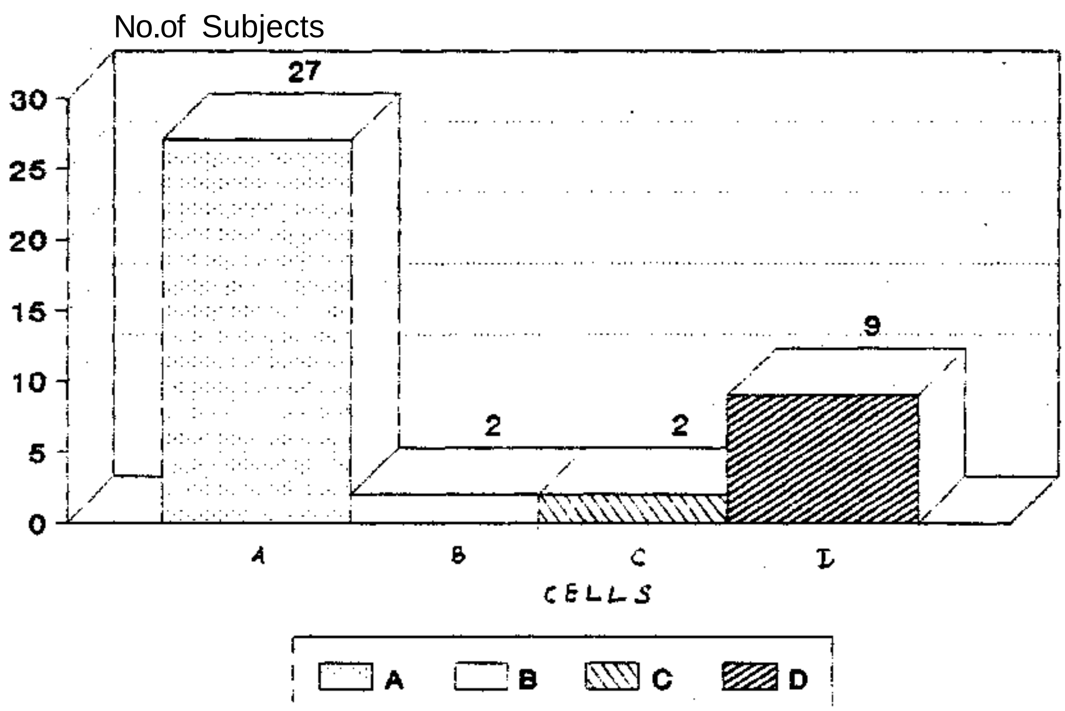
Another factor might be using 30 dB SPL as the cut off point for making a pass fail criteria at 500 Hz, 1 KHz, 2 KHz as noise levels may be varied during different test procedures.

As the items used in screening are not very specific in their frequency and intensity concentration and exact reproducibility is not possible j each time it might have resulted in false negative responses.

The intensity or level of presentation is tester controlled and might lead to variability, missing some mild to moderate hearing loss cases.

To obtain the correct responses as reported repeatability of the distance of presentation, direction, level of signal presentation is important.

Fig.4.1:Representing the no.of subjects in different cells (A,B,C,D) *re -.Table 4.1*.



CHAPTER V
SUMMARY AND CONCLUSION

It was felt that no suitable hearing screening test was available, which could be made use of in screening, with the available personnel, equipment, cost, availability and other resources at hand.

The mass screening tests were not feasible because of more number of false responses, equipment needed for test and problems in interpreting results.

The purpose of this study was to use easily available,low cost, easy to use material for screening of hearing and administered to school age children. The idea was that if such a kit was developed more number of hearing screening could be done without the need of sophisticated instruments.

The study was carried out in two phases where the first phase included finding out the items that could be used effectively for hearing screening and measuring their frequency and intensity Characteristics. The second phase included administration of these items to school age children to screen the hearing.

For finding the validity of the screening kit the test scores with mew hearing screening kit was compared with pure tone hearing screening. It was found that the results obtained with new hearing Screening kit correlated well with that of hearing screening kit.

The new hearing screening kit can be widely used to screen hearing of school age children from five years to twelve years of age, anywhere when ambient noise level is within limit. Also it needs minimum training of school teachers, anganwadi workers, primary health care workers. Any indication of hearing loss can be taken up for further detailed evaluation. It does not make use of any special equipment for administration.

RECOMMENDATION;

A few more items could be used which satisfy the criterion of easy availability, low cost, easy to use.

In order to reduce redundancy, the order or number of presentations or duration of each tone should be made different from that of the other tone.

The application o f this kit can be expanded to other population like mental retardation, cerebral palsy, unresponsive or uncooperative children.

The kit can also be used to test if it produces the same results with the adults and geriatric population.

The items recommended in the study should be, to a large extent, similar or nearly similar when used elsewhere. Recorded" audio cassette of the stumli of the screening items may be used to reduce certain of the variables .

However the new hearing screening kit is a valid screening test. The test can be usefully employed in conducting hearing screening in India.

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