COMPARISON BETWEEN BEHAVIORAL THRESHOLDS AND BRAIN-STEM EVOKED RESPONSE AUDIOMETRIC THRESHOLDS

REGISTRATION NO. 8506

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A Dissertation submitted in part fulfilment of
the Degree of Masters of Science (Speech & Hearing)
University of Mysore

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May-1987

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To

NANAJI AND MY FAMILY

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CERTIFICATE

This is to certify that the Dissertation entitled "Comparison between behavioral thresholds and Brain-stem Evoked Response Audiometry thresholds" is the bonafide work oa part fulfilment for the Degree of Master of science (Speech and Hearing) of the student with Register No.8506.

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CERTIFICATE

This is to certify that this Dissertation entitled "Comparison between Behavioral Thresholds and Brain-Stem Evoked Response Audiometry 0 Thresholds" has been prepared under my supervision and guidance.

Dr.M.N.Vyasamurthy
GUIDE.

DECLARATION

I hereby declare that this Dissertation entitled "COMPARISON BETWEEN BEHAVIORAL THRESHOLDS AND BRAIN STEM EVOKED RESPONSE AUDIOMETRY THRESHOLDS" is the result of my own study under the guidance of Dr.M.N.Vyasamurthy, Department of Audiology, All India Institute of Speech and Hearing, Mysore and has not bean submitted earlier at any University for any other diploma or degree.

Reg. No. 8506

Mysore
Dated: May, 1987.

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INTRODUCTION

INTRODUCTION

Auditory brain-stem response technique has emerged as a vital adjunct to the clinical armamentarium of the Audiologists, Otologists and Neurologists, who jointly determine hearing sensitivity, lesion site and central nervous system integrity pathology and maturation.

Study of the spontaneous activity of the brain has a long history and a well established place in clinical medicine, and so does brain electrical activity, which is brought about by an experimenter/clinician (and hence "evoked").

BSER applications in audiologic - otologic disorders and site of lesion testing have shown that the response are wall suited for the detection of hearing abnormalities (Shaia and Albright 1980). This became popular in clinical audiology because of reproducibility, ease of administration, low inter and intra subject variability and accuracy in estimating hearing sensitivity.

Assessment of hearing of children led investigators to discover that norms applied to adults were not appropriate for various developmental stages in children. This led to a series of systematic studies in premature infants, fall-term infants, and pre-adolescent children. A related application is an attempt to discover electrophysiologic correlates underlying demylinating disease such as multiple sclerosis (Chippa, Harrison and Brooks, et al (1980).

The majority of these investigators subscribe to the well-known relationship that as the peripheral and CNS mature (eg. as additional myelimization takes place, and perhaps as axon diameter increases), latency of BSER tend to decrease until an adult norm is achieved. I addition, the magnitude of the potentials are observed to increase with age.

Several investigators (Galambos and Hecox, 1977, 1978, Picton, 1978; Picton et al. 1977; Yamda et al 1975) have suggested the distinction between conductive and sensorineural impairment can be made on the basis of BSER latency-intensity functions.

Several investigators (Hecox and Galambos, 1974; Picton at al 1977; Pratt and Sohmer, 1978; Starr and Achor, 1975; Yamada et al 1975; Davis, 1976; Davis and Hirsh, 1976, 1979; Mitchell and Clemis, 1977; Picton and Smith, 1978; Picton et al. 1979; Seitz et al 1979; Weber and Folsom, 1977) have demonstrated that normal subjects yield ABRs to stimulus intensities that closely approximates their subjective threshold for the stimulus. Patients with hearing loss, however, can yield response thresholds that are elevated by varying degrees above the normal subjective threshold for the stimulus.

One question arises regarding the correspondence between elevated ABR threshold and the degree of hearing loss a patient has for pure tone audiometric stimuli. This correspondence is essential to using ABR to estimate the degree of hearing loss in pragmatic terms; i.e. in the context of the audiogram.

A number of studies have explored the correspondence between audiometric hearing loss and the ABR thresholds for clicks (Coats and Martin, 1977; Fria and saloo, 1979, Jerger and Meuldin, 1978; Mauldin and Jerger, 1979; Mollar and Bleguard 1976; Seitz et al, 1979 and tone bursts or pips (Brama and Sohmer, 1977, Mitchell and Clemis, 1977; Picton et al. 1979; and Seitz et al 1979) without exception studies using click stimuli have found that the ABR threshold correlates best with the audiometric hearing loss between 1000 and 4000Hz.

Mitchell and Clemis (1977) compared the wave v threshold in response to tone bursts (2000, 4000 and 8000Hz with 1 m.sec. rise fall times and a 2 m.sec total duration) to the audiometric threshold of 22 patients with sensorineural hearing loss. The mean difference between the wave V threshold and audiometric loss was 10.2 dB with a standard deviation of 13dB. There was a 0.67 probability that the wave V threshold was within approximately 10dB of the audiometric threshold. This is consistent with seitz et al (1979) who found that the wave V threshold to a 4000Hz tone burst was "well within 15dB of the audiometric loss at that frequency in 80 percent of 10 patients with noise induced sensorineural hearing loss.

Aims of the study:

Aim of the study is to establish the relationship between behavioral thresholds and B.S.E.R.A. thresholds using 10 normal and 10 pathological subjects.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Brain-Stem evoked Responses:

Auditory brain stem responses technique has emerged as a vital adjunct to the clinical armamentarium of the Audiologists, Otologists and Neurologists, who jointly determine hearing sensitivity lesion site and central nervous system integrity pathology and maturation (Moore, 1983).

Brain Stem Evoked Responses - According to Buchwald (1983):

1) BSER reflects graded post synaptic potentials rather than all or none action potentials discharged at the cell soma or transmitted along the axon projection.
2) BSER latency and amplitude measures reflect different physiologic processes which may interact.
3) BSER waves reflect functionally separable substrate system.

Brain Stem Auditory Nuclei:

Dobie (1980) reports, the "relay stations" between auditory nerve and cerebral cortex are, in ascending order (Fig.1).

1. Cochlear;
2. Superior olivary complex;
3. Nuclei of the lateral laminiscus;
4. Inferior colliculus;
5. Medial geniculate body; and
6. Auditory Radiation.

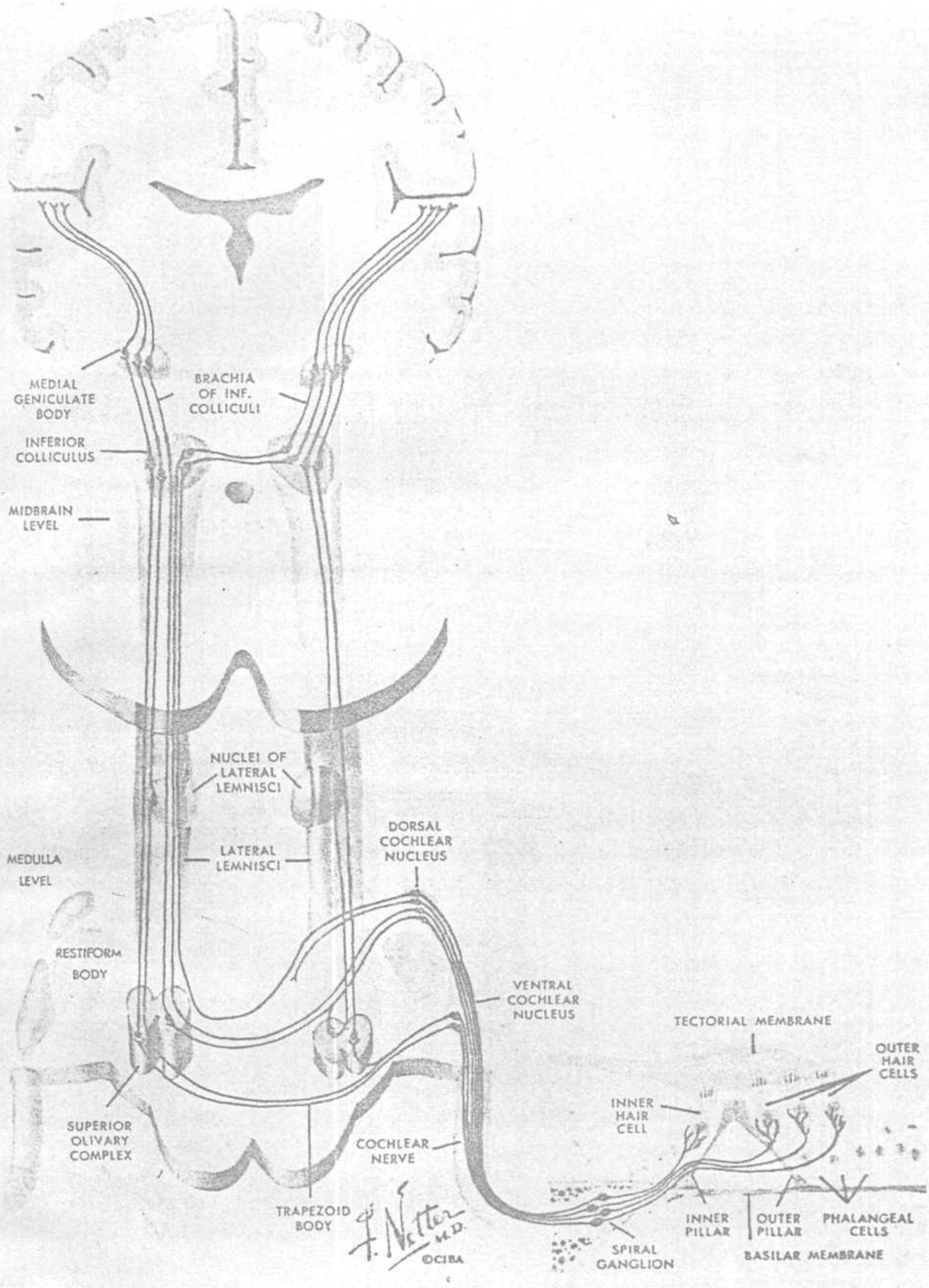

FIG. 2-9. Ascending pathways of the acoustic branch of the VIIIth nerve. (From David Myers, Woodrow D. Schlosser, and Richard A. Winchester, "Otologic Diagnosis and the Treatment of Deafness," *Clinical Symposia,* 14:39, 1962, published by CIBA Pharmaceutical Company. Used by permission.)

Each of these is actually a group of nuclei with complex structure and function. Within these neuclei, auditory information is analyzed and passed to motor neuclei where commands are issued that activate acoustic reflexes. In addition, binaural interaction occurs at all level beyond the cochlea neuclei. Animals surgically deprived of auditory cortex can still perform relatively complex auditory discrimination tasks (Neff, 1961).

Anatomical origins of response components: Various investigations have speculated about the origin of ABR component waves (Fig.2).

Based on the data from human subjects and several species, there is a general agreement that the:-

1) First vertex position potentials in the BSER sequence ia produced by acoustic nerve activity (Cat and Jewett, (1970), Hashimoto, Ishiyami and Yoshimoto (1981).
2) Data from a variety of different experiments consistently indicate that the cochlear neucleus contributes to and is essential for BSER wave-II (Buchwald, Huang, 1975).
3) In view of the direct and indirect links between MSO field potentials and wave-III, the principal substrate for wave-III generation is hypothesized as dendritic post-synaptic potential of the MSO (Buchwald, 1983).
4) Wave-IV generation is postulated as PSP activity within the lateral laminiscus cell population (Buchwald, 1983).
5) wave-V result of lesion studies suggest that the deep ventrocochles portion of the IC is particularly important for wave-V generation (Buchwald, 1983).

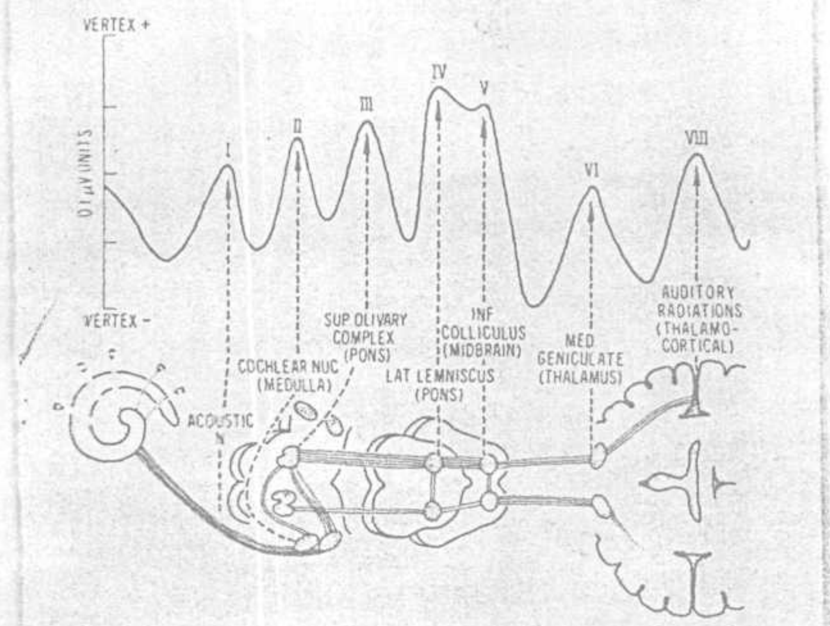

Figure 2. The presumed correspondence between ABR component waves (I through VII, upper portion of the figure) and anatomical structures in the primary ascending auditory pathway (lower portion of the figure). Evidence from various studies (Jewett, 1970; Starr and Achor, 1978) demonstrates that a given wave may reflect the composite activity of several generators, with the possible exception of wave I which appears to reflect the activity of the VIIIth cranial (acoustic) nerve. The waves shown occur in the first 10 milliseconds following a high intensity click stimulus. The above figure was adapted from the diagram that appeared in a report by Stockard et al. (1977).

6) Wave-VI arises from medial geniculate body. It is consistently ranked hardest to recognize the BSER in a normal population, it is to irregularly present and variable in waveform that its clinical usefulness has been questioned (Chiappa, Gladstone, and Young, 1979).

Normal Response Parameters:

The use of the ABR for clinical purposes involves the recognition of normal ABR characteristics, recognition of abnormal results and the variability of normal characteristics between and within subjects, and the variability due to non-pathological factors, such as the nature of the stimulus recording procedure, and subjects.

Response morphology:

Morphology refers to visual appearance of waveform. It is a more subjective parameter than either latency or amplitude, because morphology cannot be specified in measurable units such as milli - seconds or microvolts.

Although most investigators display positive waves at the vertes as upward deflections, some display the same waves aa downward deflections.

Several investigators have observed that waves IV and V often one fused together into what has been called the "IV-V complex". Variations in the waveform of the IV-V complex, based on the relative height and separation of the two waves have received attention in recent literature. Chippa et al (1979) described six variant forms in normal young adults (Fig.3). This variants were labelled A-F and consisted of t (a) A single peak with no separation of Waves-IV and V; (b) Separate IV and V waves with wave-IV lower than wave-V; (c) Separate waves with wave-IV higher than V; (6) and (e) Wave-V riding on wave-IV, and wave-IV riding on wave V, respectively, with the riding wave looking more like a "shoulder" than a peak and (f) Separate waves of the same height.

Chippa et al (1979) found that 58% of their normal adult subjects had the same TV - V complex waveform in both ears. Seventy one percent of the 104 normal ears evaluated had B or C variants. In addition, 6% of the subjects had a wave-III comprised of two separate wavelets.

In normal adult subjects wave-V is the most frequently observed component of the ABR in response to high intensity clicks, whereas waves II and IV are seen with the least frequency (Rome, 1978). Fria et al (1979) observed, wave-III as a prominent feature in the normal

Rome (1978) observed morphological differences between ears in approximately 20 percent of the 25 normal adult subjects evaluated. Wave I than V were clearly defined in the right ear responses of thes subjects but, waves II and IV were poorly defined in left ear response

Response latency:

The time relationship between any response and the stimulus eliciting that response is commonly called latency. For the ABR this

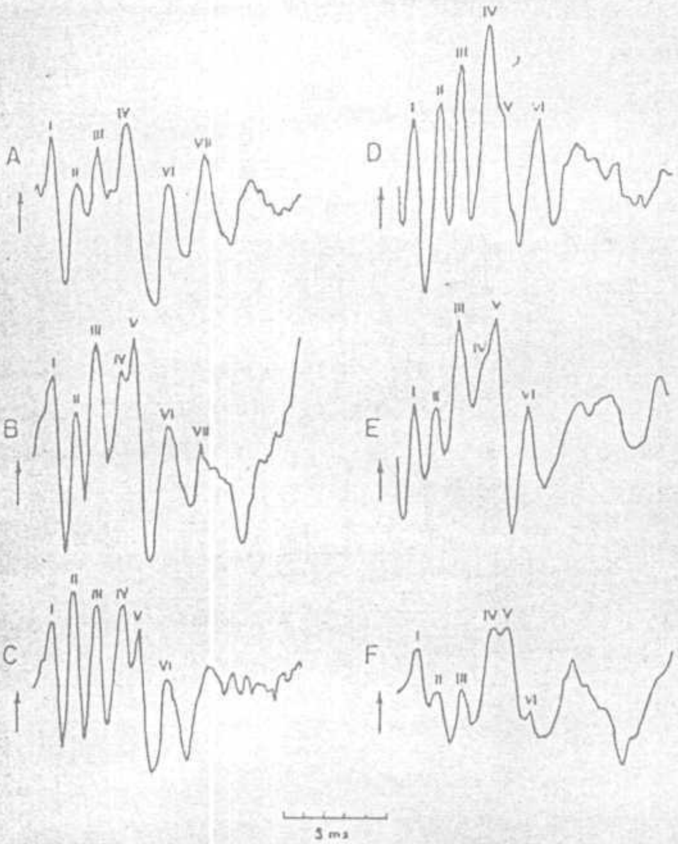

Figure 3. Possible variations in the morphology of the "IV-V complex" for normal adult subjects, as reported by Chiappa et al. (1979). The variants (A-F) are based on the separation and relative height of waves IV and V of the ABR. The variants include: (A) a single complex with no separation of waves IV and V; (B) separate waves with V of greater height than IV; (C) separate waves with IV of greater height than V; (D) wave V appearing as an inflection on IV; (E) wave IV appearing as an inflection on V; (F) separate waves of the same height. (From Chiappa et al. 1979.)

parameter is designated as absolute wave latency or interwave latency (Fig.4). Absolute latency conforms to the traditional definition; the time relationship between stimulus onset and associated response. Interwave latency, however refers to the time difference between two component waves, eg. the I-V interwave latency. Both absolute and interwave latency values are typically specified in milliseconds (m.sec).

Beagley and Sheldrake (1978) observed, the absolute latency of BSER component waves, in response to high intensity clicks, is approximated by the Roman numerical designating the wave; eg. wave I latency falls between 1.0 and 2.0 m.sec, wave II between 2.0 and 3.0 m.sec, and so on.

Table-I shows the mean absolute latency values for normal young adults reported by various studies. The standard deviation of normal latency values reported by Lev and Sohmer (1972) and Amadeo and Shagars (1973) was greater for waves beyond III; in these papers IV - V complex was labelled as one wave, and this might account for the observed increase is variability. Slarr and Achor (1975) Rosenhamer, et al, (1978); Rome, (1978), Stockard et al, (1978a); Chippa et al,(1979) observed approximately the same standard deviati for all ABR component waves; this value was typically 0.3 m.sec or 1 Despite differences between studies, the data in Table-I demonstrate a notable trend. The waves occur at approximately 1.0 m.sec intervs from roughly 1.7 to 5.7 m.sec in response to high intensity clicks.

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Table 1. A comparison of mean absolute latency for each ABR wave across laboratories studying normal adult subjects. The number of subjects, click intensity, and bandpass filter settings used in each study are also shown.

Investigation	N	Click Intensity	Filter	Absolute latency (msec)					
				I	II	III	IV	V	VI
Jewett and Williston (1971)	11	60-75 dB	10-10,000	1.7	-	-	-	4.6-5.1	-
Lev and Sohmer (1972)	10	65 dB	250-5,000	1.5	2.5	3.5	5.0	6.7	-
Amadeo and Shagass (1973)	4	60 dB	10-80,000	1.6	2.8	3.7	-	5.6	-
Picton et al. (1974)	20	60 dB	10-3,000	1.5	2.6	3.5	4.3	5.8	7.4
Starr and Achor (1975)	6	65 dB	100-3,000	1.6	2.8	3.8	4.8	5.5	7.1
Rosenhamer et al. (1978)	20	60 dB	180-4,500	1.7	2.9	3.9	5.2	5.9	7.6
Rowe (1978)	25	60 dB	100-3,000	1.9	2.9	3.8	5.1	5.8	7.4
Stockard et al. (1978)	50	60 dB	100-3,000	1.8	2.9	3.9	5.2	5.8	-
Chiappa et al. (1979)	50	60 dB	100-3,000	1.7	2.8	3.9	5.1	5.7	7.3

Belters and Brackmann (1977) reported that the wave-V latency difference between ears of the same normal adult subject was less than 0.2 m.sec. Rome (1978) reported that normal inter ear latency differences were within 0.4 m.sec. for waves I than V in 95% of the 25 subjects evaluated.

Normal interwave latency values have been reported for several combinations of ABR component waves (Stockard and Rossiter, 1977). There is an increasing tendency however, to focus on the I-III, III-V and I-V interwave latencies. The I-III value estimates transmission time than the ponto-medullary junction and lower pons, and III-V values estimates transmission time from candal pons to candal midbrain levels. The I-V latency estimates the time needed for impulses to travel the entire system and is sometime called "central" or "brain stem" transmission time. Several studies have reported normal values for these interwave latencies, and table-2 presents a comparison of findings for young adults subjects. In I—V interwave latency approximates 4.0 m.sec. and slightly more than half of this time can be attributed to the I-III interwave latency.

Response Amplitude:

In the context of ABR parameters, response amplitude refers to the height of a given wave component, and it is usually measured in microvolts (V) from the peak of the wave to the following through (assuming that vertex positive waves are displayed as upward deflections). This measurement is sometimes called absolute amplitude. The absolute amplitude of ABR component weves can also be expressed in relation to one another, and then measurements are commonly called relative amplitude (Fig.V).

Table 2. The mean and standard deviation (in-parentheses) of interwave latency values from several investigations.

Investigation	N	Interwave Latency I-III	III-V	I-V
Chinppa et al (1979)	50	2.1 (.15)	1.9 (16)	4.0 (.23)
Gilroy & Lynn (1978)	15	2.05(.15)	-	3.83(.13)
Rowe (1978)	25	1.97(.16)	1.97(.20)	3.94(.22)
Stockard & Rossiter (1977)	125	2.1 (.2)	1.9 (.2)	4.0 (.2)

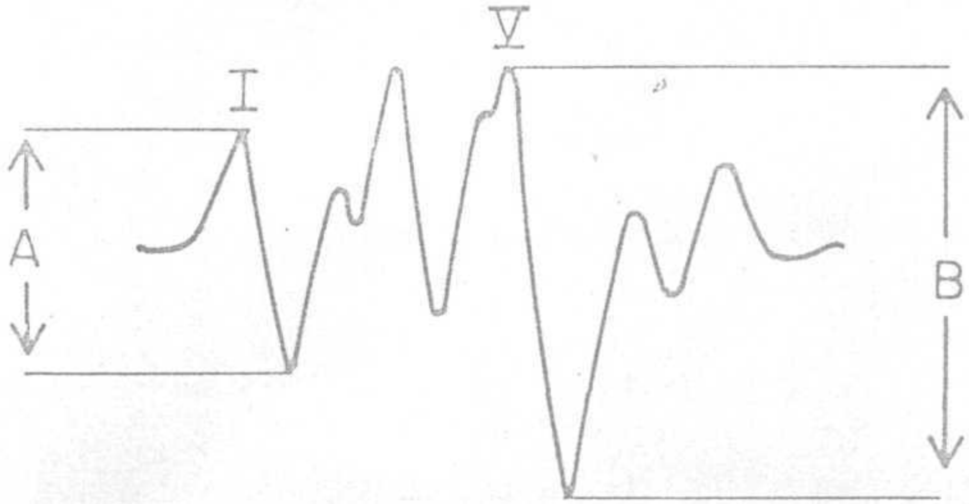

Figure 5. The distinction of absolute and relative wave amplitudes for the ABR. Most often, absolute wave amplitude is the height (in microvolts) of the wave from its peak to the following trough, as shown above for waves I and V (A and B, respectively); but relative amplitude is the ratio of the absolute amplitudes for two ABR waves. For example, in this figure the relative amplitude of wave V to Wave I would be B divided by A. Absolute amplitude measures show wide variation between and within subjects (Amadeo and Shagass, 1973; Starr and Achor, 1975); but relative measures are more consistent and are better indices for comparing amplitude phenomena between subjects; and within the same subject on different occasions (Starr and Achor, 1975, Stockard et al. 1978b). Some investigators measure absolute amplitude from the peak of the wave to the baseline, and others measure from the peak to the preceding trough.

The variation of normal values for ABR wave component amplitudes has been observed to be substantial by a number of investigators (Amadeo and Shagars, 1975; Chippa et al, 1979; Starr and Achor, 1975; Stockard et al, 1978b) reported the mean amplitude in response to high intensity clicks to be 0.15 and 0.38 V for waves I and V respectively.

In recognition of the inherent variability of absolute amplitude measurements, Starr and Achor (1975) suggested measuring the relative amplitude of waves V and I. In 50 normal subjects, they found that the ratio of V: I amplitude always exceeds 1.0 in response to click intensities below 65dB. Similar ratios for 60dB click-evoked ABR's were reported by Chippa et al, (1979). Stockard et al, (1978b) found a mean V:I ratio of 2.53 in normal ears.

Factors Affecting Normal Parameters:

Although certain pathological conditions are associated with changes in ABR properties, normal response parameters can be influenced by factors unrelated to pathology. The nature of the stimulus, recording procedure, and subjects evaluated all have associated effects on the response.

1. Procedure effects:

a) Position of electrodes
b) The use of filters (Bandwidth)
c) Choice of response reference points for the computation of latency.
d) Difference in stimulus transducer
e) Effect of masking and/or ambient noise levels.

2. Subject Effects:

a) State of the subject (awake, asleep, sedated or anesthetized)

h) Effect of temperature

c) Sex differences

d) Effect of change in muscle tone and attention

e) Effect of age.

3. Stimulus parameters:

a) Derived response

b) Intensity

c) Rate of stimulus presentation

d) Stimulus transduction

e) Polarity

f) Binaural interaction.

g) Tone-onset response

h) Frequency-following response

i) Threshold.

According to Buchwald (1933) there is general agreement among investigators of both human and animal BSER upon the following points:-

1) The BSER are a series of volume conducted neural potentials recordable from the scalp which originate from the primary auditory pathway of the brain-stem (upto, and possible including the inferior colliculus).

2) The BSER show (positive) peaks and (negative) through When the scalp electrodes registers positively againat a second noncephalic in cephalic reference electrodes.

3) The peaks through occur with latencies of less than 10 m.sec. following an intense auditory stimulus.
4) The intervals between positive peaks are approximately 1 m.sec.
5) Peak latencies for any given subject are unchanging over successive trial blocks or recording sessions; and
6) BSER latencies and amplitude are little affected by changes in arousal level or by sleep.

Type of Hearing Loss:

Several investigators have suggested that the distinction between conductive and sensorineural impairment can be made on the basis of ABR Lateney-Intensity function (Galambos and Hecox, 1977, 1978; Picton,1978; Picton et al, 1977; Yamda et al, 1975). The distinction stems from the observation that, independent of stimulus intensity, the latency of BSER components waves is prolonged in patients with conductive impairment by an amount commensurate to the degree of hearing loss (Fria and sobo, 1979; Yamda et al, 1975).

This presumably relates to the findings that conductive hearing loss reduces the effective stimulus energy reaching the cochlea. In other words, when a 60dB nHL click is used to elicit any ABR in a patient having a 40dB conductive hearing loss.

Only 20d8 reachs cochlea; therefore, the response latency corresponds to the normal value for a 20dB nHL click stimulus. As stimulus intensity is reduced from 60dB nHL, latency remains prolonged by an amount related to the 40dB loss. Consequently, the patients latency-intensity function for a given ABR wave (for example wave-V) would be parallel to the normal function, but displayed in time (Fig.6)(a).

Several reports have demonstrated that patients with sensorineural hearing yield wave-V latency-intensity function that can be characteristically different from those seen in patients with conductive impairments. Galambos and Hecox (1977, 1978) and Yamda, et al (1975) found that sensorineural impaired patients with flat audiometric om figurations have prolonged wave-V latencies in response to low intensity clicks. As intensity increases, however, response latency decreases to approximately normal values(Fig.6(b).

Patients with precipitors sensorineural hearing loss can yield wave-V latency-intensity functions that are difficult to distinguish from these seen in patients with conductive impairment (Wats et al 1979; Yamda, et al, 1979). This appears to relate to cochlear mechanics, in that more time is required for stimulation to reach comparitively healthy hair cells in more apical regions of the basilar membrane. The resulting latency-intensity function may have a normal slope, and it may be displayed in the manner similar to a conductive impairments (Fig.6(c).

Galamboa and Hecox (1978) suggested that the slope of the evoked latency-intensity function can have interpretive value in these cases. They found that the normal function has a slope of approximately 0.04 m.sec. per dB; i.e. each 10 dB decrease in

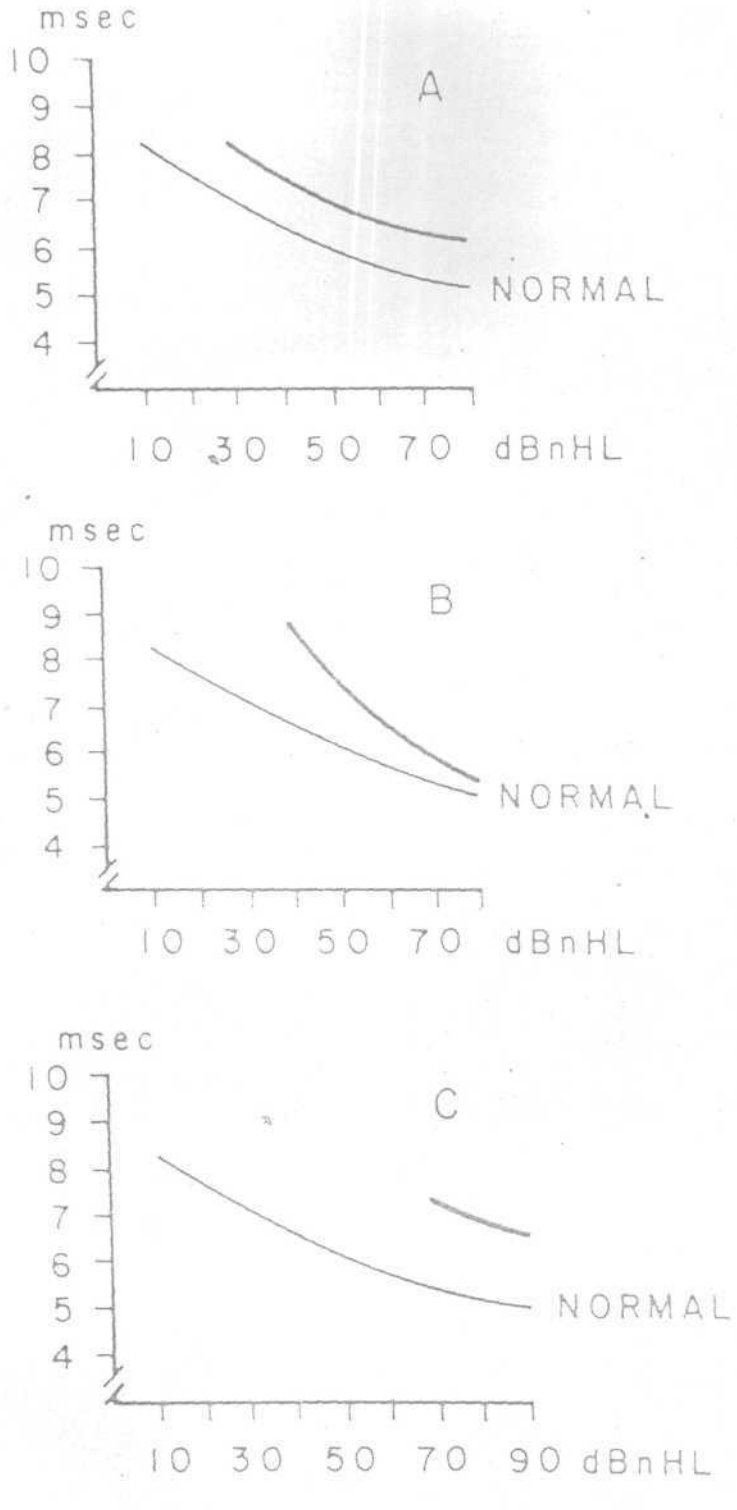

Figure 6. The presumed relationship between the click-evoked wave V latency-intensity function and conductive, sensorineural, and precipitous sensorineural hearing impairments. The conductive impairment (A) reduces the effective stimulus energy reaching the cochlea, and the associated latency-intensity function is parallel to the normal function; but displaced in time by an amount that corresponds to the degree of conductive loss (Yamada et al., 1975). In most cases with sensorineural impairment (B), the latency-intensity function approaches the normal function at high click intensities; but as the click intensity is reduced toward threshold, the slope of the function increases and is thereby separated from the normal function. Some authors have observed that this phenomenon may co-exist with loudness recruitment (Galambos and Hecox, 1978; Picton et al.

stimulus intensity was assoicated with a 0.4 m.sec. increase in response latency. Galambos and Hecox (1978) found, in their experience, that loudness recruitment was usually associated with slopes greater than 0.06 m.sec. per dB, and slopes less than 0.03 m.sec. per dB ensured a diagnosis of high frequency hearing loss. If neither situation is obtained, however recruitment of precipitous high frequency hearing loss cannot be ruled out.

Galambos and Hecox (1978) suggested that evoking the ABR with a bone-conducted click stimulus might assist in distinguishing the precipitous sensorineural impairment from the conductive impairment. Normal ABR latencies in response to bone-conducted clicks are approximately 0.5 m.sec. later than those produced by airconducted clicks with the same intensity. This is probably due to the greater amount of low frequency energy that is transduced when a click is delivered to a clinical bone conduction vibrator (Manldin and Jerger, 1979; Picton and Smith, 1978).

Conductive sensorineural impairments can differentially alter ABR latency-intensity functions, and the departure from the normal curve can indicate which impairment is likely to exist. Most studies have shown the influence of conductive and sensorineural impairment on the latency-intensity function of wave-V. The use of wtave-V functions for determining probable type of impairment ia infa is unacceptable. Far too often the age-related and hearing loss effects on wave-V latency cannot be separated in maturing infants. Wave I latency-intensity functions represents a more sensitive index in these instances (Fria and Sabo, 1979; Mendelson et al, 1979).

Configuration of Heating Loss:

Several investigations have demonstrated that normal subjects yield ABR's to stimulus intensities that closely approximate their subjective threshold for the stimulus. This has been reported for click stimuli (Hecox and Galambos 1974; Picton et al, 1977; Pratt and Sohmer, 1978; Starr and Achor, 1975; Yamda et al, 1975) and for tone pipes and bursts (Davis.1976; Davis and Hirsh, 1976; 1979; Mitchell and Clemis, 1977; Picton and Smith, 1978; Picton et al. 1979; Seitz et al 1979; Weber and Folsom, 1977).

A number of studies have explored the correspondence between audiometric hearing loss and the ABR threshold to clicks (Coata and Martin, 1977; Fria and Sabo, 1979; Jerger and Manldin. 1978; Mauldin and Jerger. 1979; Moller and Bleguad, 1976; Seitz et al, 1979; Yamda et al, 1975) and tone bursts or pips (Brama and Sohmer. 1977; Mitchell and Clemis, 1977; Picton at al, 1979; and Seitz et al, 1979) without exception the studies using click stimuli have found that ABR threshold correlates best with the audiometrie hearing loss between 1000 and 4000Hz.

Yamda et al (1975) found that click evoked ABRs predicted the degree of conductive hearing loss at 4000Hz to within 15 dB for 83% of the 23 subjects he studied. In 7 subjects with sensorlneural hearing loss, however, the degree of loss at 4000Hz was consistenly underestimated by ABR predictions. Sensitivity loss was underestimated by as much as 30 to 40dB in some cases.

Meller and Blegnad (1996) reported similar findings for 48 patients with sysmetrical bilateral sensorineural hearing lose. Wave-V threshold correlated best with the audiometric loss at 2000 and 4000Hz, but there was a tendency for wave-V thresholds to underestimate audiometric thresholds. The correspondance between wave-V threshold, the pure tone average loss (500-2000Hz), and the speech reception threshold waw best for patients with flat audiometric configuration. In contrast, there average audiometric indices were consistently over estimated by the wave-V threshold in patients with gradually or steepy sloping audiograms.

Several investigators have used masking techniques to infer the contribution of apical basilar membrane regions to the ABR in response to clicks (Don and Eggermont, 1978; Don et al 1979; Parker and Thornton, 1978a, 1978b, 1978c). In general these experiments are designated to "derive" responses from specific regions of the basilar membrane by "high pass" marking the contribution of regions above(toward the stapes) the segment of interest. when two segments are marked sequently, the associated ABRs are subtracted from one another and the difference (derived response) is presumed to represent the contribution of the region commonly eliminated by both marked segments.

Findings of Hearing Loss with Recruitment:

Portmann, et al (1973) characterized recruiting ears by a diphasic AP waveform, a rapid increase of AP amplitude with intensity without a plateau in the input/output curve, and a latency of less than 2 m.sec at threshold. Yoshie and Ohashi (1969) found an abrupt increase in latency for levels close to the subjective thresholds. Eggermont (1977b) showed that latency at threshold depends on the audiogram configuration, as well as on the type of stimulus used. This may lead to audiogram prediction but uncertainly as to the type of pathology (Elberling and Salmon 1976). For practical purposes the slope of the amplitude-intensity functions has been proposed (Eggermont and Odenthal, 1977).

The use of the latency-intensity function for clicks (in EcochG and BSER) is not without pitfalls. Interpretations is straightforward in cases of a flat, pure conductive loss (Parallel shifted curve) and flat, pure cochlear loss (latency curve within the normal range), but offers serious problems when dealing with mixed losses or with high frequency sensorineural hearing loss (McGee aad Clemis, 1980). The latency-intensity function for tone bursts may eliminate some of these problems (Eggermont).

Differentiating conductive, sensorineural and mixed hearing loss:

Following conventional audiometric procedures, the use of bone conducted sound vs. airconducted sound is a major issue in electro audiometry concerned with topical diagnosis. The electro audiometric application of bone conduction offers numerous serious problems entered around the vibratory enertia of most bone conductors (Yoshie, 1973; Arlinger and Kylan, 1977).

In BSER audiometry it is observed that the width of the latency intensity range for normal ears at each particular latency value is about 20dB. The implication is that the minimum pure conductive hearing loss that can be detected on this basis will be about 20dB, and, in addition, the inaccurary in the amount of conductive hearing loss that has been estimated will also be about 20dB. The same impression is gained from the data presented by Berlin et al (1974).

An additional complication arises when the wave V latency-intensity function is used, but wave I is absent. In such cases, there is no control upon the amount of wave V delay attributable to an increased central conduction time that ia thought to result from brain stem or pontine angle lesions (Starr and Hamilton, 1976). This could lead to a serious over estimation of the amount of conductive hearing loss, which is especially important in children having the quite common combination of conductive hearing loss and retardation in development (Mair, at al, 1979). Both factors cause wave V delay irrespective of stimulus intensity (Mokotoff, et al 1977; Starr, 1977).

The normal range of amplitude intensity curves has for the lower amplitude values, a width of about 30 dB (Eggermont 1976a). The same spread has to be assumed in conductive loss. Because amplitude values are negatively correlated (r=0.8) to latency values as expressed in the amplitude latency scattergrams (Eggermont, Odenthal and Schmidt, et al, 1974; Eggermont, 1976a), the combined use will generally not yield a better result than one criterian alone.

In sensorineural hearing loss the slope of the amplitude intensity curve in elevated, with respect to those for normal hearing and conductive hearing loss (Eggermont 1976a).

Claims have been made that mixed hearing losses are characterized by normal latencies (for click A.P) at high intensities and progressively deviated (increaaing difference) latancies for lower intensities (Berlin et al 1974). The same shift, however is observed in pure tone high frequency sensorineural hearing loaa for high frequencies, when the audiogram has a shape steeper than 30dB/octave (Yoshie and Ohashi, 1969; Aran and Negra Verghe, 1973). Differentiating mixed hearing losses of upto 50dB into a conductive and sensorineural component on the basis of click stimuli seems to be mainly based on wishful thinking.

The general "receipe" to distinguish with some success, between conductive, sensorineural and mixed hearing loss is

(1) Use frequency - specific stimuli, (2) determine the slope and shift of the AP (or wave V) amplitude-intensity function referred to a normal group results (3) Determine the slope and shift of the AP (or wave V) latency intensity function referred to a normal group result (when dealing with wave V, any delay due to more central dysfunction should be eleminated, and (4) be aware of the confidence region around the estimated values, due to the considerable overlap of the various response criteria.

Differentiation of various types of sensorineural hearing loss:

It is a standard practice to subdivide sensorineural hearing loss into cochlear vs retrocochlear losses. The cochlear type may be distinguished into sensory and neural losses. With respect to retrocochlear hearing loss, we tend to restrict to those caused by pontine angle tumors and only briefly address the problem of pseudohypacusis.

Differentiation of coehlear hearing loss:

Audiometrically, a cochlear hearing loss is at times, diagnosed by the presence of loudness recruitment. The relationship between loudness recruitment and deterioration in frequency selectivity has been indicated. From experiments on single nerve fibre, it has become clear that a very large number of ototoxic agents result in the same change in tuning curves i.e, the loss of the sharply tuned portion (Evane, 1975). Among these ototoxic agents are drugs such as Kenamycin (Kiang et al 1970) and other physical agents auch as noise (Kiang, Liberman and Leuni, 1976), hypoxia (Robertson and Manley, 1974) removal of perilymph (Robertson, 1974) on stimulation of the olivo cochlear bundle (Wiederhold and Kiang, 1970).

Audiologic ABR strategy:

1) Click-evoked ABRs provides a better eastimate of type of impairment than of the degree of loss at frequencies between 1000 and 4000 Hz.
2) ABR threshpolds for tone bursts of 2000 and 4000Hz afford reasonable prediction of high frequency audiometric configuration, bet predictive accuracy suffers as the slope of hearing loss above l000Hz, steepness; and
3) Several techniques (derived responses, tone pips in notched noise, the FFR, and the SN_{10}) can be used to approximate hearing at 500 end l000Hz. Consideration of these points can culminate in the selection of an ABR strategy for audiologic purposes.

Apart from the ABR strategy applied for the eatimation of hearing loss, andiologic application of the ABR must include an assessment of neurologic status in the context of interwave latency and relative amplitude measurements. The presence of neurologic disorders can reduce the accuracy of audiologic predictions.

Potential use of BSER:

Brain stem evoked response (BSER) are the evoked potentials from auditory structures in the brain stem as recorded with surface electrodes (usually vertex vs mastoid or earlobe) and arising within 10 m.sec. after stimulus presentation. BSER is sensitive to binaural stimulation. BSER provides (only at moderate-to-high sound intensities) a wave I (AP) and only at the highest intensities a discernible CM (Moore, 1971, Thornton, 1975a).

The slope of the AP magnitude vs intensity function has provento be a good indicator for the presence of loudness recruitment (Eggermont 1977b). When tone bursts are used as stimuli, this indication can be given for each frequency under study. Using BSER claims have been made that the wave V latency versus intensity function could be used in this way, but it appears that it mainly distinguishes flat pure conductive losses from flat sensorineural hearing losses (Galambos and Hecox, 1977)

This features that the latency intensity function for the AP as well as wave V tends to shift parallel to the normal function in ears with a pure conductive hearing loss, has frequently been used in discriminating middle from inner ear disturbances (Berlin et al 1974; Galambos and Hecox, 1977). The for of the latency-intensity function, however, does not unambigously relate to the type of hearing loss.

Differentiation of cochlear lesions on the basis of CM and SP measurements is only possible with ECochG (Eggermont, 1976c, 1979a).

It appears that the main diagnostic potentiality of the BSER is in its excellence in site-of-lesion testing within brain stem structures. With ECochG, attempts to discriminate batween cochlear and retrocochlear hearing loss generally reveal poor results (Brackmann and Selters, 1976; Clamis and Mitchell, 1977).

Clinical applications:

The use of the BSERA for clinical purposes involves a two phase process. First, the distinction must be made between normal and abnormal results in the context of the technical and subject related factors.

Second, the results must be interpreted together with related information (eg. behavioral audiometric reaults, case history information, physical findings and the results of other investigations studies) in order to support or contradict a work diagnosis of a specific lesion, impairment, or disease, This two phase process inherently involves the understanding of how pathological conditions affecting the auditory system can influence normal ABR parameters. These conditions include impairments of hearing (audiologic) and disorders of neural function (neurologic) (Fria, 1979).

Audiologic Applications:

The audiologic applications of the ABR involve the estimation of hearing in pediatric patients who cannot be tasted bahaviorally or who yield ambiguous or unreliable behavioral hearing test results. In this context, the technique is used to predict the type and degree of hearing loss with particular emphasis on estimating frequency specific thresholds.

It must be realized that the ABR cannot test "hearing" in the perceptual sense. Rather, it serves to monitor the responsivity of neuronal elements in the peripheral and brainstem auditory tract. A child who cannot integrate sound at the cortical level may yield "normal" BSSR results. Moreover, the failure to elicit BSER does not always indicate hearing loss, since the synchronous firing of neurons required for the response is not necessary for a behavioral response to pure tone signals, and hence, Children with normal audiograms may not yield a recordable BSSR (Worthington and Peters, 1979). These limitation emphasize the need to interpret the ABR in the context of other clinical findings.

METHODOLOGY

METHODOLOGY

I. Subjects:

10 mormal hearing subjects and 10 pathological subjects with mild-to-moderate sensorineural hearing loss, in the age range of 17 to 40 years were selected on random basis. The subjects with normal hearing were selected on the following criteria:

1) They should not have had any history of ear discharge, tinnitus, giddiness, earache or aay other otological complaints.
2) They should be able to relax and feel comfortable with electrodes on, within 10-15 minutes after their placement.
3) They should not have had any history of epilepsy or other neurological complaints.
4) Their electrophysiological input should come below 500 microvolts within 10-15 minutes after electrode placement.

The pathological subjects were selected on the following criteria:

i) They should not have had any history of eardischarge or any other middle ear pathology.
ii) These hearing loss should be of mild to moderate sensorineural type.
iii) They should be able to relax and feel comfortable with electrodes on, within 10-15 minutes after their placement.

II. Equipment:

The following instruments were used is the study.

The equipment consists of a stimulating system (a stimulus generator which feeds the stimuli to a transducer earphone or a bone conductor) and a recording system. The latter consists of electrodes, amplifiers, filters, averager and display together with some device for obtaining a permanent record.

Brief Description of the Equipment:

It consists of a SLZ-9793 desk tap console which contains all of the operating controls, indication and readouts for the system. SLZ-9794 preamplifier which is an isolated BBS preamplifier with frequency response and gain specifically designed for ERA. Also a set of standard silver cholride electrodes, TDH-39 earphones and circumaural cushion MX-41/AR. Calibrated paper to record the responses, electrolyte gel, adhesive tape, spirit and bone conduction vibrator.

Controls and their operation:

TA-1000 operates on 4 knobs and 9 push button switches.

All knobs are marked to indicate their functions. All such buttons indicate, by means of internal lamps, the active state of the selected function.

The knobs are:—

1) the stimulus function knob which permits selection of frequencies 2 KHz, 4 KHz or 6 KHz at a repetitive rate of 5 or 20 stimuli per second, and patient's response intervals of 10 msec. or 20 msec immediately following the acoustic logan stimulus,
2) Stimulus attenuation knob permit to establish the presentation level from 0 dBHL to 100 dBHL,
3) the scale function knob which permits selection of system sensitivity and number of average response samples,i.e., for 2048 samples 0.2, 0.5, 1 and 2 uV per div. sensitivities are available. For 1024 samples 0.5, 1 and 5uV per div. sensitivities are available. For 4096 samples 0.1 uV, 0.2 uV , 0.5 uV and 1 uV per div. sensitivities are available, and
4) the latency control knob provides a cursor mark on the oscilloscope display of the BSER wave for a precise determination of latency. Readout of latency in m.sec. to 0.1 msec. is displayed in digital form directly above this control.

The Push-Button Switches:

These are:—

1) Power Switch energizes the system and indicates the system status,

2) score switch controls the oscilloscope display,
3) Clear push button clears the microprocessor averager, memory resets the sample display counter and corrects the microprocessor operating mode to correspond to the current control status.
4) Start/stop push button initiates the micro processor average function. As the number of samples accumulates, the averager can be stopped to evaluate intermediate results and restarted without disturbing the averager action. The averager function is automatically terminated when the selected number of samples has accumulated, of when any average memory channel is full automatic termination requires a clear to permit restart,
5) record push button indicates the plotter readout of the averager is not active,
6) mask push button applies broad band noise masking to the contralateral ear only when either air left or air right stimulus is active,
7) air left stimulus to left earphone.
8) air right stimulus to right earphone, and
9) bone push button stimulus to bone vibrator transducer.

TA-1000 also has facilities for the following functions besides the ones mentioned earlier:—

i) paper thumb wheel for the chart paper,

ii) limit indicate which is very active at high sensitivities,

iii) TWF/RUN/EEG - normally RUN position is used. When in TWF position after clear, the oscilloscope will display a characteristic test waveform to confirm oscilloscope operations. In EBG position, after clear, the oscilloscope will display the ongoing patients EEG activity, the raw signal from which the averaged response is derived.

Clinical Audiometer:

Make - Grason-Stadler
Model - GSI-10
Power - Directly from AC source of 220 volts
Earphone - TDH 39 with MX-41/AR Supra-aural cushions.

III. Test Environment:

The experiments ware carried out in sound treated and centrally air conditioned room at the Aadiology Department of All India Institute of Speech and Hearing, Mysore - 570 006.

IV. Procedure:

There are two stages in the experiments carried out in the present study. The two stages were:

i) Pure Tone Audiometry, and

ii) B.S.E.R.A.

1) Pure Tone Audiometry:

Pure Tone Audiometry for the both the ears were done. The special tests were also administered for the confirmation of the hearing loss of sensorineural type.

2) Electric Response Audiometry:

Instructions:- The subjects were instructed to lie in relaxed position on an examination table. Subjects were told that the electrodes would be placed and they would be hearing intermittent sounds. The subjects were not sedated. Electrode placement was as follows:
Red(+) signal, to high forehead,
White(-) reference, at the mastoid of the test ear.
Black: ground, at the mastoid of the non-test ear.

To the normal hearing subjects only right ear was tested. For the bilateral sensorineural hearing loss subjects both ears were tested and for the subjects with unilateral hearing lost only the pathological ear was tested.

Headphones were placed and the headset was positioned in such a may that it was comfortable to the subject.

E.R.A. was set as follows:

1. Stimulus frequency on 2KHz, 4KMz and 6KHz, 20 pulses pet second and 10 ms. sample time.

2. The scale switch on 2048 samples and 0.2 uV/div.
3. Stimulus intensities ware varied for getting the V wave at the lowest intensity, to determine the threshold at each test frequencies.

Latency of the V peak of BSER at 2KHz, 4KHz and 6KHz were determined.

All the subjects were tested in the same manner.

② OSCILLOSCOPE

Built-in with electrostatic focus and deflection. All functions such as intensity, focus and blanking, are automatically controlled for the convenience of the operator. Automatic 4X, 2X and 1X microprocessor-controlled gain displays the pattern at maximum usable amplitude.

① LATENCY CONTROL AND DISPLAY

Controls the position of the latency cursor on the oscilloscope. The digital display indicates the position of the cursor, in 0.1 milliseconds increments of patient response time.

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RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

The aim of the present study was to establish the relationship between behavioral thresholds and ABR thresholds, using 10 normal and 10 pathological subjects.

The wave V threshold was obtained in both the above mentioned population. The raw data was treated for mean and standard deviation. The results are putforth in a tabular form.

Table-1: States wave V threshold at 2 KHz, 4 KHz, and 6 KHz for 10 mild-moderate sensorineural hearing loss eases. The data is obtained from both unilateral and bilateral cases. The table states values for both behavioral thresholds and BSERA thresholds.

Table-2: States wave V threshold at 2 KHz, 4KHz and 6 KHz for 10 subjects with normal hearing. The data is obtained only for the right ear. The table gives values for both behavioral thresholds and BSERA thresholds.

Table-3: It illustrates the mean and S.D. values for 2 KHz, 4 KHz and 6 KHz in 10 mild-moderate sensorineural hearing loss cases.

Table-4: It illustrates the mean and S.D. values for 2 KHz, 4 KHz and 6 KHz for the normal hearing subjects.

TABLE-II

vioral Thresholds and B.S.E.R.A (V wave) Thresholds at 2KHz, 4KHz, and 6KHz of 10 normal hearing ects. (Thresholds of right ear only).

Pure tone Thresholds (dB)			BSERA Thresholds (dB) (V wave latency, m.sec)					
2KHz	4KHz	6KHz	2KHz	Latency	4KHz	Latency	6KHz	Latency
5	10	5	30	6.8	30	7.3	40	6.8
5	15	10	30	6.7	30	7.4	35	6.8
10	0	0	35	6.7	25	7.5	30	6.3
5	10	5	30	6.8	30	7.3	30	7.0
10	0	5	30	6.7	30	6.8	25	7.2
10	10	5	30	6.8	30	6.7	25	7.3
5	15	10	30	6.3	40	6.1	30	6.7
0	5	0	30	6.3	30	6.4	25	7.1
15	0	5	40	6	30	6.2	25	7.2
	15	10	30	6.5	40	6.0	30	6.8

TABLE -I

Behavioral Thresholds and B.S.E.R.A.(V wave) Thresholds at 2KHz, 4KHz and 6KHz of 10 mild-moderate sensorineural hearing loss subjects (For both, Unilateral and Bilateral hearing loss subjects).

Sl.No.	Pure tone Thresholds (dB)						BSERA Thresholds (dB) (V wave Latency, m.sec.)											
	Right ear			Left ear			Right ear						Left ear					
	2 KHz	4 KHz	6 KHz	2 KHz	4 KHz	6 KHZ	2 KHz	Latency	4 KHz	Latency	6 KHz	Latency	2 KHz	Latency	4 KHz	Latency	6 KHz	Lat ncy
1	50	60	55	-	-	-	70	5.2	65	5.4	70	5.5	-	-	-	-	-	-
2	10	15	10	15	30	55	35	6.8	30	7.2	35	6.8	40	6.5	60	6.3	70	6.3
3	40	55	50	35	50	55	60	5.7	75	5.5	70	5.6	55	5.7	60	5.8	75	5.5
4	55	75	70	50	70	70	75	6.0	70	6.3	90	5.9	80	5.9	80	6.1	95	6.0
5	25	25	45	30	45	50	50	6.5	55	6.0	55	6.1	40	6.2	65	6.1	75	5.4
6	30	25	45	35	25	45	60	5.9	70	5.4	75	5.6	70	5.6	75	5.5	75	5.3
7	45	35	35	10	20	20	75	6.1	65	7.3	80	6.3	35	6.8	40	6.1	45	6.3
8	35	40	45	5	15	10	60	6.1	65	5.7	65	5.9	35	6.7	30	7.3	35	6.8
9	15	30	55	-	-	-	40	6.5	60	6.3	70	6.3	-	-	-	-	-	-
10	40	55	55	35	50	50	60	5.7	75	5.5	70	5.6	-	-	—	—	-	-

TABLE-III

Mean and Standard Deviation values of Behavioral Thresholds and BSERA (V Wave) Thresholds at 2KHz, 4KHz and 6KHz in 10 mild-moderate sensorineural hearing loss subjects.

	Pure tone Thresholds (dB)						BSERA Thresholds (dB) (V Wave Latency, m.sec.)											
	Right ear			Left ear			Right ear						Left ear					
	2 KHz	4 KHz	6 KHz	2 KHz	4 KHz	6 KHz	2 KHz	Latency	4 KHz	Latency	6 KHz	Latency	2 KHz	Latency	4 KHz	Latency	6 KHz	Latency
	34.5	41.5	46.5	26.88	38.13	44.38	58.5	6.05	63	6.06	68	5.96	50.71	6.2	58.57	6.17	67.14	5.94
	13.86	18.03	15.0	14.34	17.49	18.45	12.85	0.44	12.49	0.68	14.0	0.39	16.78	0.45	16.63	0.52	18.87	0.52

TABLE-IV

n and Standard deviation values of Behavioral Thresholds and B.S.E.R.A. (V wave) Threshold, at 2KHz z, and 6KHz of 10 normal hearing subjects (Thresholds for Right ear only)

No.	Pure Tone Thresholds (dB)			BSERA Threshold (dB) (V wave latency. m.sec).					
	2KHz	4KHz	6KHz	2KHz	Latency	4 KHz	Latency	6KHz	Latency
in	7	8	5.5	31.5	6.56	31.5	6.77	29.5	6.92
	4	6	3.5	3.20	0.26	4.5	0.55	4.72	0.29

DISCUSSION:

The mean values are plotted on an audiogram representing both behavioral thresholds and BSERA thresholds for both ears. There are separate audiograms for normals and the sensorineural loss cases.

It is determined from the graph that BSERA thresholds correlate best with audiometric hearing loss between 2000Hz to 6000Hz.

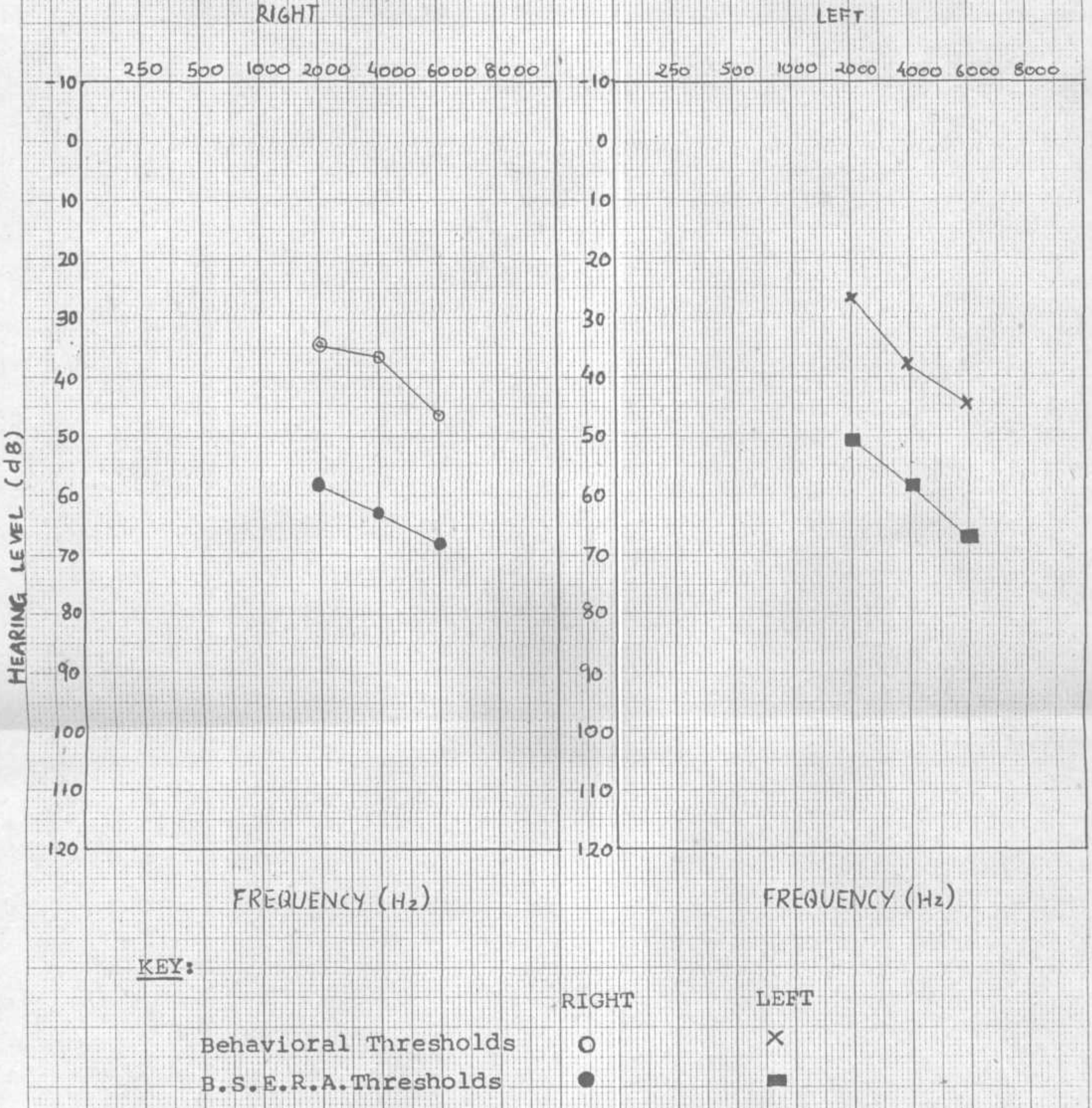
In the 10 subjects with sensorineural hearing loss, the mean difference between the wave V threshold and behavioral threshold was 22.6 dB for right ear and 22.3 dB for the left ear. There is a probability that wave V thresholds are approximately 22dB of the behavioral thresholds.

In the 10 normal subjects the mean ifference between the wave V threshold and behavioral threshold was 28.5dB for the right ear.

This correspondence is essential for using ABR to estimate the degree of hearing loss in pragmatic of hearing term is in the context of the audiogram.

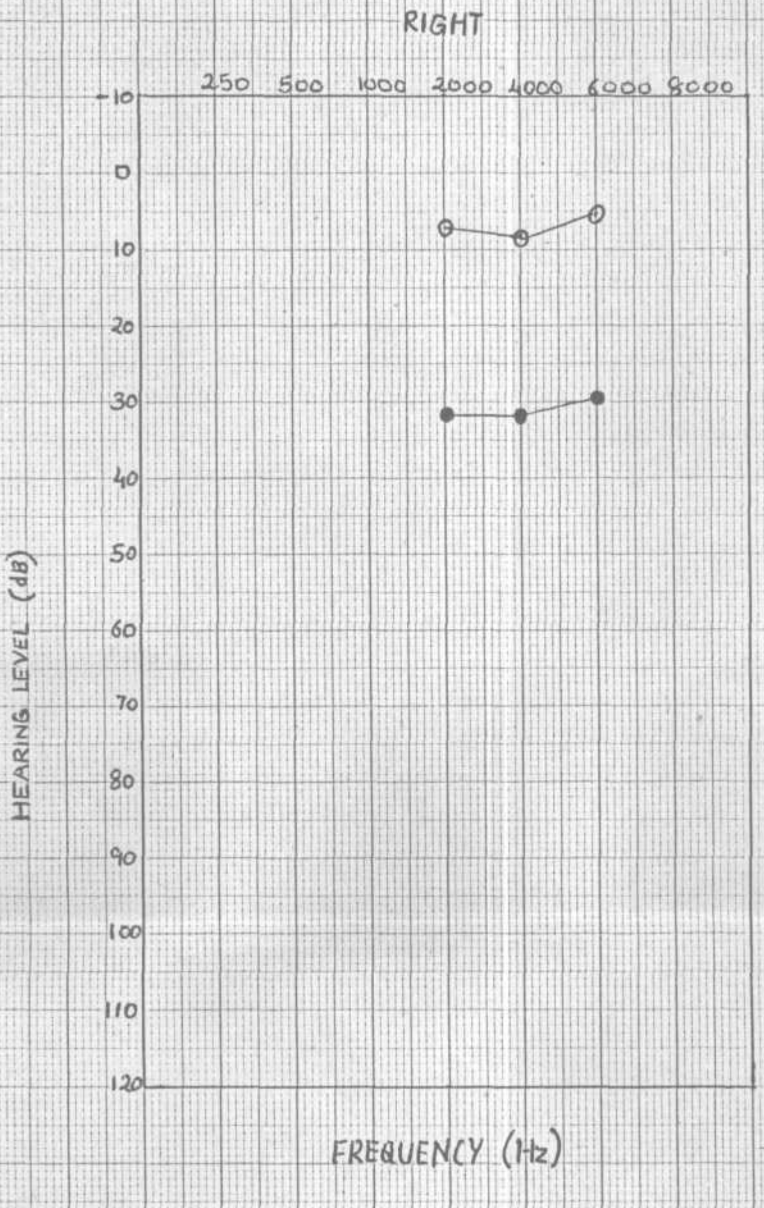
GRAPH-I

Mean values of Behavioral Thresholds and B.S.E.R.A. Thresholds (V Peak) at 2KHz, 4KHz, and 6KHz for Mild-Moderate Sensori-neural loss subjects. (N=10).



GRAPH-II

Mean values of Behavioral Thresholds and B.S.E.R.A. Thresholds (V Peak) of Right ear at 2KHz, 4KHz and 6KHz for Normal Hearing Subjects (N=10).



KEY:

	RIGHT
Behavioral Thresholds	○
B.S.E.R.A. Thresholds	●

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

The present study was done with an aim to establish the relationship between behavioral thresholds and ABR thresholds, using 10 normal and 10 pathological subjects.

The frequencies tested were 2 KHz, 4KHz and 6 KHz. The scale was set to 2048 samples and 2 v/Div. Sample time of 10 m.sec was chosen and rate of presentation was kept constant 20/sec.

It was determined that in normals the wave-V threshold an approximately 28.5dB of the behavioral thresholds. For the mild to moderate sensorineural hearing loss subjects the wave V thresholds are approximately 22 dB of the behavioral threshold.

Implication of the study:

Several investigators have demonstrated that normal subjects yield ABRs to stimulus intensities that closely approximate their subjective thresholds for the stimulus. Patients with hearing lose now even can yield response, thresholds that are elevated by varying degrees above the normal subjective thresholds for the stimulus.

The results expressed in audiogram 1 and 2 approximates Seitz, et al (1979) results who found that the wave V thresholds to a 4000Hz tone burst was "well within" 15dB of tht andiometric loss at that frequency in 80% of 10 patients with sensorineural hearing loss.

The study to a certain extant answers the question regarding the correspondance between the elevated ABR threshold and the degree of hearing loss, a patient has for audiomatric stimuli.

Limitations:

The study was limited to only right ear threshold for the 10 normal subjects.

The age factor was not comparable for the two populations i.e. the sensorineural hearing loss cases and normal subjects.

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