COMPARISON OF BEHAVIOR OBSERVATION AUDIOMETRY AND VISUAL REINFORCEMENT AUDIOMETRY IN INFANTS AND CHILDREN

Register No. M9906

An Independent Project Submitted as part fulfillment
for the First year M.Sc. (Speech & Hearing) to University of Mysore.

ALL INDIA INSTITUTE OF SPEECH AND HEARING, MYSORE-570006
MAY - 2000

Certificate

This is to certify that the independent project entitled "Comparison of Behavior Observation Audiometry and Visual Reinforcement Audiometry in Infants and Children" is the bonaflde mark done in part fulfillment for the degree of Mster of Science (Speech and Hearing) of the student with Register No. M9906.

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May 2000

Certificate

This is to certify that the independent project entitled "Comparison of Behavior Observation Audiometry and

Visual Reinforcement Audiometry in Infant and Children" has been prepared under my supervision and guidance.

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Declaration

I hereby declare that this independent Project entitled "Comparison of Behavior Observation Audiometry and Visu-al Reinforcement Audiometry in Infants and Children is the

result of my own study under the guidance of Dr. Asha Yathiraj .Reader, Department of Audiology, All India Institute of (Speech and Hearing. Mysore, and has not been submitted earlier at any other University for any other Diploma or Degree.

Register No. M9906

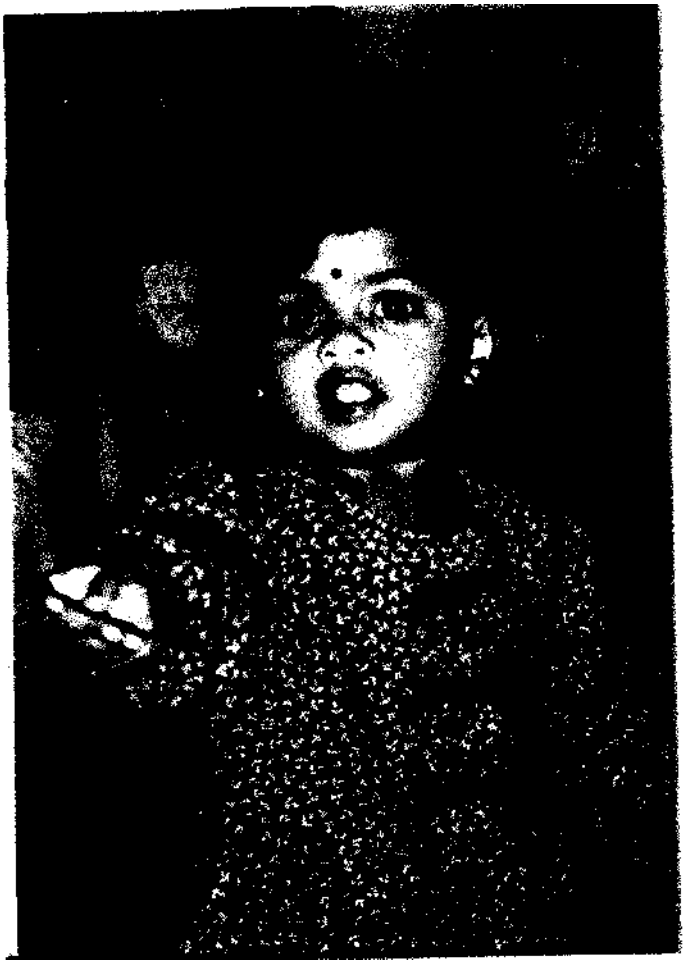
Mysore

May 2000

Dedicated to

DEAR "ANDREA" AND ALL THOSE

-LITTLE ONES" WHO WERE MY SUBJECTS.



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My deepest gratitude to all those parents who willingly brought their children to me for the testing

Dearest Naveen and Ajith "Thanks" is not a word I would use for you two. Let me tell you something :-

"I do not need a certain number of friends,

Just a number of friends

I can be certain of".

I' am glad and fortunate to have friends like you.

Dear Prachi, Things would have been not so easy for me without you being there at my side. I really needed it...... Thanks so much.

Dear Kaveri, Komal, Karneesh & Arushi, Thanks for taking care of me in this "home away from home"

Thanks to all my classmates for their constant moral support.

Dear Kavita, Arul, Mukunthan and Srivatsan, great to have pals like you around

Dear Sara, Manoj, Sajith, Visa and Archana. "Wish you could see this book right away!" Though miles apart you are always there in my thoughts.

Dearest mummy, daddy, Peter, Lima, Henry and Prema- whatever I am today is all because of you. Love you all.

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INTRODUCTION

One of the most crucial factors in any child's development is the acquisition of spoken language. Language is the key to the door by which we express our thoughts, needs and feelings to others (McConnell and Liff, 1975). The acquisition and development of language is highly dependent on an adequate auditory system. Unmanaged deafness has a major impact on a young child's normal progressive development (McCormick, 1994).

Children with congenital hearing levels of 65 dB HL upwards, (i.e. the severe to profound range) will not develop normal speech and language (Ling, 1976). Without adequate language, the child will experience many cognitive deficits and is often unable to communicate with the outside world. This in turn may lead to behavioral problems also (Myklebust, 1954). Bess et al (1999) reports that 37% of children even with mild Sensorineural hearing loss have speech, language, emotional and social problems.

The longer auditory language stimulation is delayed, the less efficient will be the ability of the child to communicate . The reason is that a critical period exists for the development of biologic functions and language is one of the biologic functions of humans (Chomsky, 1957; Lenneberg, 1967). It is for these reasons that it is urgent to identify hearing impairment which is a silent handicap in children, as early as possible. It requires a lot of skill, knowledge and insights on the part of the clinician to assess the hearing capabilities of children. There are no poorly responding babies - only inadequately prepared clinicians (Northern &

Downs, 1991). In order to start language training early, it is essential to test and identify the problem early.

Tests to assess hearing can be classified into :

1) Behavioral tests and
2) Objective tests

(Martin, 1977; McCormick 1986; Northern & Downs, 1991)

Behavioral tests involve careful behavioral observation and assessment of unconditioned / conditioned responses given by a subject which are active responses to the presence of a sound stimulus (Northern and Hayes, 1996).

Objective tests are non-behavioral methods to assess the hearing status. They are physiological or electrophysiological methods and do not require active participation from the subject e.g. auditory brainstem response (ABR) , Oto acoustic emissions (OAE), Immitance audiometry etc. (Northern and Hayes, 1996).

Although non-behavioral or objective measurements are useful and may be necessary in the evaluation of hearing in infants, the ultimate confirmation of hearing loss by behavioral audiometry is preferable. However, it is to be remembered that no single auditory test is precise enough to be a perfect and complete assessment tool (Northern and Downs, 1991).

Jerger and Hayes (1976) strongly recommended the use of the 'cross check principle' in pediatric audiometry i.e., using objective measures (ABR & Reflexometry) as confirmation of behavioral results. Bachmann and Hall (1998) state that although OAEs were first reported in 1978 by Kemp, they have only recently begun to assume a pivotal role in pediatric diagnostic auditory assessment.

. OAEs have led to an updated expansion of the 'cross check principle' articulated first by Jerger and Hayes (1976).

However, regardless of how sophisticated testing techniques become, there will always be a need for behavioral hearing evaluation as objective tests are not true tests of hearing (Northern and Downs, 1991). Considerable progress has been made even in behavioral testing in recent years to develop better, more accurate means to evaluate hearing in infants and young children.

Behavioral assessment measures have been further classified as

A. Unconditioned behavioral assessment procedures
B. Conditioned behavioral assessment procedures

(Gerber and Mencher, 1974; Wilson and Thompson, 1984 ; Thompson and Folsom, 1985)

(A) Unconditioned behavioral assessment procedures

These evaluation techniques do not incorporate reinforcement principles. These are based on careful observation of some active response from the subject to the presence of a sound stimulus. The responses are defined not in terms of a predetermined criterion, but in terms of reflexive reactions (i.e., startle, eye blinks) or changes in attention (Ewing and Ewing, 1944 ; Northern & Downs 1991).

Limitations of unconditioned behavioral observation audiometry include ;

1. Rapid habituation of the response, which is related to the state of the infant during testing

2. The parameters of the acoustic stimulus

3. Need for extensive training of the audiologist to use Behavioral Observation Audiometry (BOA) (Thompson and Weber, 1974 ; Wilson and Thompson, 1984)

4. The definition of what behavior is accepted as a qualified response (Wilson and Thompson, 1984).

5. A major, and probably uncontrollable, limitations with BOA is that it is a test of responsiveness and not of threshold (Gans. 1987).

The advantage of using BOA is that it is time and cost efficient and does not require extensive technical equipment. BOA is usually carried out with new borns and infants less than 18 months of age (Gans, 1987; Wilson and Thompson, 1984; Hodgson, 1985; Thompson and Folsom, 1985). However, the 1994 position statement of the Joint Committee on Infant Hearing Screening concludes that behavioral observation methods can not validly and reliably detect hearing loss of 30 dB HL in infants younger than 6 months of age. Hence use of objective measures is mandatory for this age group.

(B) Conditioned behavioral assessment procedures

These use reinforcements for the elicited action in response to the stimulus. The response is specifically defined and is a repeatable active response. It is strengthened through the use of some type of reinforcement, which is typically some pleasurable sensory experience, or brief play activity (Ewing and Ewing, 1944 ; Wilson and Thompson, 1984 ; Northern and Hayes, 1996).

Some of the conditioned behavioral assessment procedures are:

- CORA - Conditioned Orientation Reflex Audiometry (Suzuki and Ogiba, 1961)
- VRA - Visual Reinforcement Audiometry (Liden and Kankkunen. 1969)
- TROCA - Tangible reinforcement operant conditioning audiometry (Spradlin and Lloyd, 1965 ; Lloyd, Spradlin and Reid, 1968 ; Llyod and Cox, 1975 ; Hodgson, 1985)
- VROCA - Visual reinforcement operant conditioning audiometry (Boothroyd, 1991; Northern and Downs. 1991).
- Play audiometry (Ewing and Ewing, 1947 ; McCormick, 1991,1994)

Thompson and Thompson (1972) reported success in using the VRA technique in infants as young as 5 months of age. Matkin (1977) achieved 90 % success with VRA under ear phones, in children with normal hearing and hearing impairment between the age of 12 to 30 months. Most 3 years olds can be tested satisfactorily using play audiometry (Hodgson, 1983; Northern and Downs, 1984). Play audiometry may be difficult to teach at the early 2 year level (Hodgson, 1985).

Thompson, Thompson and Vethivelu (1989) reported that on an average 2 year olds who can be conditioned to perform play audiometry are likely to provide more responses prior to habituation than they would if tested with either VRA or

VROCA. Hence conditioned play audiometry, if possible should always be the preferred test of choice for children around 2 years or older.

BOA has to be relied upon for children less than 6 months of age even though they may not clearly reflect their auditory thresholds (Wilson and Thompson, 1984). VRA is however a better behavioral technique from about 6 months to 3 years as it involves the child's attention under an operant control (McCormick, 1991).

Aims of the Study

The aims of the present study are to :

1. compare the hearing thresholds obtained on children in the age range of 6 months to 3 years by both non-operant and operant procedures, BOA being the non-operant procedure and VRA the operant procedure.
2. note which among the two tests gives more accurate or better thresholds when children between the ages 6 months to 3 years are evaluated.
3. evaluate which of the two tests is more appropriate for the 3 different age groups 6 months to 12 months, 12 months to 24 months, 24 months to 36 months.
4. find out the test-retest reliability of BOA vs. VRA.

Need for the Study

The study has the following implications

1. It determines the method that will establish thresholds most accurately.
2. It determines which of the two methods is more time effective.

3. The study also establishes the age ranges in which either BOA or VRA is more reliable or efficient.

4. The study also gives us information about the test-retest reliability of both BOA and VRA.

REVIEW OF LITERATURE

" Normal hearing " is relatively well defined for adults and older children. They can be taught to respond actively to test stimuli. However, definitive responses in the 0-20 dBHL range can not be expected from infants and young children. Their immature development precludes the use of conventional audiometric techniques. As an alternative, such children are usually tested behaviorally by some observational technique (Thompson and Weber, 1974).

Over the years, literature in the area of speech perception has provided support for the notion, that, infants possess far more sophisticated auditory abilities than previously has been suspected (Eilers, 1978 ; Kuhl 1980). Central to this theme is the thesis that the infant is an active receptor of auditory information. An infant if given a chance, will interact with, and control, his or her auditors' environment. Behavioral test procedures that acknowledge and capitalize on this fact provide more powerful indices of auditory function in infants than behavioral procedures that view the infant as a passive reactor to sound (Jerger, 1984).

Behavioral Observation Audiometry (BOA) and Visual Reinforcement Audiometry (VRA) are two general test approaches available for testing infants and young children (Thompson and Folsom, 1985).

BOA - Involves presentation of calibrated sounds in the sound field to the child. One or more observers look for and record what they believe to be unconditioned responses to the sounds. There is no systematic reinforcement used (Thompson and Folsom, 1985 ; Gans, 1987). Dienfendorf (1988) describes BOA as an active response from an infant or toddler passively involved in the task at hand.

The auditory responses of infants and young children can be described in terms of reflexive or attentive behaviors. Reflexive behaviors include the startle response, arm or leg jerks, slow limb movements, the auropalpebral reflex, change in sucking behavior, eye blinks and facial twitches. Attentive behaviors are described as quieting responses, like, decrease or increase in ongoing activity, breath-holding or a change in breathing rate, onset of vocalization, sudden stopping of vocalization, starting or stopping of crying, eye widening, searching or localization, smiling or other changes in facial expression, brow furrowing or shriek of surprise (Northern and Downs, 1991).

An infant or child's responsiveness to test sounds of different nature, i.e, noise makers, pure tones, warble tones, narrow band noise or complex noise have been studied (Ewing and Ewing, 1944 ; Mendel, 1968 ; Hoverstein and Moncur, 1969 ; Moore, Wilson and Thompson, 1977 ; Samples and Franklin, 1978 ; Thompson and Folsom, 1985 ; McCormick, 1986).

Various variations of BOA have been described in literature. These have evolved based on the age of the child, stimulus parameters, environmental factors, the examiners involved and the newer available equipment.

Behavioral responses can be elicited in sleeping or aroused state in new born babies and infants from 0 to 4 months of age using calibrated noise makers or other sound field stimuli. The best behavioral response is arousal from sleep within 2 to3 seconds of stimulus presentation (Northern and Down, 1991 ; Primus, 1991). For relatively older babies, i.e.. 6 months and older Ewing and Ewing (1944) gave the " distraction test " which involves a head turn from the baby in response to the sound stimulus. This response they say most likely occurs when the *sound* is presented in the horizontal plane of the ear. McCormick (1977) suggested the requirement of 2 testers, one to present the signal, while the other to control the baby's attention.

Though sound field and earphone testing can give equally reliable and

recearable results (Byrne and Dillon, 1981; Arlinger and Jerwall, 1987)

earphones are not desirable for use with babies (McCormick, 1993).

As with the arousal responses for the newborn's and head turn responses for babies from 6 months to 1½ year are the feasible responses, an older child greater than 18 months can do a Co-operative test or a Performance test. This is because, by this age the children start comprehending simple verbal instructions. Based on these are described the Co-operative test (Ewing and Ewing, 1947), the Four-toy pointing test (McCormick, 1991) and the Performance test (Northern and Down, 1991; McCormick, 1993).

The objective of the Co-operative test is to develop a giving game with simple toy materials and to record the minimum listening level required for the comprehension of simple instructions such as " give this to teddy " (which should be within the child's vocabulary). The Four-toy eye pointing test required the child to eye point to each of the four items in response to the request by the tester.

The performance test involves conditioning the child to wait for an auditory stimulus and then respond in a play activity such as placing a ball on a stick, ringing the peg, stacking cubes etc. Use of headphones has also been recommended for the Performance test (McCormick, 1993).

Two further behavioral tests tapping the better speech identification ability of a 2½ year old than an 18 months old are the Toy Discrimination Test (McCormick, 1997) and the Automated McCormick / IHR (Institute of Hearing Research) Toy discrimination test (Ousey, Sheppard, Twomey & Palmer, 1989 ; Palmer, Sheppard and Marshall, 1991). The former consists of using 14 toys in a finger pointing task to the examiner's request. The latter consists of speaker presentations of digitally stored speech waveforms of the words used in the Toy Discrimination Test. The automated version has a button control for presentation and recording of responses. Selection of the speaker and choice of warble tones, with frequency selection and level control in 10, 5, 2 or 1 dB steps is also present. An adaptive procedure is used for testing (McCormick, 1993).

Hence we see that the above behavioral test methods are based on the child's development of attention and capabilities to respond. Cooper, Moodley and Reynell (1978) provide a useful summary of the development of attention which passes through extreme distractibility in the first year of life. This is followed by fairly inflexible attention to concrete aspects of the environment in the second year. A more flexible and shifting of attention control in the third year of life leads to the stage in the fourth year, at which the child can choose to control his / her own attention. It is at this stage that the child may be able to undertake the co-operative requirements of formal pure tone audiometry.

Thus it can be noted from the review of literature that BOA has several variations. Each of the variations are used for specific age groups. There are several variables that affect a BOA response. These are discussed in the section below.

Factors affecting BOA responses:

1. Age of the Child

The age of the child is an important variable when carrying out BOA. With maturation, the responses seen to auditory stimuli vary. Also with increasing age, the intensity, frequency and duration of the stimulus required to elicit a response vary (Ewing and Ewing, 1944 ; Hoverstein and Moncur. 1969; Moore, Wilson and Thompson ; Samples and Franklin, 1978 ; McCormick, 1986). Pediatric BOA is the most cost and time effective way of evaluating hearing, in newborns and children through 2 years of age (Northern and Downs, 1991). It is very evident that response behaviors mature with age. An infant exhibits responses more in the form of arousal from sleep, eye blink, eye widening, startle, increased or decreased motion (Gans, 1987) usually to intense stimuli (Wedenburg, 1956; Ling, Ling and Doehring, 1970). An older infant (i.e., older than 6 months) can demonstrate head turning or localizing responses to sounds of even low intensities (Hoverstein and Moncur, 1969 ; Thompson and Thompson, 1972). Muir, Abraham, Forbes and Harris(1979) studied the head turn behaviour in 1 to 4 month old babies using a rattle.They found that at birth a very high percentage of infants turn toward the sound and, at 1 month even a higher percentage. At 2 months chance behaviours are dropped and at 3 months head turn behaviour comes back. Hence they conclude that the head turn behaviour initially may be reflexive and strongly mature back by 4 to 6 months. Children more than 1 year of age can exhibit higher level functions such as smiling, laughing, vocalization and pointing (Gans, 1987).

However, there are other authors who differ slightly in their viewpoints regarding the reliability of BOA especially for children less than 6 months.

Trehub, Schneider and Bull, (1981), Wilson and Thompson (1984) opined that non operant evaluation has limited value for determining thresholds in very young infants. BOA is a test of responsiveness and not of threshold (Gans, 1987).

Bench, Collyers and Mentz (1976a)and Flexer and Gans (1986) report that normal hearing children are not very responsive to low level sounds until after 4 months of age. Ling, Ling and Doehring (1970) says that the chance is too high for observing random responses and judging them as valid responses to sound. Mencher (1972) found that the chance of erroneously recording a response from a sleeping baby is about 1 %.

Hence, it is considered that, attempts to estimate threshold in babies with BOA are usually futile (Thompson and Weber, 1974 ; Wilson and Thompson, 1984). Wilson and Thompson (1984) however stated that, " Even though BOA lacks precision as an indicator of hearing status, It is the only behavioral procedure for some profoundly retarded children or very young infants who can not be conditioned to respond to auditory signals". Matkin (1977) found that one third of children below 12 months of age cannot be conditioned. So BOA retains its place in the pedo-audiological test battery.

Considering the advantages and disadvantages of BOA as reported by various studies above, it is apt to include BOA in the pedo-audiological test battery. This is because, in the hands of a skilled tester BOA can give valuable information regarding true hearing status, which may or may not be reflected in objective measures. Hence, BOA can always be considered for children from birth to at least 12 months of age beyond which other conditioning measures are more powerful tools to evaluate hearing.

As stated earlier certain stimulus factors also vary with age (intensity, frequency and duration etc.). Eisenberg (1965) found that acoustic events probably have differential functional properties that are innate, unconditioned and relevant to the ontogeny of communication functions. She concluded (1969) that the discriminable property of sound for newborns is the organization of the stimulus envelope.

Intensity Factors

There are many studies with respect to the intensity of the stimulus. Haller (1932) found that an infants' motor activity increased with intensity and the activity was very regular. Eisenberg (1969) and Rudmose(1976) opine that responses of infants are intensity bound. A more intense signal gives a more reliable response. However, Kaga and Tanaka (1980) reported mean responses for

BOA (for 1 KHz and 2 KHz pure tone) of approximately 40 dB HL at 7 months and 25 dB HL at 2 years.

According to Northern and Downs (1991) a rather loud sound is usually required to elicit a behavioral response in 0 to 4 month old babies. We can, hence conclude based on the above studies that older children require lower intensities to respond when compared to the younger age groups.

Frequency Factors

In addition to the intensity of the stimulus, the frequency of the signal has also been found to have considerable effects on responsiveness.

There has been a preference for frequencies around 3000 Hz for infants and children. Most tests for infants, tend to use more of high frequency stimuli rather than low frequencies(Pratt Nelson and Sun, 1930; Marquis, 1931; Haller, 1932; Stubbs, 1934). The choice of the stimuli was probably based on the fact that infants are more responsive to high frequencies. However, Eisenberg /1976) suggests that infants' hearing for a 4000 Hz pure-tone is poorer than for a 500 Hz tone.

Early researches used buzzers, clappers and bells(Ewing and Ewing, 1944), while more modern researchers have used complex signals (Eisenberg, 1966). Downs and Steritt (1964) used Narrow Band Noise which peaked at 3000 Hz. Heron and Jacobs (1968) used FM tones centered at 3000 Hz. Gerber, Mulac and Swain (1976) used pure tones and narrow band noise distributed around 3150 Hz.

However, Eisenberg (1976) suggests that infants' hearing for a 4000 Hz pure-tone is poorer than for a 500 Hz tone.

Eisenberg (1965), Ling, Ling and Doehring (1970) found that newborn infants are more responsive to narrow band noise than to pure tones. Mendel (1968) found that responses of 4 to 8 month old infants were related to stimulus bandwidth. More responses occurred to broad band noise stimuli than to a narrow band noise stimuli or a warble tone. Hoverstein and Moncur (1969) tested 3 month to 8 month old normal infants using BOA. Four types of stimuli were administered randomly at four hearing levels. The stimuli used were pulsed white noise, 500 Hz and 4000 Hz warble tones, live voice and music. The percentage of responses increased with increased hearing levels. In order to reach 50 % of responses hearing levels had to be higher than the adult thresholds by 23 dB HL for voice and 72 dB HL for the 4000 Hz warble tone. In their study voice generally resulted in the largest percentage of responses and 3 month olds gave fewer responses than 8 month olds.

Thomson and Thompson (1972) reported that complex auditory signals are more likely to evoke spontaneous responses than FM tones. Bench and Mentz (1975) found that tonal stimuli are inefficient as regards elliciting responses. Gerber (1976) found no differences between narrow band noise centered at 3 KHz and frequency modulated tones around 3 KHz. Samples and Franklin (1978) observed the responses of 7 to 9 month old infants to speech signals, warble tones, and noise bands. They found that the intensity level required for a response was lower and the number of responses were significantly higher to speech signals than to either the warble tone or broad band noise stimuli.

Bench , Collyer and Mentz (1976 a,b,c) compared a wide band signal extending from 2000 Hz to 500 Hz at several levels to such other signals as narrow band noise and speech. They concluded that the wide band signal was a more effective stimulus than the narrow band at high sound pressure levels.

Thompson and Thompson (1972) studied the responses of infants and young children with normal hearing using the following stimuli - broad band signal, high pass filtered signals and a 3000 Hz pure tone. Infants were tested using BOA and older children using play audiometry. The infants responses varied as a function of the stimulus used. They found that in 22 to 36 months old infants, there was no longer an advantage of one auditory stimulus over another. However, in general their 3000 Hz stimulus gave fewer responses than did the other stimuli. This result is important for the assessment of high frequency hearing loss in infants and young children.

Arlinger and Jerlwall (1987) found that adults too could more easily detect warble tones compared to steady tones. Olsho et al. (1988) estimated pure tone thresholds at frequencies 250 Hz to 8000 Hz for 3, 6 and 12 months old infants and for adults. The maximum difference was seen at 8000 Hz. In 6 to 12 month olds the thresholds was 10 to 15 dB higher than that of the adults with the difference greatest at the lower frequencies. Two major conclusions of the study were that pure tone thresholds improve with age and the timing of this improvement is frequency dependent.

Flexer and Gans (1986) noted that narrow bandwidth auditory signals are simply not effective in eliciting responses from infants as are broader bandwidth stimuli (including speech) because in all likelihood the broader bandwidth signals sound louder. There are however contradictary studies which do not find any significant relationship between stimulus factors like intensity, frequency, duration and responsiveness.

Bench (1969) used 85 dB signals of 500 Hz and 2000 Hz and found that there was no significant difference in the response elliciting properties of the two tones. Gerber, Mulac and Swain (1976) reported that they were unable to find that the response to sound varied as a function of speech. Ling et al. (1970) were unable to find stimuli of 3000 Hz any more effective than stimuli of 2000 Hz. Feinmesser and Tell (1976) using narrow band signal that peaked at 3000 Hz, eventually concluded that this stimulus was not valid for screening.

Hence in general it is seen that broader bandwidth stimuli are more effective in eliciting responses than narrow band stimuli. Pure tones are generally not used as they have been found to be less interesting for the children compared to warble tones, noise or speech. Most researchers agree that stimuli centered around 3000 Hz are most frequently used effectively.

Duration Factors

Mendel (1968) found that the temporal configuration of the sound had no effect on the number of responses.

However, with respect to durational aspects many authors have found differences in responsiveness. Stubbs (1934) finds that the response activity was proportional to duration upto 15 seconds, i.e., longer the duration greater the response activity. Gerber (1971) said that neonates seem to react to those stimuli which have rapid rise time and are of relatively brief duration.

Too much increase in the duration of the stimulus or repeated presentations are also not very favourable to testing as it increases stimulus habituation or adaptation especially, for older chidren. Pratt (1934) observed that signal repetition every 10 seconds led to a clearer response than repetition of the same stimulus every 60 seconds.

Herer (1967) recommended observing the first stimulus administered, because frequent repetition of the stimulus is not helpful and often confuses the picture.

There are not many studies talking only about durational aspects of the signal, in detail. The stimulus durations and interstimulus durations, depend on the age, state or activity of the child being tested. There are not many contradictory studies reported in literature regarding this.

Mental Retardation

While considering the age of a subject, mentally retarded children or multihandicapped children also need special mention. This is because due to the developmental delay the mental age of the child is lower than the chronological age.

The retarded child passes through the same auditory developmental stages as the normal child. However the retarded child develops more slowly and with less potential (Baker, 1979 ; Kamli, 1982).

Flexer and Gans (1986) found that profoundly handicapped children display relatively more reflexive than attentive behaviors and exhibit fewer behaviors per response man do normal children. They also stated that the multihandicapped responded to broader bandwidth signals better, probably because the broader bandwidth signals sound louder. Flexer and Gans, (1982, 1983) found that the sequence of stimulus presentation (ascending or descending) made no differences on responsiveness of handicapped children.

Hence, we see that age of the child in a way alerts us regarding the kind of responses to look for, as the type of responses have been seen to consistently vary with age. Also, the stimulus parameters like intensity, frequency and duration of the stimuli are closely related to the age of the subject. Hence selection of the appropriate test method and stimulus parameters is important for BOA to be efficient in evaluating hearing.

Other Stimulus Factors

There are certain other stimulus factors which are independent of the age of the child. Other stimulus factors which may affect BOA are Recorded vs Live voice as stimuli, acoustic characteristics like reverberation and the sequence of stimulus presentation (ascending or descending). These have not been frequently related to age of the subject.

Goodhill (1954) introduced the use of recorded stimuli for testing, as live voice were not satisfactorily calibrated. However, Fisch (1965) found no difference between the recorded and live sounds.

Walker, Dillon and Byrne (1984), Arlinger and Jerlwall (1987) said that a great advantage of warble tones is that they are less influenced by reverberation.

For BOA, some studies recommended that the signals be presented in an ascending order until a response is noted (Hoverstein and Moncur, 1969 ; Samples and Franklin, 1978 ; Thompson and Thompson 1972 ; Suzuki and Ogiba, 1961). On the other hand a few other studies recommended a descending order (Watkins, Stewart and Ryan, 1966 ; Weir, 1979). Flexer and Gans (1982, 1983) also noted that a preset order of stimulus presentation reduces clinician anxiety by being easier to implement, than when, on site decisions are required.

Hence, in conclusion it can be stated that the stimulus parameters influence the testing of infants just as they do for adults. The response behavior as well as the sensitivity to sound matures with age. Therefore, age as well as the stimulus parameters interact with each other closely, as well as independently in determining the child's responsiveness to sound.

Scoring of behavioral responses (Observer Biases)

A major limitation with BOA is that observer bias often affects interpretation of results. A number of studies have been done with BOA in this regard. As a result of these studies various methods have been recommended to increase the objectivity of BOA.

Several studies have confirmed that there is a tendency for judges to score responses when no auditory signal was presented (Moncur, 1968 ; Ling, Ling and Doehring, 1970 ; Langford, Bench and Wison, 1975). Ling, Ling and Doehring (1970) masked the observers hearing so that they did not know when the stimulus was presented to the infants. 70 % of the responses recorded occurred in the absence of the stimulus. The observers did not know which responses were to sound and which were random.

Mencher (1972) reported that the probability of mistakenly recording a response during a fixed observation interval was only about 3 %. If two observers agreed on the presence / absence of the response the error is there by cut by a factor of 2 to 1.5 %. Hence Mencher recommended that there be two observers who score the results independent of each other. The two observers must record two motor movements during a fixed observation interval following the stimulus presentation. He added that the scorer should be unaware of the stimulus being present and that both the observers must agree on the response being present at least twice in eight presentations in order for it to be considered as a true response.

Tweedie (1975) instituted video recording as a way to better evaluate responses to sound by handicapped children but no attempts were made to control for possible scorer bias. Gans and Flexer (1982) investigated observer bias in BOA with profoundly multiply handicapped children. They found clear observer bias in 85 % of the children. The observers under-estimated responses at lower intensities and over estimated responses at higher intensities. When they investigated possible contamination effects of scorer bias in evaluating the hearing they found that knowledge of the stimulus intensity affected how observers rated the presence or absence of a response. Hence they recommended that objectivity could be increased for BOA if observers were denied information about the presence and type of sound.

Weber (1969) was the first to develop a BOA screening technique using "no sound" or catch trials. Judges were required to score as possitive or negative during a specified time interval for 20 trials. Half were sound (speech at 60 dBHL) and half were catch trials. The judges wore earphones and heard all stimuli, but did not know which were presented to the child. The use of two persons for testing, the observer in the test room and the tester in the control room, was suggested.

Langford, Wilson, Bench (1975) studied the response behaviors to BOA under controlled conditions for observer bias by video recording the sessions and introducing a single catch trial among sound trials. A six-point rating scale (1 - real sure, no; 2-pretty sure,no; 3-not sure,no; 4-not sure,yes; 5-pretty sure,yes; 6-real sure,yes) was used to evaluate certainty of response rather than simply a "Yes" /" No " reply. This rating allowed for more indepth analysis of response behavior by separating out subtle from more overt responses. This rating scale, also reflects different strengths and types of responses elicited when different stimuli are used.

Gans (1987) recommended the use of multiple observers to make the judgements more reliable. The judgements were to be made within 3 seconds of stimulus presentation. The rating was done on a six-point certainty scale as recommended by Green and Swets (1966) and Langford, Bench and Wilson (1975). There were sound as well at catch trials for both of which the observers were presented with a cueing signal for 2 seconds to rate the child's behavior. No actual sound was presented in the test suite for a catch trials. Video and audio recording of the children were made and played back to the observers. Each time the sound catch trial was presented a wideband noise cueing signal interrupted the audio portion of the video recording. This ensured that the observers had no knowledge of stimulus or intensity,or even whether sound was presented or not. The sounds presented were in a predefined order, so that on site decisions about stimulus presentation were not required. Finally, a flowchart was developed on the protocol for estimating the minimum response level. The results showed that there is a definite shift in response behaviors from weak to strong responses and from attentive to reflexive, as the intensity increases. The children also responded with a similar repertoire for the sound and catch trials. The only deviation from this trend was for the 80 dB HL sounds where the children tended to exhibit a higher percentage of strong, reflexive behaviors as compared to catch trials.

Hence, the observer bias can be dealt with, by having multiple observers, independent scoring, use of catch trials or using video and audio recordings of the test to be played to multiple judges. Even in the absence of video or audio recording facilities, the judges can observe from the control room and earphones with masking noise can be given as the cueing signal to them in the place of sound and catch trials. In any test involving multiple observers it is also important to make sure (after a few subjects have been tested), that the inter judge reliability is high. The judges should be almost equally competent in order to have reliable test results. If the inter judge reliability is detected to be low then the judges may require further training before testing any further subjects of the study.

The above factors should hence be kept in mind when carrying out BOA. BOA responses can be most reliable when the age appropriateness, the stimulus factors and observer bias are taken into consideration.

VRA

When reinforcement is used, the testing approach is a form of operant conditioning. In this the auditory signal cues the availability of the reinforcement following the desired response behavior (Thompson and Folsom, 1985). Suzuki and Ogiba (1961), were the first to report on a conditioning procedure involving the localization response. Their procedure was based on the observation that infants will reflexively turn their heads towards a strange auditory or visual stimulus and was called conditioned orientation reflex audiometry (CORA).

Based on the CORA, various methods, using conditioning and reinforcement have evolved. Barr and Junker (1969) created a technique of distraction with sound from a fixed visual attention. They used a rattle, a jingle bell and a music box.

Miyazaki (1970) also developed a distraction procedure called the " Teddy bear test". It consisted of toys with loud speakers, a tone generator and light.

Much earlier the peep show technique was frequently used for children over 2 years. Recommended by Dix and Hallpike (1947) it involved allowing the child to view a set of cartoon or puppet characters through a peep- hole as a reward for a correct response by its illumination. Green's (1958) version of this uses a moving toy and is called a "pup show".

Liden and Kankkunen . (1969) were the first to use the term visual reinforcement audiometry to describe a modified COR procedure which they developed. They accepted any type of response behavior that could be judged and provided a reinforcement. It differs from CORA in two ways. Unlike in CORA where the speakers are at 30 ° azimuth, 70 cms apart with the reinforcer on the top, in Liden and Kankkunen's VRA the speakers were located at 90 ° azimuth, 15 cms from each of the child's ears. The reinforcers remain at 30 ° to 45 ° azimuth. The two ears are hence separated by the head shadow effect (Gerber, Jones and Costello, 1977).

A method of VRA may also be different in terms of loudspeaker arrangements. Magnusson. Borjesson and Axelsson (1997) did a comparison of loud speaker arrangements. The two arrangements were as follows.

1. Loud speakers mounted on separate movable arms and positioned 15 cms from each ear.
2. Loud speakers which were rigidly mounted close to the respective picture monitor at a distance of 50-70 cm from the child.

Comparison was done by measuring real ear SPLs and actual sound field conditions. The results indicated that predominantly monoaural stimulation was best achieved by using the 15 cm position. However, measurements were afected significantly by small head movements in this close position.

When assessing the acoustic as well as practical aspects it was concluded that loudspeakers mounted beside the picture monitors at a distance of 50-70 cm from the child makes a generally appropriate arrangement for VRA

Liden and Kankkunen (1969) found no need for total localization. Many children with impaired binaural or unilateral hearing would be rather poor at localization of sound (Durlach, Thompson and Colburn, 1981). Demand for successful localization in the COR task confounded basic sensitivity skills with higher order localization skills (McCormick 1993).

A next innovation was the use of a bar press procedure coupled with food reinforcement. It was called Tangible reinforcement operant conditioning audiometry (TROCA) by Spradlin and Lloyd (1965), Lloyd, Spradlin and Reid

(1968), Lloyd and Cox (1975). They used it mainly for the difficult-test population and the mentally retarded. In the TROCA, after the sound stimulus is given the infant responded by pressing the manipulandum. The reinforcement included a light to draw the infants attention to the area where the food was to be presented and then the food bit. When a visual reinforcer is used, it is called visual reinforcement operant conditioning audiometry (VROCA), (Jerger, 1984).

Haug, Baccaro and Guilford (1967) described a version of VRA. They used only one loud speaker 2 m from the child at 90 azimuth. Hence no localization was aimed at. This procedure to overcome the problem of testing only the better ear is the " Puppet in the window illumination test ". The tester is in the adjacent control room. A gross head turn is reinforced by the appearance of a puppet behind a lighted window. After a conditioning period with the sound field stimulus, each ear was assessed separately using headphone presentation but still associated with the glove puppet reinforcer in the observation window. Matkin (1977) found that, VRA is useful with ear phones and that it is successful with 90 % of both normal hearing and hearing impaired children, In sound field, VRA tests only the better ear in some children even though loudspeaker on each side of the child produce the stimuli or lights. Hodgson (1985) stated that a child with a severe hearing loss will not have learnt to localize sound hence it is best to use one loudspeaker in testing. To distract the child from looking at the loudspeaker constantly, an animated toy could be activated in another direction.

However, McCormick (1993) reported that success with conventional head phones is possible, but their experience suggests that the use of light weight insert earphones such as Etymotic ER-3A or eartone 3A provides an alternative means of obtaining ear and frequency specific data using VRA with fewer practical difficulties.

Haug ,Baccaro and Guilford (1967) reported results from 54 infants aged 5 to36 months. Sound field measurements were completed successfully on all but 2 children in the 19 to 24 month age range. Pure tone, air and bone conduction thresholds were successfully assessed on all but five children, two from the 5-12 month age range and three from the 19-24 month range. Of the 49 for when both sound field and head phone thresholds were assessed, the agreement at 500 Hz and 1000 Hz was in all cases within 10 dB.

Another popular method involves the use of Play-tone audiometer. This facilitates hearing evaluation in, 3 to 7 year old children. The child is conditioned to press a button on the response box following presentation of an auditory stimulus. A brief animated colour video occurs following each correct responses made. The test signal speech is adopted to the response speed of the child. In the automatic mode several validity checks are included (Keith and Smith, 1987).

The most recent methodology in VRA is the use of computer software based automated testing procedures. (Intelligent, Visual reinforcement audiometry IVRA, Visually reinforced infant discrimination VRISD) . The procedure used may be Classification of Audiograms by Sequential Testing (CAST), Optimized Hearing Testing Algorithms (OHTA), 5 - Up 5 - Down staircase procedure.

Bernstein and Gravel (1990) found that one of the main limitations of the VRA paradigm is the decrease in motivation with increase in trials. This lead to the order effect with the response gradually declining with change over to the consecutive frequency. They developed a single examiner computer assisted staircase procedure, the Interwoven Stair-case Procedure (ISP). It interwove three adaptive threshold searches using trial by trial randomization of the test frequency in a single test run to obtain threshold estimates at all three frequencies tested and a measure of motivation effects.

Eilerset ah (1991a) investigated the interaction of test parameters with infant behavior and hearing status in an attempt to devise an automated, four frequency threshold estimation procedure capable of being completed in a single session with a single examiner. A computer implemented model, designed to simulate infant responses using VRA, was developed. Results indicated that accuracy was most influenced by the probability of task orientation, which reflects factors such as attention, state and responsiveness in infants and is minimally affected by stopping rules. The results also suggested that accuracy and test length were adversly affected by starting levels. Starting levels close to threshold result in more accurate estimates of threshold than those farther from threshold. Test length used in this simulation as a measure of efficiency , was affected most by the stopping rule (defined by the number of reversals used) and to a lesser extent by starting intensity. In order to assess the adequacy of the model used in the simulation, a follow up investigation (Eilers et at, 1991b) compared results of VRA from 146 infants aged 6 - 2 4 months with normal and abnormal tympanograms. with simulation results. The comparison indicated that the procedure successfully distinguished the two groups of children.

Automated VRA facilities may include a manual system in which reliability of response is judged subjectively. One or two testers are used and fewer trials are run to establish thresholds. However technological advances, increased knowledge of infant learning and behavior and a desire to improve accuracy and efficiency has lead to the development of expanded, automated versions (FVRA) including computer assisted portable systems. An automated version of VRA may be implemented using an audiometer in the test room to access a computer interfaced to a logic system outside the test room. Communication with the computer from the test room may also be accomplished by activating switches connected to the interface. The equipment selects trial type, stimulus presentation and level activates reinforces and provides trial by trial record of the infants responses. A computer assisted system can be programmed to present a variety of digitized signals, to include pre-programmed control and probe trials, to limit the time window of the child's response and to reduce observer bias by introducing masking noise at the onset of every trail interval (McCormick, 1993). Other automated versions using modified VRA protocols may include interactive video techniques (Boothroyd, 1991)

The VRA paradigm has also been used extensively in supra threshold tasks such as speech discrimination ability (McCormick, 1993). Eilers, Wilson and Moore (1977) used a procedure known as the Visually Reinforced Infant Speech Discrimination(VRISD). Using this procedure they were able to demonstrate that a high percentage of infants aged 6 to 14 months could discriminate subtle speech contrasts.

Nozza, Rossman, Bond and Miller (1990) used the VRISD paradigm to investigate the effects of noise on the speech / sound discrimination of a group of infants 7 to 11 months old. Their data suggested that infant speech processing abilities are more susceptible to noise than those of adults.

Hence, newer procedures utilizing computer technology influences operant conditioning paradigm. They provide better, faster, accurate and more controlled ways of evaluating hearing in infants. The few draw backs may be high expense in installation of the software and inability of the tester to deviate from the preset or predetermined stimulus parameters once the testing are initiated.

The above were the early as well as the recent methods in VRA. Successful testing depends on the skill of the tester and the age of the child.

The customary factors like age of the subject, stimulus parameters and other test conditions apply to VRA also just like it applies to BOA or testing of adults. These factors may affect the testing independently or interactively.

Factors affecting VRA responses:

1) Age of the subject

Age of the subject has always been one of the most crucial factors in testing of children as,with age, the choice of the test method, the stimulus parameters and responsiveness of the child vary. A child in VRA is required to make a head turn, in order to be able to localize the sound or view the reinforcement. Hence the child should have attained head and neck control. Frisina (1963) says that a child can make an eye turn by 2-4 months. Northern and Downs (1974) found a lateral head turn possible in children by 6 months of age. Gerber (1969) reported that on an average a head turn takes 7½ months to be fully developed.

Suzuki and Ogiba (1960, 1961), Suzuki, Ogiba and Takei (1972) recommended that CORA be done for children from 1 years to 3 years as they successfully estimated thresholds in 85% of their cases. They suggested a starting intensity 30 dB above the estimated threshold followed by threshold estimation in descending order. Miyazaki's (197C) "Teddy bear test" was successfully used with children between 5 months and *2* years and with mentally retarded children. Miyazaki also reported that response of female infants was more mature than the males and this was also supported by Gerber(1969).

Wilson, Moore and Thompson (1976) found 60% success at 5months of age with TROCA using candy and trinkets. The same authors in 1977 reported that VRA is effective for infants as young as 5 months of age and thresholds can be obtained at 20 dBHL or less. Matkn (1977) found that the technique is useful with earphones and that VRA is successful with 90% of both normal hearing impaired children between the age of 12 to 30 months. Northern and Downs (1991) say that VRA and COR techniques are the evaluation procedures of choice in children between 6 and 24 months of age, although it should be obvious that the older children in this range will condition more easily and quicker than the younger children.

Primus and Thompson (1985) found that two-year-old habituated to VRA more rapidly than one year old. Later again in 1985 they found mat the rate of habituation in VRA appeared to increase with age under the assumption that habituation and threshold reliability are related. Hence, reliability may vary as a function of patients age. In an earlier study Thompson and Folsom (1984) also noted that two year olds required fewer presentations than one year olds to establish minimum response levels.

Barr (1955) used VRA for puretone audiometry in pre school children. The Play tone audiometer uses VROCA, a slightly modified version of the VRA technique. It was a computer-controlled audiometer, which could be operated by the children themselves to get the reinforcement (in the form of video images), in response to sound stimuli. This method facilitated hearing assessment in 3-7 year old children (Keith & Smith, 1987).

The age of a mentally etarded child also needs to be given due consideration. They are compared with the normal based on their mental age. Greenberg, Wilson, Moore and Thompson (1978) reported a study of the use of VRA with 41 children with Down's syndrome aged between 6 months and 6 years. Using complex noise stimuli they found that about one-third of the children did not turn towards the sound spontaneously, nor could they be taught to turn for the visual reinforcement of the remaining two-thirds thresholds were established for the complex noise in 81% of the cases in a single session. Threshold values ranged from 30-60 dBSPL. Hence in conclusion they said that downs syndrome children with a developmental age of less than 10 months could generally not be tested with VRA procedures. In testing Down's syndrome infants with VRA, Wilson (1982) found that they did not achieve a high success rate until ten months of BSE) equivalent age (Bayley scales of infant development).

Similarly, efficiency of VRA has also been studied in other associated abnormal condition. Thompson and Folsom (1992) investigated the relationship between corrected and developmental age and auditory responsiveness as predictions of VRA performance is 60 pre-term infants. In contrast to the results of studies using VRA with full term infants, who have shown good response to VRA by a chronological age of 6 months, the same level of response was not achieved by pre term infants until approximately at 6 months developmental age (8 months corrected age).

Gravel and Tranquina (1992) used VRA to obtain threshold estimates for 211 babies and infants aged 6 to 24 months who had the following abnormal conditions ; sensory neural hearing loss, otitis media, cranio facial abnormalities and neuro-developmental disorders. At the first assessment session frequency specific data were obtained either under headphones or in the sound field from 90% of the infants. 84% of them provided ear specific results. This study declared VRA to be a practical and efficient procedure for the routine assessment of most 6 to 24 month old infants, including those considered difficult-to-test.

Keeping in mind the previously mentioned studies we can conclude the VRA can be successfully used with children from 6 months to 2 years of age. A lower age group child may be unable to make a head turn and an older child will get habituated very fast to the test and hence will give up responding adequately, unless the test is completed with in a few presentations only. VRA has been successfully used with children with associated problems like mild and moderate mental retardation, hearing loss, cranio facial abnormalities or other neuro developmental disorders. A few studies however have been unable to use it successfully with Down's syndrome children of less than 10 months of developmental age.

2) Stimulus variables

In general various stimulus factors have been found to affect VRA. Liden and Kankkunen (1969) found warbled tones more interesting for young children. Localization of skills among children vary considerably and seen to be a function of age and the parameters of the stimulus warbled tones are much more difficult to localize than speech or narrow band noise stimuli (Northern and Downs, 1991). Thompson and Folsom(1985) found that after young children had been conditioned to perform VRA, there were no significant differences in hearing thresholds as a function of band width of auditory stimulus (2000Hz warble tone, 2000Hz tone pips and 2000-400CHz noise band). Primus and Thompson (1985) found that in 1 year olds who met a conditioning criterion, neither complexity.(mid frequency band of noise vs 1500 Hz warble tone) nor intensity (50 dB HL vs 25 dB HL) of the auditory stimulus had any effect on the number of responses obtained prior to habituation of response. Hence, the above two studies suggest that if conditioning can be established, the bandwidth characteristics of the stimulus have no influence on the responsivity of infants and the examiner is therefore free to use auditory signals with a higher degree of frequency specificity such as warble tones. Mc Cormick (1993) opines that VRA becomes most powerful if it can be used to estimate thresholds at 500 Hz. 1000 Hz, 2000 Hz and 4000 Hz. With hearing losses it may be useful to use 250 Hz and occasionally 3 and 6 KHz as well to monitor sloping hearing loss.

Walker, Dillon and Byrne (1984) recommended the warble tone as the stimulus of choice and say that pure tones are not recommended for sound field use. There have also been various studies on VRA, comparing earphones presentation, speaker presentatior and presentations with the insert earphones.

Tolland (1992) did VRA in sound field Vs insert earphones in a group of 10 infants aged 6-19 months (6 had hearing with in normal limits and 4 had varying degrees of hearing loss.) The mean thresholds obtained from 5 infants with normal hearing levels were in agreement with those reported in the literature for sound field testing and better than those reported for head phones testing.

The study hence demonst ates the feasibility of using insert earphones for the ear specific information. Homer and Horner (1979) used a VRA technique to estimate headphone air conduction thresholds in 31, 5-11 month old infants. In six cases the procedure was unsuccessful. In the remaining 25 infants, thresholds could be established using head phone. Average number of tone presentations required to establish threshold was 8.7. Mean air conduction thresholds ranged from 0 to 30 dB HL. Matkin (1977) found VRA is useful with earphones, as sound field VRA tests only the better ear.

As far as the choice of a stimuli is concerned, warble tones, noise or speech are always preferred and pure tones are not recommended. The insert phone is the best choice followed by the head phone and then the sound field testing as the former give ear specific information. Not only the stimulus characteristics and presentation methods affect VRA Studies have also concentrated on the effects of the reinforcer on the response behavior of infants.

3) The reinforcer and the reinforcement

Each child varies from another with respect to preferences of the reinforcer. Some children are more responsive to social reinforcers and others to visual reinforcement. This depends on their social maturity also. Doll (1953) reported that 12-18 month olds are relative y immature in social development. According to Mussun, Conger and Kagan(1969), 12-18 month olds are more visually responsive.

Moore, Thompson and Thompson (1975) studied the influence of four reinforcement conditions on the auditory localization behavior of normal children 12 to18 months of age. The same stimuli were used for all the subjects at supra-threshold levels. The four conditions were

- No reinforcement
- Social reinforcement
- Simple visual reinforcement (blinking light) and
- Complex visual reinforcement (animated toy animal).

The two visual reinforcement conditions produced the most localization responses followed in order by the social reinforcement and no reinforcement. They concluded that combined use of visual and social reinforcement would complement each other and these factors have implications for threshold measurements.

Wilson and Thompson (1984) report that visual stimuli do indeed reinforce (increase the frequency of) head turn responses for infants as young as 5 months of age. Moore, Wilson and Thompson (1976, 1977) found that 2-5 month olds and 7-11 month olds responded significantly more frequently to the signals that are reinforced visually than to those that are not reinforced. In another study (1977) they used the complex reinforce! to examine the lower age boundary of VRA. Ten infants were taken in each group of the three age groups 4 months. 5 to 6 months and 7 to 11 months. Each of them was given 30 visually reinforced trials and 10 control infants were given trials with no reinforcement conditions. The mean response rate was significantly higher for the reinforcement, for the 5 to 6 and 7 to 11 month groups. This result indicates that VRA is usable (at least at higher SPL s) for normal children from 6 months onwards.

Primus and Thompson (19K5) suggest use of novel (multiple) reinforcers as they severe to increase the number of responses obtained prior to habituation to the VRA task Four different toy animals served as the reinforcers - a standing golden bear that beat a drum, a bunny that played a drum set, a panda that played a drum set and a pup that moved is legs, sat up and barked. Better responses were obtained by the group, which received 4 reinforcers than the control group that received just one of them. In the same study effects of using intermittent reinforcement schedule (67 to 7 5 %) as opposed to the 100 % reinforcement schedule, (which is typically used in the VRA protocol) was investigated. Their investigation revealed no significant differences in response behavior between different reinforcement schedules.

An earlier study of reinforcement schedules was carried out by Hetsko and Gans (1981). They measured the number of responses produced by groups of 12 to 24 month old children receiving 100% or 50% reinforcement in conditioned orientation reflex audiometry. They found no difference in performance criterion of 80%. In the ten trials following this criterion, however the group receiving 50% reinforcement, which provided more responses than the continuously reinforced group,

Thompson & Folsom (1985) in their study on 30 normally developing 1 year old infants and 63 premature children between 8 to 24 months revealed that using reinforcement, responses could be obtained for narrower bandwidth stimuli also where as in case of no reinforcer a broader bandwidth was required.

Primus (1987) reported that use of animation and not the toy reinforcers (non animate still toys with out any action or animation or only light) resulted in more than two-fold increase in the number of subject responses. Thompson and McCall (1992) evaluated strategies for increasing number of VRA responses before habituation from normal 1 and 2 year old children a single clinical visit. In agreement with previous studies they found that use of novel reinforcers significantly delayed the onset of habituation but that 2 year olds habituated more rapidly than 1 year olds did not provide additional responses even after a short break in contrast to the 1 year olds who provided on an average a further five responses after being given a short break.

Culpepper and Thompson (1994) evaluated the effects of reinforcer duration on response behavior. The reinforcer duration's used were 0.5 sec, 1.5 sec and 4.0 sec. The stimulus used was a 50 dB HL complex noise band pass signal. The VRA was done fore 6 pre-term 2 year olds. Decreasing the duration of a subjects exposure to the visual reinforcement resulted in more responses with significantly slower habituation rates. They also concluded that the amount of audiometric information obtained from children in the upper age bracket of VRA can be increased by decreasing theii exposure duration to the visual reinforcement.

Appropriate and adequate reinforcers and reinforcement is the essence of VRA. The reinforcers should be age appropriate, should be multiple, randomly sequenced and of a brief duration in order to be interesting for a child and to prevent or delay habituation, which affects the test results.

4) Tester Bias

This has been overcome by the automated hearing testing procedures as mentioned earlier in the methods used for VRA. The computerised hearing testing defines the correctness of response in various ways, like, using a fixed response interval, control trials, being able to abort a trial (in case a false positive is reinforced), randomising the stimulus frequencies as well as the reinforcers etc.

5) Effect of the distractor

Detrimental effects of introducing alternative i.e. visual stimuli into the test environment have been questioned, as the test signal must compete with the visual stimuli for attention (Primus, 1988) To test the above effect Primus (1988) made the following modifications

i) A pre-trial warning was provided for each signal presentation to cue the child that signal presentation was imminen.

ii) The distracting toys were eliminated during signal presentation.

The results on 16 infants evaluated with conventional VRA and modified VRA revealed an average 5.5 dB improvement in threshold with the modified technique. Correction for adult performance in similar tasks indicated a 3.3 dB attentional effect between infant and adult thresholds. The shift in thresholds reflects on the adequacy of VRA as a threshold procedure.

Hence, while carrying out VRA it should be seen to that the distractor does not effect the test results.

Thresholds BOA Vs VRA

There have been studies to determine the minimum response levels of infants and young children by BOA and VRA independently as well as in comparison with each other. According to Northern and Downs (1991) thresholds or the minimum response levels by BOA of babies reduced to better levels with age. From birth to two years of age the warble tone thresholds improved from 75 dB HL to 25 dB HL respectively. For speech it improved from around 50 dB HL to 5 dB HL respectively from birth to 2 years of age.

Hoverstein and Moncur (1969), using interrupted 500Hz and 4000Hz puretones in a BOA procedure with 8-month-old infants, reported that the 50% response level occurred at 45 dB 5 PL at 500 Hz and 49.5 dB SPL at 4000 Hz. However Moore and Wilson (1977) observed that slightly younger infants in the VRA paradigm got results 25 dB lower or better at 500 Hz and 35 dB lower or better at 4000 Hz. Their VRA data did not show the pronounced "developmental trend in response levels reported for BOA, especially high frequency puretones (Hoverstein & Moncur 1969, Thompson & Thompson 1972)

Wilson, Moore and Thompson (1976) studied 90 normally developing infants 5-18 months of age. Threshold was first obtained by BOA followed by VRA. This was done using a complex noise signal. In VRA a complex reinforcement was used and auditory thresholds were estimated using a "20dB down, l0dB up" technique. Threshold was the lowest presentation level at which the infant responded at least 3 of 6 times. The results showed that the VRA responses were significantly better than the behavioral observation responses. Average thresholds across subjects fell in the 21-29 dBSPL range with the 10th and 90th percentile points being 20 and 40 dBSPL for the 5 month olds and 20and 30 dBSPL for the 6- 18 month olds respectively. Hence,the variability for children over 6 months old was only 10 dB and this was very encouraging.

Wilson and Moore (1978) used VRA to estimate headphone thresholds in 30 normal infants aged 6-7 and 12-13 months respectively. Thresholds were measured at 500 Hz, 1000 Hz, 4000 Hz in two 15 minutes sessions using warble tones. Average thresholds were 33 dB SPL for 5000 Hz . At 5000 Hz the younger age groups gave thresholds 5 dB worse and 24 dB SPL at 1000 Hz and 4000 Hz respectively. For the latter 2 frequencies there was no difference between the age groups . Wilson and Moore (1978) Goldman (1979) stated that VRA can be used successfully for frequency specific stimuli and VRA can be used to track estimated thresholds in infants down to with in l0dB of adult thresholds.

Another study by Karikoski et al(1998) was designed to longitudinally compare each child's best BOA response level(lesser than 12 months of age) with the conclusive puretone thresholds of the better ear by conventional play audiometry (3-6 years).At hearing levels of 30 to 39 dB, BOA registered 10-15 dB poorer levels than the pure tone audiometry. The puretone averages of 500 Hz, 1000 Hz and 2000 Hz of 50-69dB agreed best with BOA responses. In severe impairments of more man 70 dB HL the BOA registered good hearing. Hence they concluded that

1) Pure-tone hearing levels agreed with that of BOA at the frequencies 500 Hz to 4000 Hz.

2) BOA averages less than 30dB rarely indicate hearing loss demanding fitting of a hearing aid.

Due to maturation of auditor' acuity the puretone thresholds are higher in normal children under 3 years of ag; than in older children or adults (Suzuki and Ogiba 1960; Liden and Kankkunen 1969)

VRA is reported to give more precise responses levels than BOA alone (Moore, Thompson and Folsom 1992) as BOA is considered to be a test of responsiveness and not thresholds (Gans, 1987). Berg and Smith (1983), Nozza and Wilson (1984), report that wher infants are under operant control inter-subject threshold reliability is high and equivalent to that of adults.

Intra-test, Inter-test and test retest-reliability BOA Vs VRA.

Primus (1991) said that test-retest reliability warrants special concern with infants because they experience habituation and other shifts in behavioral state that could significantly affect their performance. However, he also stated that single session results are particularly important for infants who cannot or do not return for multiple sessions.

Fulton and Spradlin (1971) demonstrated that the establishment of stimulus response control prior to each assessment session was a major factor in determining intra-test reliability. They determined intra-test reliability with three groups of severely retarded children. One group required to meet the stimulus response criterion each session before threshold measures were determined. Second group was required to meet the criterion only once. The third group was not required to meet any criteria other than to demonstrate that they comprehended the basic task by responding to auditory stimulus.

Results indicated mat as stimulus response criteria were relaxed, intra-session threshold variability increased. The investigators then selected four of the most variable subjects from the latter two groups and applied the more stringent criteria to determine if threshold variability decreased. Results indicated that variability decreased supporting the contention that maintaining stimulus response control criteria is an important fact or in threshold assessment.

Pulton & Spradlin (1974'.) and Spradlin, Locke and Fulton(1969) provided evidence of repeated measure relability with severely retarded children. This reliability (±5dB) has been demonstrated under varying conditions of reinforcement for as long as 32 sessions (Fulton and Spradlin 1974a) and with both ascending and descending threshold assessment procedures.(Fulton and Spradlin, 1971; Spradlin, Locke, & Fulton 1969).

Nowells(1971) found that 2 year old children provided reliable (±5 dB) test retest thresholds with operant procedures. Yarnall (1973) compared conventional and operant audiometric procedures with four groups of children. The groups represented normal easy to test children (mean age was 9 years 4 months); relatively easy to test hearing impaired children (mean age was 8years 9months); difficult to test severely retarded children (mean age was 15 years, 3 months) and difficult-to-test deaf- blind multiply handicapped children (mean age was 10 years 1 month.) The result indicated that some thresholds were not obtainable with conventional procedures, where as the thresholds were obtainable for all conditions with operant procedures. It was also demonstrated that subjects in total and by group showed greater test-retest reliability (±5dB) for the operant procedure than the conventional procedure. This test retest data indicated that the operant procedures (even with normal easy to test subjects) produce less variability than conventional procedures. Test time was longer for the operant procedures. The investigator contended that the additional tune warranted the demonstration of improved audiologic information.

Yarnall (1973) also found concurrent validity between operant and conventional threshold measures. Wilson, Moore and Thompson (1976) found a threshold shift of no more than 10 dB on retesting after 2 to 5 months by operant measures. Trehub and Schneider (1983) determined a correlation of 0.82 between infant thresholds on operant procedures acquired in sessions separated by at least one week.

Rudmin (1984) reported two 11 month old infants with severe sensorineural hearing losses in whom VRA was used to define headphones thresholds across the range 250 Hz to 4000 Hz for each ear. Test retest reliability across two sessions,(l day in one case and 5months in the other) was good, thresholds differing by no more than 15dB.

Talbot (1987) report a study of 17 hearing impaired infants who were first tested using VRA procedures when aged between 6 and 27 months (9 with sound field VRA using warble tones and 8 with sound field VRA using puretones)

The same children were retested at 25 and 41 months respectively using conventional play audiometry at frequencies 250 Hz, 500 Hz, 1000 Hz and 2000 Hz. A down l0dB, up 5dB technique was used for both the techniques. All children showed SNHL of moderate or severe degree. Agreement between VRA thresholds and later play audiometry was very good. Individual cases did not vary between VRA and play audiometry by more than l0dB across all thresholds except for two cases who had a difference of 15 dB and 20dB between VRA and play audiometry respectively.

Primus (1991) determined the test retest reliability in a single evaluation session on 8-11 month olds in both operant and non operant procedure. He concluded mat threshold reliability across test sessions is higher for operant audiometric procedures than non-operant audiometric procedures. Hence, the general acceptable view is that operant procedures like VRA have higher test retest reliability as well as intra test and inter test reliability than non-operant procedures like BOA.

Thus the review on BOA & VRA show that both tests have their advantages. However, BOA also has the advantage of being the only behavioral test that can be administered on infants younger than 6 months. VRA is found to be a more reliable test for children between the age of 6 months to 2 years.

METHODOLOGY

The study compared thresholds obtained on infants and children using two tests, i.e., Behavioral Observation Audiometry (BOA) and Visual Reinforcement Audiometry (VRA). Both the tests were conducted one after the other with a rest period of about 20 minutes between the two. The behavioral observation audiometry always preceded the conditioned visual reinforcement audiometry.

Subjects

The subjects consisted op thirty children between the age of 6 months to 3 years. There were ten subjects in each sub-group.the sub-groups being 6 months to 12 months, 12 months to 24 months and 24 months to 36 months. The mean age was 1 year 6 months. The criteria for the children to be included in the study were :

1) Normal birth history.
2) Normal general or overall development according to parental report.
3) No parental concern about hearing loss or middle ear involvement.
4) Normal vision and no unusual medical history based on parental report.
5) No physical or emotional disturbances.
6) No exposure to assessments involving reinforcers using toys etc. at least 5 months prior to the testing.

Sex or socio-economic status was no bar for subject selection.

Auditory stimuli

The following test stimuli were used for both BOA and VRA.

1) Frequency modulated (warble) tones at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz

2) Speech stimuli consisting of th e stimulus *ba.ba:/*

Live voice was used in BOA and recorded stimuli for VRA. The speech signal for VRA was pre recorded and supplied along with the instrument.

BOA

a) Instrumentation

The stimuli were presented through a Grason Stadler 61 audiometer. They were transduced through a Grason Stadler speaker in the test room.

b) Test room Arrangements

The testing was carried out in a sound treated two-room situation. The child was seated comfortably on the parent/ guardian's lap in the test room at a distance of 1 m from the loudspeaker.The loudspeaker was placed at an angle of 45° azimuth. One of the two observer s was seated in front of the child and the other observer was seated at an angle of about 50° azimuth with reference to the child. The second observer could see the child properly without distracting the child.

c) Stimulus parameters for BOA

The warble tones were puretones warbled at a rate of 5Hz with the allowable deviation of ±*5%* around the selected center frequency. Stimulus duration was 2seconds and inter-stimulus interval varied between 5-15 seconds approximately, depending upon the activity of the subject. Testing was initiated at 20dBHL for all frequencies and for speech. A pre-determined order of stimulus presentation was followed till the termination of the test.

d) **Test procedure**

The test involved one tester (in the control room) and two observers (in the test room). The signal was always presented only after one of the observers seated in front of the child got the child's attention to the midline. A colorful but non noisy toy/ object was used as a distractor. The testing for all the stimuli was started at 20dBHL. The signal increment was in l0dB steps. At each intensity, the stimulus was presented twice. A predetermined order of stimulus presentation was used, i.e., two intensities on one frequency followed by two intensities on the next frequency. Speech stimuli were presented randomly between the warble tones.

One or more of the following were considered as a response if it occurred at least within 3 seconds of the stimulu s presentation: -

- Aural palpebral reflex
- Startle response
- Eye movement

- Head turn
- Body/ limb movement
- Imitation of the signal
- Crying /cessation of crying
- Smiling/laughing or pointing behavior.

Each observer noted the responses independently. Calibration of the sound field stimulus was monitored at regular intervals. (ANSI standards, 1989).

e) Scoring procedure

The two observers scored the response behavior to the various trials. Both were post-graduate students of speech language pathology and audiology who had previous experience of BOA. The observers were told to record the presence or absence of a response with in 3 seconds following the test signal. The lowest level a: which both the observers reported having observed a response was considered the threshold.

VRA

a) Instrumentation

The children were tested using the IVRA-100 (Intelligent Visual Reinforcement Audiometry) developed by the IHS (Intelligent Hearing Systems) winch is a computer based instrumtent. The signals were tranduced through a sound field speaker system (JBL).

b) Test room arrangements

The testing was carried out in a sound treated two-room situation. The IVRA computer system was housed in the control room while the sound field speaker system was in the test room. The child was seated comfortably on the parent/ guardian's lap in the test room at a distance of 1 m from the speaker placed at an angle of 45° azimuth. The examiner was seated in front of the child. The four reinforcer toy cabinets were placed next to the speaker which delivered the test stimuli.

c) Stimulus parameters

Stimulus used for conditioning was a 500 Hz, 70 dB HL warble tone. Testing was initiated at: -

60 dB HL for 6 month to 12 month olds and 50 dB HL for 12 month to 24 month olds for both warble tones and speech. This was based on the modified Auditory Behavior Index given by Northern & Downs (1991). It has been consistently observed that older children respond to lower intensities when compared to younger children. The warble tones were warbled at a rate of 20Hz with the allowable deviation of ±20% of the selected center frequency. Each warble tone was heard four times with a gap of 500 ms each other. Duration between two test signals varied from 5-10 seconds depending on the activity of the child. Duration of the reinforcer was 3 seconds and the response interval was 5 seconds (time within which the response should be reinforced).

d) Test procedure

Subject particulars and stimulus parameters were loaded before the testing. Each test began with a training procedure. The infant's attention was maintained at midline by the examiner using a series of quiet distractors before every stimulus presentation during the training and subsequent testing. The number of training trials depended upon the child's ability to be conditioned. Training was followed by testing using the OHTA (Optimized Hearing Testing Algorithm) procedure. The four frequencies were tested non-sequentially and the intensities varied automatically depending on the child's responses.

A response was defined as a head turn towards the stimulus or the reinforcer which should occur with in 3 seconds of the stimulus presentation. For every response the visual reinforcser was activated with in the stipulated response interval of 5 seconds. The "head turn button"/ "reinforcer button" was also pressed if the infant responded during control trials, (stimulus absent trials). These data were used to evaluate the infant's false alarm behavior. A head turn initiated by chance and not in response to sound if reinforced was not counted as a response. The examiner deleted the trial by pressing the "abort button". The next trial was identical in type to the aborted signal. The instrument automatically indicated the termination of the testing. Calibration of the sound field stimulus was monitored at regular intervals (ANSI, 1989).

e) Recording of results

All trial responses were recorded automatically in the particular file name or number assigned to the subject to bae retrieved later.

The thresholds thus obtained using the two techniques i.e. BOA & VRA were subjected to statistical analysis (mean, standard deviation and t-test of significance between means).

RESULTS AND DISCUSSION

The present study aimed at comparing the hearing responses and thresholds obtained on infants and young children using behavior observation audiometry (BOA) and visual reinforcement audiometry (VRA). The subjects were divided into three age groups, (i.e. 6 to 12 months; 12 to 24 months and 24 to 36 months) with each group having ten subjects. The thresholds for the warble tones of four center frequencies (500 Hz, 1000 Hz. 2000 Hz, and 4000 Hz) and speech stimuli (ba:ba:) were obtained for the 30 subjects. These thresholds were statistically analyzed using the following procedures :-

A) The mean and standard deviation of the thresholds were calculated for BOA and VRA. This was done with respect to each stimuli for the three age groups.

Based on this the following we re analyzed

1. Comparison of thresholds across the warble tones within each age group (t-test)
2. Comparison of thresholds for each stimulus across the three age groups (t-test).
3. Responses and thresholds for all subjects as seen in BOA and in VRA respectively.
4. Speech thresholds vs thresholds of each warble tone (t-test)

B) The Wilcoxsin paired t-test was done to compare the thresholds for each stimulus across age groups and test procedures.

C) Test retest reliability of BOA and VRA were also checked.

Results Of BOA

A) Mean and standard deviation of the BOA responses for 10 subjects in each of the three age groups was obtained for each stimulus. This is shown in Table A.

Table A : Mean, SD and Range for responses obtained through BOA.

		A 6-12 months	**B 12-24 months**	**C 24-36 months**	**Avg. of 3 age groups**
	M	28.0	34.6	27.0	29.8
500Hz	SD	5.27	5.23	5.16	
	R	23-33	23-33	23-33	
	M	36.0	37.0	34.	35.6
lOOOHz	**SD**	6.99	4.83	5.16	
	R	30-50	30-40	30-40	
	M	35.0	38.0	35.0	36.0
2000Hz	**SD**	5.16	5.42	6.03	
	R	29-39	29-39	29-49	
	M	38.0	37.1	38.	37.7
4000Hz	**SD**	5.76	4.01	7.37	
	R	29-49	29-39	29-49	
	M	29.2	30.0	28.0	29.0
Speech	**SD**	6.85	5.27	4.83	
.	**R**	25-45	25-35	25-35	

M- Mean (dB), SD- Standard deviation, R- Range.

1. **Comparison of BOA responses across the warble tones, within each age group.**

The mean BOA responses (Table A) for the various stimuli were compared using the t-test. The results revealed that there was no significant difference between the means across the 3 frequencies, 1000 Hz, 2000 Hz and 4000 Hz. The threshold for the 500 Hz stimuli was however significantly lower than all the other three frequencies (P:< 0.05) for the youngest and the oldest age group. It was not significantly different for the middle age group. The results of the present study is supported by research done on behavioral observation. Eisenberg (1976) found that infants' hearing for a 4000 Hz pure tone, is poorer than for a 500 Hz tone. This observation supports the view that infants hearing may be poorer in the high frequencies and better in the low frequencies. Moore and Wilson (1978) also in their study found that 4000 Hz is not inherently a signal that infants do not respond to. It is the signal infants prefer not to respond to. Hoverstein and Moncur (1969) said that infants are much more responsive at 500 Hz than at 4000 Hz and said that this simply was not true when the paradigm was changed.

This finding, of significant y better response levels for 500 Hz is contrary to many earlier studies which report a preference for 3000 Hz stimuli and its adjacent or higher frequencies in infants (Downs & Steritt 1964, Eisenberg, 1966). Some studies state that infants have a greater sensitivity than older persons for extremely high frequencies. This may be because high frequencies are the first to develop and function, followed by the low frequencies (Pujol Lavigne - rebillard, 1992). Also according to Von Bekesy (1960) individuals normally lose 80 Hz from the high end every 6 months of life, i.e. Individuals lose high frequency hearing (Gerber, Jones and Costello 1977). However, there are other studies that report that infants do not respond to any one stimuli more than the other especially in children over 2 years (Bench, 1969; Thompson and Thompson, 1972).

2. Comparison of BOA responses for each stimulus across the three age groups.

The mean BOA responses were evaluated across the three age group using the t-test This was done for each test stimulus. It was found that only for the 500 Hz stimuli ($p < 0.05$), there was a significant difference for the three age groups. At 500 Hz the middle age group showed significantly higher response levels than the younger and the older age groups

No developmental trend in thresholds was seen across the three age groups. The younger and the older age groups obtained significantly lower thresholds than the middle age group. This could be because of the small sample size (10 in each group). However, most studies on the development of auditory behavior in infants show that thresholds improve with age (Sweitzer, 1977 ; Northern and Downs 1991). This has been attributed to the maturation of the auditory acuity as well as **a** response abilities (Gans, 1987 ; Ling, Ling and Doehring, 1970).

3) Comparison of **BOA** responses of all 30 subjects

The mean responses obtained for all thirty subjects for the stimuli 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz and speech were 29.8 dB HL, 35.6 dB HL, 36 dB HL, 37.7 dB HL and 29 dB HL respectively. The range of responses for the warble tone was between 28 dB HL to 33 dB HL (Table A).

The BOA responses obtained in this study were higher than the normal adult thresholds. Thompson and Weber (1974), Northern and Downs (1991) also reported that infants and children lave minimum response levels, which are higher than the normal adult thresholds. According to the modified Auditory Behavior index (McConnell and Ward, 1967) responses of 7 month to 2 year old children range between 25dB HL to 45dB HL for warble tones. This is in agreement with findings of the present study. However, the responses for speech stimuli were reported to be as low as 10 to 5 dB HL for 7 month to 12 month old children by McConnell and Ward (1967). The children in the present study responded at a higher level. This could be because of different stimuli used in the two studies. In the present study the stimulus /*ba* :ba:/ was used which had a short duration. The stimuli used by McConnell and Ward, (1967) could have been a more familiar one or of a longer duration.

4. **Comparison of BOA response levels for speech Vs warble tones.**

The mean response for each of the warble tones (500 Hz, 1000 Hz. 2000 Hz and 4000 Hz) was compared with the speech responses. This was done for each age group using the t-test. The me an speech responses were better than the warble tone for all the three age groups. There was a statistically significant difference between the warble tones and the speech response levels ($p < 0.05$), the speech response level being better. However, this difference was not seen between 500 Hz and speech responses (Table B).

Table B : Significance of difference between speech thresholds vs warble tone thresholds.

	T values for 6mo to 12m		T values for 12mo to 24mo	T values for 24mo to 36mo
500 Hz	0.35		1.95	0.43
1000 Hz	2.15*		3.11*	2.6*
2000 Hz	2.16*		3.18*	2.8*
4000 Hz	2.98*		3.45*	3.4*

* Significant at $p < 0.05$

The reason why the children responded to speech at lower levels could be attributed to the fact that it is a more natural sound than warble tones. Children are exposed to voice more than any other stimulus in their environment hence they are more familiar with speech. .Also, speech consists of a broader range of frequencies and authors have found that infants respond to broad band stimuli more than narrow band stimuli or pure tones (Mendel, 1968 ; Thompson and Thompson, 1972 ; Thompson and Folsom, 1985). Various other studies also report that complex stimuli or speech yield belter response levels than pure tones or warble tones for infants and children (Eisenberg, 1965 ; Hoverstein and Moncur, 1969 ; Ling, Ling and Doehring, 1970).

Results of VRA

A. The mean and standard deviation in VRA thresholds for the 10 subjects in each of the three age groups was obtained with respect to each stimuli. This is shown in Table C.

Table C : Mean, SD and Range for thresholds obtained on VRA

		A **6-12 months**	**B** **12-24 months**	C 24-36 months	Avg. of 3 **groups**
500Hz	M	26.3	27.6	25.3	26.4
	SD	4.10	5.73	2.74	
	R	.22.1-35.1	22.1-40.1	22.1-32.1	
lOOOHz	M	38.0	31.9	36.43	35.4
	SD	4.73	4.62	2.23	
	R	33.3-48.3	25.3-56.3	33.3-40.3	
2000Hz	M	30.1	31.0	32.0	31.0
	SD	6,64	6.31	3.94	
	R	20.2-43.2	28.2-58.2	28.2-41.2	
4000Hz	M	30.4	32.1	29.2	30.5
	SD	3.13	5.27	3.39	
	R	26-34	26-41	26-34	
Speech	M	38.6	38.0	38.9	38.5
	SD	9.29	6.54	10.71	
	R	30-55	30-50	22-58	

M- Mean (dB), SD- Standard deviation. R- Range.

1. Comparison between VRA warble tone thresholds.

The t-test was used to evaluate the significance of difference between means of the four warble tones for each age group.

The t-test revealed that there was a significant difference for the 500 Hz stimuli (p:<0.05) from the other three frequencies. The 500 Hz stimuli showed better thresholds, as seen in BOA. The results of the VRA test also support the research that the hearing of infants may be poorer at higher frequencies and better in lower frequencies (Moore and Wilson, 1978 ; Hoverstein and Moncur 1969).

Primus and Thompson (19 55) found that once conditioning criteria is achieved there is no advantage of on; stimulus over another especially for children over the age of 2 years . This contradicts the findings of the present study where significantly better thresholds were Obtained at 500 Hz. This better threshold was probably seen for all the three groups, since all the children were trained to give conditioned responses using this frequency, thus making the signal more familiar.

2. **Comparison** of VRA **thresholds between the three age groups.**

The mean thresholds for each of the warble tones and speech stimuli were compared for the three age groups.

The t-test revealed no significant difference between the age groups for most of the stimuli. The only exception was that the middle age group showed significantly better thresholds than the other two age groups for 1000 Hz stimuli.

The range of thresholds was also greater for the 1000 Hz stimuli in the middle group when compared to the other two age groups. This variability could have also lead to this difference.

3. Comparison of VRA thresholds of all subjects.

The mean VRA thresholds obtained were 26.4 dB HL, 35.4 dB HL, 31.0 dB HL, 30.5 dB HL and 38.5 dB HL ::or 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz and speech (Table C).

Mean VRA thresholds were higher than the normal adult thresholds. Rudmose (1967), Kaga and Tanaka (1980) states that infants and children on behavioral tests including the VRA, paradigm, yield higher thresholds than the normal adult thresholds. The find ngs of the present study are in agreement with these studies. Mean VRA thresholds for all 30 subjects in the study ranged from 25 to 38 dB HL for the warble tones and were around 38.0 dB HL for speech stimuli.

4. **Comparison of speech thresholds vs warble tone thresholds.**

The t-test was used to determine the significance of difference between means for the speech thresholds and each of the warble tone thresholds. (Table D).

Table D : Significance of difference between speech thresholds vs warble tones.

	T values or 6mo to 12mo	**T values for 12mo to 24mo**	**T values for 24mo to 36mo**
500 Hz	3.6*	3.5*	3.7*
1000 Hz	0.17	2.34*	0.5
2000 Hz	6.64*	2.25*	1.86
4000 Hz	2.46*	5.27*	3.39 *

* Significant at p: < 0.05

There was a significant difference between speech and the warble tones for all the stimuli and for all the age groups except the 1000 Hz tone for the youngest and the oldest group and 2000 Hz for the oldest group. The speech thresholds were poorer than the warble tone hresholds in general.

The probable reason for this result could be that the speech stimuli was a recorded one and hence lacked the naturalness of a live voice. Thus it was not interesting enough to attract the attention of the children. Studies regarding use of live voice or recorded voice Lave been relatively few and have shown contradictory results. Goodhill (1954), Hoverstein and Moncur (1969) found recorded stimuli better than live voice in eliciting responses. The only study that finds no difference between live and recorded voice was by Fisch (1965).

Further, the reason for higher thresholds obtain in speech could be that VRA speech was always the last \ arameter tested in the whole test procedure . Hence, by the time children went through BOA followed by VRA warble tones, their attention had dropped.

B. Comparison of BOA response *Vs* VRA thresholds.

The significance of differen :e between mean thresholds obtained through BOA and VRA was done using the paired t-test. (Table E).

Table E : Significance of difference between BOA and VRA thresholds.

	T values fe 6mo to 12n	**10**	**T values for 12 mo to 24mo**	**T values for C 24mo to 36mo**
500 Hz	0.76		3.22*	0.87
1000 Hz	0.71		2.29 *	1.29
2000 Hz	1.85		2.59*	1.04
4000 Hz	3.53 *		2.28 *	3.29*
Speech	2.46*		2.88*	2.89*

* Significant at p : < 0.05

A significant difference at the 0.05 level, between BOA and VRA thresholds was obtained for all the stimuli in the middle age group. Such a significant difference was seen only for 4000 Hz and speech for the younger and older age groups. VRA showed belter thresholds for the warble tones than BOA. This trend was seen for most of the other frequencies for the younger and older age groups, though it was not statistically significant. This result is in agreement with some of the earlier studies (Wilson and Moore, 1978 ; Berg and Smith, 1983 ; Nozza and Wilson,1984 ; Wilson and Thompson (1984). These authors opine that babies give more precise response:; when they are under operant control rather than just reading to sound passively.

The response for speech was better in BOA than in VRA. This is contrary to what was expected. This would probably be attributed to the fact that the recorded stimuli /ba : ba :/ in VRA was not natural as live voice and hence was not a very interesting stimulus for the child (Hoverstein and Moncur, 1969). Also. VRA was done always after BOA and speech in VRA was the last parameter to be tested. Hence by the end of the VRA test procedure, the children were more habituared and paid less attention 1 o the speech signal.

The lower age group (6 months to 12 months) probably did not respond significantly better in the VRA when compared to BOA as their visual responsiveness was not as mature as the 1 to 2 year olds. They even took more conditioning trials and longer conditioning time because of which they could have been less interested in the signals in the following presentation and lacked attention for a longer time.

The older age group (24 months to 36 months) took few conditioning trials but got habituated to the stimuli and the reinforcers very fast. This has also been supported by Primus (1985). This age group was also not very responsive to visual reinforcers especially when it was repeated and was for longer durations. Their lack of interest in the reinforcers and the activity could have resulted in the higher thresholds.

Hence, for the 6 months to 12 months old babies BOA is a quick and efficient assessment tool in the hands of a skilled examiner. Also for this age group BOA results can help to determine appropriate levels for conditioning and starting intensities of further conditioning tests like VRA (Thompson and Weber, 1984). This would make the VRA test time shorter and also the child's attention can be sustained throughout the test.

For the oldest age group it is suggested that play audiometry or a performance test should be the test of choice. Only if the child is not co-operative or is difficult to test (mild mentally retarded) with play audiometry, VRA should be used for this age group. Thompson and Weber (1984) reported that play audiometry thresholds have been consistently seen to be lower than BOA or VRA.

C. Comparison of test-retest thresholds in BOA and VRA.

The test-retest reliability of both BOA and VRA was checked for 2 subjects aged 8 months and 11 months respectively. The average response of the two subjects is given in Table F.

Table F : Test-retest reliability for BOA and VRA

	BOA					VRA				
Stimulus -Hz)	500	1000	2000	4000	Speech	500	1000	2000	4000	Speech
Trial 1 (dB)	28.0	35.5	34.0	34.0	32.5	28.1	33.3	29.2	28.5	34.0
Trial 2 (dB)	23.0	30.0	24.5	32.0	30.0	28.5	33.3	28.2	26.0	38.0
Range ofthr. differen- ces	2 - 9.5 dB					O-4dE				

The threshold differences for both the subjects on the VRA procedure was within ± 4 dB (Range 0 to 4 dB) for both warble tones and speech, showing a high test - retest reliability. Similar findings were not seen for BOA. The threshold difference was as high as 9.5 dB. This was observed in 2 KHz. This shows that the

Hence from the study it can be concluded that BOA and VRA can be used for the younger age group (6 to 12 mo). BOA can be more appropriate if used to detect just the levels of the starting intensities for further conditioning tests like VRA which hence reduces testing time. As VRA is a conditioning procedure it is sure to yield more reliable responses than unconditioned measures provided the testing time is as short as possible.

VRA is the most appropriate test for the middle age group (12 to 24 mo) as the children of this age group are most responsive to visual reinforcers and respond well to a conditioning procedure. For the oldest age group (24 to 36 mo) neither of the test BOA or VRA is recommended as these children are more likely get habituated to signals fast and are not very responsive to visual reinforces especially for longer durations. They lose interest and attention very fast for both the tests. For this group play audiometry, though not used in this study is recommended as the most appropriate test.

From the results of the study the following were inferred

BOA

A. Responses for the 500 Hz stimuli were lower for the youngest and the oldest age groups than the other stimuli. There were no significant differences among the other three frequence s within each age group.

B. There were no significant (ifferences across age groups for most stimuli except for the 500 Hz warble one for which the middle age group showed higher thresholds.

C. Average BOA responses were higher than the adult thresholds and ranged between 28 to 33 dB HL for warble tones and 25 to 45 dB HL for speech.

D. The mean response levels for speech were better than that of the warble tones.

VRA

A. The thresholds for the 500 Hz stimuli were lower compared to other stimuli. There was no significant difference across the other three frequencies.

B. There was no significant difference across age groups for most of the stimuli. For the 1000 Hz stimuli mere was significantly lower thresholds for the middle age group.

C. Average VRA thresholds were higher than the adult thresholds and ranged from 25 to 38 dB HL for warble tones and were around 38 dB HL for speech stimuli.

D. The mean response levels for speech were poorer than that of the warble tones

- Number of conditioning trials required was more for the lowest age group than for the older age groups.
- Testing time was more for he VRA procedure than the BOA procedure.
- Test-retest reliability was better for VRA than for BOA.
- VRA gave significantly better thresholds than BOA especially for the middle age group.

SUMMARY AND CONCLUSIONS

Hearing assessment of infants and young children involves a clinical strategy aimed at obtaining relevant information accurately, within as short a time as possible. This facilitates early intervention for the hearing impaired child.

Over the years various techniques have been developed to assess hearing in children. These are mainly categorized in to subjective and objective techniques (Martin, 1977 ; McCormick, 1984). The subjective or behavioral techniques are further classified as unconditioned and conditioned tests (Gerber and Mencher, 1974-; Thompson and Folsom, 1985) which have been the focus of this study. Though information obtained through objective techniques are quite accurate and reliable, many audiologists still use behavioral test results as a procedure for evaluating the hearing in infants and young children.

In the present study two behavioral tests Behavioral Observation Audiometry (BOA) and Visua Reinforcement Audiometry (VRA) were administered on 30 children in the age range of 6 months to 3 years. The subjects were divided into three age groups 6 months to 12 months, 12 months to 24 months and 24 months to 36 months. The subjects were tested with 4 warble tones and a speech signal / ba: ba : / in both BOA and VRA. The responses / thresholds of all the subjects were analyzed and the following results were compared. The following results were obtained :

- VRA is a better test than BOA for the children in age group 12 months to 24 months. These children consistently give significantly better responses on VRA than BOA. For the younger age group (6 months to 12 months) and the older age group (24 months to 36 months) no significant difference between the two tests was seen expect at 4000 Hz.

- BOA is most reliable for the younger age group. This is because children of mis age group give more reflexive behaviors and are not very responsive to visual stimuli and conditioning procedures especially for long durations. BOA may also be used just to find appropriate levels for conditioning and to find the starting intensities for further conditioning tests like VRA. This would also contribute to save testing time for the conditioning techniques. VRA for the youngest age group cannot yield very accurate thresholds unless the testing time is reduced, for them to sustain their attention through out the test. Moreover these children are not very responsive for visual stimuli for longer duration. This age group also requires more conditioning trials than the older age group.

- VRA gives most appropriate results for the middle age group as children in this age group requires fewer conditioning trials, get lower thresholds and are more responsive to visual stimuli. BOA is not suggested for the middle age group as these children get habituated to the signals after a few presentations only.

- BOA is not suggested for the oldest age group as the children in this age group get habituated to the signals very soon and hence lose their attention and interest in the test. VRA can not be reliably used for the older age group as these children get habituated to the test signals much earlier than the two younger age groups.

- Number of conditioning trials required is more for the lowest age group than for the two older age groups.

- Testing time is more for t the VRA procedure than the BOA procedure.

- Test-retest reliability for /RA is better than that for BOA.

Hence, in general the advantages of non-operant and operant procedures over each other are related most importantly to the age of the child being tested.

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