ESTABLISHING NORMS FOR LOW INTENSITY STIMULI FOR BRAIN STEM EVOKED RESPONSE AUDIOMETRY

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TO

AMMA

ALL THAT I AM OR HOPE TO BE

I OWN TO MY DEAREST MOTHER

CERTIFICATE

This is to certify that the Dissertation entitled "ESTABLISHING NORMS FOR LOW INTENSITY STIMULI FOR BRAIN STEM EVOKED RESPONSE AUDIO-METRY" is the bonafide work on part fulfillment for the Degree of Master of science (Speech and Hearing) of the student with Register No. 8606.

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CERTIFICATE

This is to certify that the Dissertation entitled: "ESTABLISHING NORMS FOR LOW INTENSITY STIMULI FOR BRAIN STEM EVOKED RESPONSE AUDIOMETRY" has been prepered under my supervision and guidance.

Dr.M.N.Vyasamurthy.
GUIDE.

DECLARATION

I hereby daclare that this Dissertation entitled: "ESTABLISHING NORMS FOR LOW INTENSITY STIMULI FOR BRAIN STEM EVOKED RESPONSE AUDIOMETRY" of Dr. M.N. Vyasamurthy, Department of Audiology, All India Institute of Speech and Hearing, Mysore and has not been submitted earlier at any University for any other diploma or degree.

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INTRODUCTION

INTRODUCTION

Brain-stem evoked responses are the most recent electro-physiological procedure to be integrated into the audiological test battery.

When a person is quite and relaxed his brain wave activity has a definite wave pattern. A change in this pattern of brain waves ia found when an external stimulus, example, sound is presented to the person. This is called evoked response or evoked potential or complex or vertex potential. The type of audiomertry which was this basic methodology is called Evoked Response Audiometry.

The response evoked on presentation of stimulus just once is negligible. Hence the stimulus is presented a number of times and the averaging computer averages the stimulus time-locked responses and magnifies the change. Greater the number of stimuli used greater the amplitude of the resultant stimulus (generally used are 1000-2000 stimuli).

The development of the ABR has focused on two principal areas of application (1) the evaluation and diagnosis of the peripheral auditory system and related pathology, and (2) the neural integrity, to the acoustic nerve and caudal levels of the brain-stem pathway (Hecox and Jacobson, 1984).

In the assessment of auditory sensitivity, one of the primary objectives of the ABR is to identify, as closely as possible, the patient's hearing status.

The second major application of the ABR and perhaps its most significant in its role of a diagnostic tool is the identification of neurological abnormalities. This ability has been used to predict eighth nerve and brainstem lesions, and also demyelinating and degenerative diseases and vascular lesions. ABR has also bean used in the examination of high risk neurologically impaired newborns confined to the neonatal intensive care nursery.

Finally, neurological application of the ABR is being used with growing interest as an intraoperative monitoring technique and in comatose and brain dead patients.

According to Buchwald (1983) BSER reflects graded post-synaptic potentials rather than all-or-none action potentials discharged at the cell some or transmitted along the axonal projection. He also said BSER latency and amplitude measures reflect different physiologic processes which may interact. BSER waves reflect functionally separate substrate system.

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

1. Cochlear
2. Superior Olivary Complex

3. Nuclei of the lateral lemniscus
4. Inferior colliculus
5. Medial geniculate body.

Each of these is actually a group of nuclei with complex structure and function, within these nuclei auditory information is analysed and passed to motor nuclei where commands are issued that activate acoustic reflexes. In addition, binaural interaction occurs at all levels beyond the cochlear nuclei.

Thus, the above five areas were supposed to be the origins of the BSER waves.

Based on the data from several species, there is general agreement that the:-

(1) First vertex positive potentials in the BSER sequence is produced by acoustic nerve activity (Cat, Jewett, 1970; Hashimoto, Ishyami and Yoshimoto, 1981).

(2) Date from a variety of different experiments consistently indicate that the cochlear nucleus contributes to and is essential for BSER-II (Bashwald, Huang, 1975).

(3) In view of the direct and indirect lines between MSO field potentials and wave III, the principal substrate for wave III generation is hypothesized as dendritic post-synaptic potentials of the medial superior olivary nucleus (Buchwald, 1983).

(4) Wave IV generation is postulated as post-synaptic potential activity within the lateral leminscus cell population (Buchwald, 1983).

(5) Wave V result of lesion studies suggest that the deep ventro-lateral portion of the inferior colliculus in partially important for wave V generation (Buchwald, 1983).

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

(7) Wave VII arises from auditory radiations (thalamocortical) and is also irregularly present and variable in waveform.

In infants the wave I, originating in the cochlea is found to be of maximum amplitude and clearest. In adults, wave V is found to be most stable and reliable for diagnosis purposes. According to Dobie (1980) responses usually of wave V latency are measured for several reasons:-

(1) Wave V is usually the largest component in BSER.
(2) Wave V is least variable from subject to subject.
(3) Under adverse conditions such as low intensity and high repetition rate, wave V persists while the other waves become increasingly indistinct.

(4) Latency of any of these waves is far less variable than response amplitude.

Evoked responses are known to change from the normal or affected due to a number of factors. These factors are listed below:-

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) Freqency-following response
(i) Threshold

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 level
(f) Filtering system

Subject Effects:-

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

(b) Effect of temperature

(e) Sex differences

(d) Effect of change of muscle tone

(e) Effect of attention

(f) Effect of age

These factors need to be controlled while testing in order to get valid and reliable results. This study gives us the norms for the BSERA peak latencies, on studying the effect one of the parameters.

Aim of the Study:

This study aims at establishing norms for brainstem evoked response peaks for low intensity stimulus presentations (that is, at 30dB, 40dB, 50dB and 60dB HL).

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Basic Principles:

Day and night, the brain continues to do its function, irrespective of whether a person is awake and active or relaxed and asleep. At the time when a person is relaxed and quite or asleep, there is a definite pattern for the brain wave activity to be seen.

On the presentation of an external stimulus, for example, a sound, a change is noticed in the pattern of brain wave activity. This response is called the evoked response or evoked potential or complex potential or vertex potential. The type of audiometry which uses this basic methodology is called the Evoked Response Audiometry.

The potentials which are evoked within the first ten milliseconds following stimulation are referred to as "Brain stem evoked potentials". These potentials represent the bioelectrical response of the eighth nerve and brain stem nuclei.

These waves were first observed and reported by Sohmer and Feimosser (1967). Jewett and Villiston (1971) were the first to give a detailed description of ABR properties in human subjects and influence of various stimulus and procedure related factors on response parameters.

The ABR latency epoch consists of five to seven wave peaks (positive peaks) with latencies varying from 2 to 7 milliseconds and amplitude varying from 1-4 / V subsequent to presentation of click stimulus.

In the newborn and infant population the response usually consists of only three wave peaks (I, III and V) whose latency and amplitude differ from adult values (Jacobson, Morehouse and Johnson, 1982).

The responses evoked on presentation of stimulus just once is negligible. Hence the stimulus is presented a number of times (at least 2000 times) and the averaging computer averages the stimulus time-locked responses and magnifies the change. Greater the number of stimuli used greater the amplitude of resultant stimulus.

Thus, the BSERA finds clinical application in the evaluation of hearing abnormalities involving that portion of the auditory pathway between the cochlea, where the acoustic stimulus is first converted to an electrical signal, and the brain-stem, where this signal initiates the coordinated neuron discharge subsequently recognized as sound.

THE DESCRIPTION OF BSERA:

Acoustic stimuli for BSERA:

The BSSRA stimuli are characterized by abrupt onset and decay; and are of short duration, unlike the sustained pure tone of conventional audiometry.

This is necessiated by the diagnostic significance of response differences of less than 1 millisecond and the very rapid response of the cochlea by acoustic stimuli. So, the peak SPL of an auditory brainstem response (ABR) stimulus at hearing threshold ia approximately +25 dB greater than that of sustained pure tone audiometery (Ward, 1981).

Patient's ABR to such stimulus is a minute electrical voltage, typically less than 0.00000025 volts or 250 nano volts. Thus, relaxed state or often sedation may be necessary (Davis, 1976).

In this study we have used LOGOS stimulus. The logon stimulus is a l.5 cycle burst of the desired stimulus frequency, having onset and decay times equal to 0.75 cycles of that frequency. Its waveform is a single major peak, preceded and succeeded by minor peaks of opposite polarities. The logon's energy spectrms is approximately one octave in band-width centered on that frequency determined by the interpeak time of its waveform. The logon stimulus is more frequency specific and finds clinical application in more detailed exploration of hearing abnormalities, typically in the 500-4000Hz frequency range.

Electrodes:

In bipolar recordings used in ABR measures, three electrodes are usually applied to the scalp and commonly referred to as the "active", "reference" and "ground".

These terms are misleading and do not accurately represent the underlying physiological events ABR measures are based on neural synchronized discharges from subcortical levels. These electrical fields generated from caudal regions of the auditory mechanism are transmitted with in a volume of conductive medium of extracellular fluid and tissue. Thus, any electrode located on the scalp and remote from the electric field source will potentially register neural activity, therefore the label "reference" suggesting a nonactive or indifferent electrical site is not applicable to such recording methodology.

Two sets of alternative electrode terms are gaining popularity. They are "positive" and "negative" related to electrode input at the preamplifier stage, and "non-inverting" and "inverting" describing amplifier function.

The third electrode, the "ground" or more appropriately the "common" electrode serves as a reference electrode for the other two.

The differential preamplifier used in the instrument is to amplify the resulting neural activity after a process of polarity reversal at the inverting electrode. The degree of internal noise cancellation is called the common mode rejection ratio.

The Response:

Jewett and Williston (1971) demonstrated that the normal ABR consisted of five to seven vertex positive wave occuring in the first nine milliseconds following a click stimulus.

Fig-I (See page No.12).

This wave series was impressively consistent across and within subjects. Wave V was the most prominent component of the response and the most robust in its resistance to the effects of increased stimulus repetition rate. Wave VI was a fairly consistent part of the responses, but wave VII occurred inconsistently across subjects.

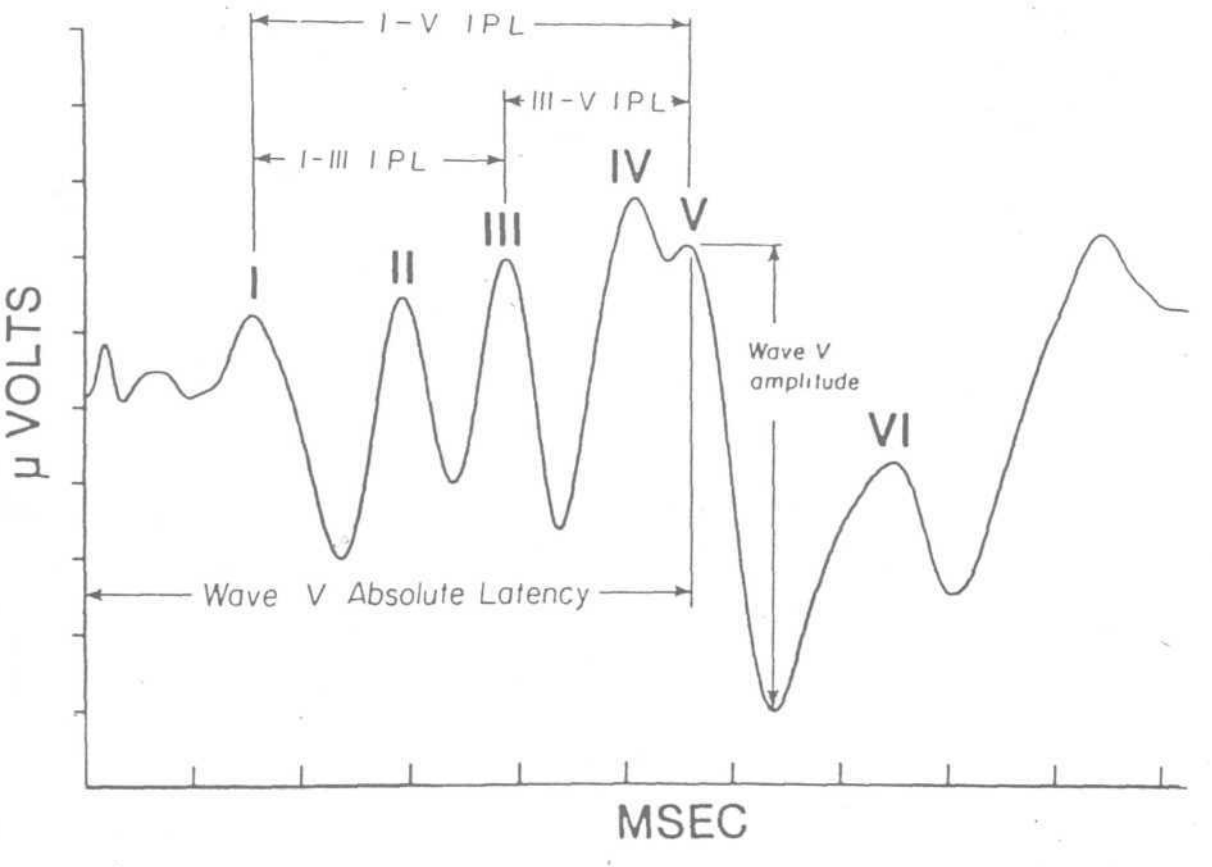
Schmer and Feinmesser (1967) found that the early waves of the response (Wave-I through Wave-IV) were found to be particularly sensitive to increases in the stimulus repetition rate, i.e., the reduction of these waves was markedly reduced at higher repetition rates.

Jewett and Williston (1971) found that lower frequency tone pip resulted in a less distinct waveform than higher frequency tone pip. They also were first to record 1.0 to 10 millisecond brain stem responses unaffected by sleep or sedation.

Hecox and Galambos (1974) applied BSERA to infants and adults.

FIGURE I

Example of a normal ABR for an adult male. Shown is the Jewett scheme for peak labeling (vertex-positive up) and the measurement of absolute and interpeak latency and peak-to-trough amplitude.



Shai and Albright (1980) found that BSERA applications in audiologic-otologic disorders and site of lesion testing have proved well - suited for the detection of hearing abnormalities.

Anatomical Origins of Response Components:

From the very beginning, various investigators have speculated about the origin of ABR component waves.

Studies by sohmer et al., (1974); Starr and Achor (1978); Starr end Hamilton (1976) demonstrated that wave-I was typically the only recommend when lesions involved the ponto-medullary function or when the brain-stem was externally damaged. Alterations of waves II and III were associated with lesions in the medulla and pons i.e., the cochlear nucleus, trapezoid body and superior olive lesions affecting midbrain auditory structures were associated with changes in wave IV and V. (Fig. II - See page No. 14).

Picton et al., (1974) concluded that waves I through IV represented activity of the auditory nerve and brainstem auditory nuclei, but the ABR waves recorded from vertex to mastoid reflected the composite contribution of multiple generators.

Geoff et al., (1977) produced the following table:

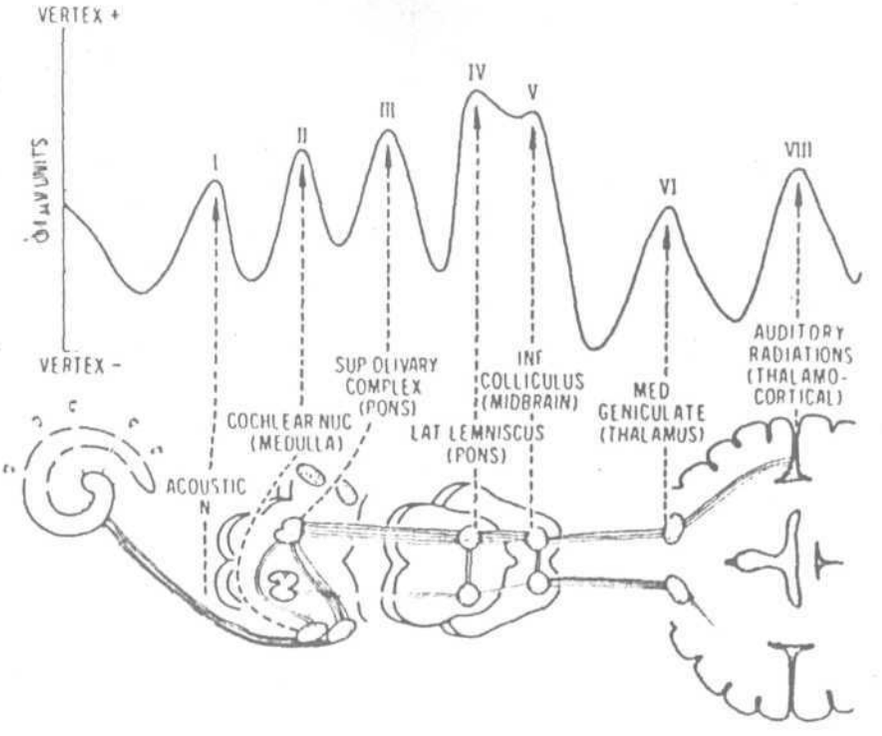


Figure II *The presumed correspondence between ABR component waves (I through VII, upper portion of the figure) and anatomical structures in the primary ascending auditory pathway (lower portion of the figure). Evidence from various studies (Jewett, 1970; Starr and Achor, 1978) demonstrates that a given 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).*

ABR Component waves		Specific Neural Generators
I		Acoustic Nerve
II	Cochlear	Nerve (Medulla)
III		superior Olivary Complex (Pons)
IV		Lateral Lemniscus (Pons)
V		Inferior Colliculus (Midbrain)
VI		Medical Geniculate (Thalamus)
VII		Auditory Radiation(Thalamo-cortical)

Moller's (1985) current work on human intracranial recordings represent an important advance in establishing the origin of ABR potentials and increasing ear Knowledge of auditory function of the brain stem. His investigations indicate that Wave I of ABR is generated from the lateral aspect of the auditory nerve. Wave II originates from the medial aspect. Wave-III probably has more than one generator as do most of other subsequent waves of ABR. However, it appears that the cochlear nucleus is the principle generator for Wave III (1983, 1985). Wave-IV also probably has multiple generator sites, but it rises predominantly from a superior elivary complex with a contralateral influence that may be stronger than the ipsilateral contribution.

According to Moller (1982, 1985) and Wada and Starr (1983), Wave V is generated from lateral lemniscus.

This is still an oversimplified scheme for deriving origins of the ABR. It must be realized that the ABR waveform is generated from synchronous discharges along the auditory nerve and brain-stem pathway. Neural fibers with a similar response latency for a given stimulus compose the ABR waves. But, these neural fibers may come from a variety of different structures in the brain stem and so the ABR anatomical relationship for the brain stem cannot be derived.

However, there is a good possibility that the first five waves of the ABR may be generated entirely within the auditory nerve and pons.

Animal studies by Wade and Starr (1983) as well as Moller's (1985) findings with human have shown the firat 5 waves of the ABR are not affected by specific lesions of the inferior colliculus.

Still further research is required to arrive at conclusion concerning the anatomical origin of ABR for sure.

NORMAL RESPONSE PARAMETERS

The criteria for ABR interpretation are based in general, on the:-

(1) Latency (in millisecond) of individual waveforms;

(2) Latency differences between primary peak components (interpeak latency);
(3) Peak amplitude (in microvolts);
(4) I-V amplitude ratio, and
(5) Waveform Morphology.

Since some of these parameters (eg. latency and amplitude) lead themselves more to quantitative interpretation, diagnostic decisions are often based on alterations in one or more of these response parameters. Consequently, individual patient responses must be compared to a normative referrant to determine if any of the response parameters falls outside of a prespecified range of normalcy.

A. Response Latency:

The absolute latency of a given waveform can be defined as the time period (in milliseconds) between the onset of the acoustic stimulus (eg. rectangular wave click) and the peak of the averaged response . (Fig.III- see page No.16).

Latency is measured at the point representing the beginning of the down-slope of a given peak component. This measurement is of particular value when a wave form does not present a clearly defined peak, but rather shows a merging of two separate waveforms, as is often encountered in the IV/V complex or has minor glitches at the peak of the response.

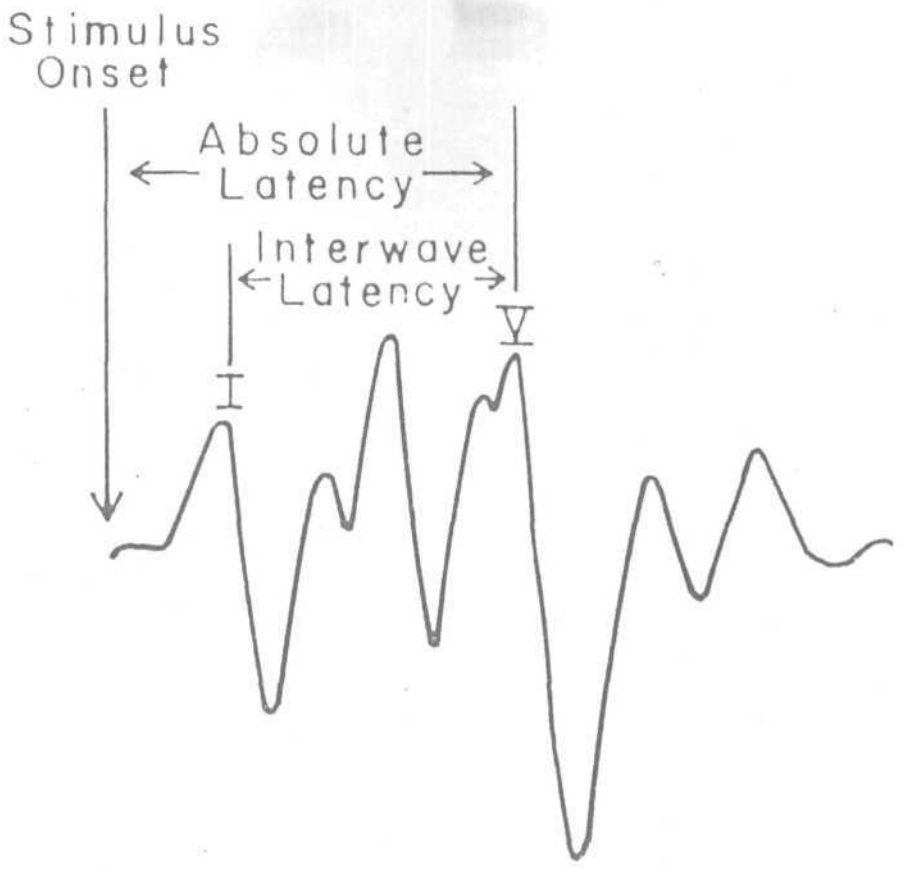


Figure III. The distinction between absolute and interwave latency for component waves of the ABR. By definition, absolute latency is the time (in milliseconds) from stimulus onset to the occurrence of a given wave peak; in this figure, the absolute latency of wave V is represented. Interwave latency is the time difference (in milliseconds) between the absolute latencies of two ABR waves; in this figure the I to V (I-V) interwave latency is depicted. As described in the text (see Procedure effects), some investigators reference absolute latency to the estimated time of arrival of the stimulus at the ear; instead of using stimulus onset. In addition, some authors measure latency to the peak of the wave, but others measure to the beginning of the wave's negative slope.

"Interwave latency" refers to the time difference between two component waves, example, the I-V interwave latency. Both are typically specified in milliseconds. This value gives differential diagnosis of space occupying lesions, either intrinsic or extrinsic to the brainatem, and the disruption of neuroelectric activity secondary to demyelinating disease. The difference is generally between the waves I, III and V.

Variation between studies for a given ABR wave latency might reflect the number of subjects evaluated and/or the click intensity and filter settings employed.

Absolute latency for each ABR wave: (See page No.20)

Increasing tendency to focus on I-III, III-V and I-V interwave latencies is due to the information made available by studying them.

I-III — We get transmission time through the ponto-modullary function and lower pens.

III-V - We obtain transmission time from caudal pons to caudal midbrain.

I—V — We obtain time needed for impulses to travel the entire system and is sometimes called "Central" or "brain-stem" transmission time.

B. Waveform Amplitude:

Response amplitude refers to the height of a given wave components and it is usually measured in microvolts (/ V) from

ABSOLUTE LATENCY FOR EACH ABR WAVE

Studies	N	Click Intensity	Filter	I	II	III	IV	V	VI	I-III	III-V	I-V
Jewett and Williston (1971)	11	60-70dB	10-10,000	1.7	2-	-	-	-	-	-	-	-
Picton et.al (1974)	20	60dB	10-3,000	1.5	2.6	3.5	4.3	5.8	7.4	-	-	-
Rosenhamer et al(1976)	20	60dB	180-8,500	1.7	2.9	3.9	5.2	5.9	7.6	2.26	2.0	4.27
Rowe (1978)	25	60dB	100-3,000	1.9	2.9	3.8	5.1	5.8	7.4	1.97	1.97	3.94
Stockard et al. (1978)	50	60dB	100-3,000	1.8	2.9	3.9	5.2	5.8	-	2.1	1.9	4.0
Chippa et al. (1979)	50	60dB	100-3,000	1.7	2.8	3.9	5.1	5.7	7.3	2.1	1.9	4.0
Jacobson (1985)	50	75dB nHL	75-1,500	1.65	2.85	3.8	4.99	5.66	-	2.05	1.85	4.0

the peak of the wave to the following trough (assuring that vertex positive waves are displayed as upward directions) Fig.IV (see page No.22).

Amplitude values do not appear to be normally distributed (Rowe, 1981), are highly susceptible to myogenix activity and noise level, are difficult to replicate, and are easily influenced by minor alterations in recording technique.

One technique for controlling the variability of the amplitude measure was preferred by Thomton (1975-1976). His approach was to plot normative data on coordinates that represented response amplitude on the ordinate and latency on the obscissa. Individual data points for each wave component are subsequently grouped within ellipses corresponding to a prespecified range of normal values (eg. confidence intervals), thereby reflecting the variability of the measure.

Relative amplitude of waves is absolute amplitude of ABR component waves expressed in relation to one another.

An alternative to absolute amplitude measure that has achieved increased clinical acceptance in recent years is the calculation of the relative I-V ratio. In normal patients, weve-V is usually greater in amplitude than wave-I, resulting in an amplitude ratio >1.00 (Chiappa, Gladstone and young, 1979; Rowe, 1978; Starr and Achor, 1975). Hence, a I-V amplitude ratio of < l.00 is considered abnormal and indicative

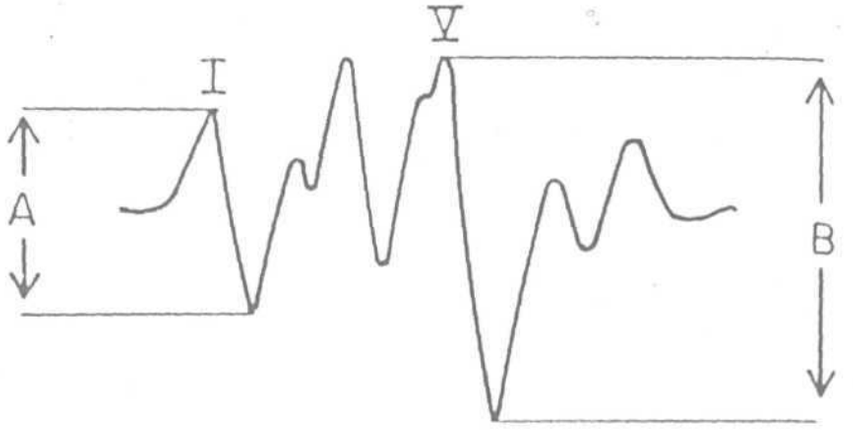


Figure IV The distinction of absolute and relative wave amplitudes for the ABR. Most often, absolute wave amplitude is the height (in microvolts) of the wave from its peak to the following trough, as shown above for waves I and V (A and B, respectively); but relative amplitude is the ratio of the absolute 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.

of retrocochlear pathology (Musick, Kobbe, Rackliffe and Welder, 1984). It is believed that if clinicians elect to employ the I-V amplitude ratio in the clinical decision masking process, it behooves them to establish their own normative data for this measure.

C. Waveform Morphology:

Morphology refers to the visual appearance or actual shape of the averaged response. This is entirely subjective and a qualitative descriptor.

Jewett and Williston (1971) advocated the use of Roman numerals to label the seven distinct and sequential series of waves that occurred within the first 9 ms. following the introduction of an acoustic transient. This has become the convention.

In contrast, other investigators have elected to describe individual peak components on the basis of wave latency, resulting in such designations of P6 (Davis,1976); FFP7 (Terkildsen, Osterhammel and Hins in't Veld, 1977). Still other label peaks chronologically (Thornton,1975).

The figure No.(3), exemplifies the morphologic variations that one can obtain on normal subjects. The well known IV-V complex is not always apparent. At times, Wave V seems to

side just below the rest of peaks IV (A) or these may be a total fusion of waves IV and V into ona broad peak (H). Similarly, it is not uncommon to show bifircation of waves I and/or III (G and H), thus making it difficult to measure latency if one uses a peak reference point.

Response morphology can be affected by age, pathology and measurement related variables. These alterations are thus "soft" clinical signs of neuroauditory pathology.

To summarize accurate and reliable interpretation of the ABR is based on the quantitative and qualitative assessment of waveform latency, amplitude and morphology.

FACTORS INFLUENCING THE AUDITORY BRAIN-STEM RESPONSES:

Due to the absence of standards to specify recording parameters and methods used to measure the ABR, it is imperative that each individual clinical facility establish its own normative data. Differences in electrical and electromagnetic field variation between clinical sitesm as well as heteroeneity in stimulus recording and analysis parameters, electrode placement, and transducer type, all lead to small but significant differences in wave latency, amplitude, and morphology which together can cloud ABR interpretation.

A. THE EFFECTS OF STIMULUS PARAMETERS ON THE ERA:

I. The choice of the stimulus:

Clicks of short duration were recommended Perl, Galambos and Glerig (1969).

Pulses made of positive half of a pure tone was recommended by William and Graham (1963).

Perl, Galambos and Glorig (1969) and Williams and Grapham (1963), recommended clicks, as it was easier to evoke a response with them than with pure tones. This was because ABR requires short duration stimuli and the rise time of a click is shorter than the rise time of a pure tone, and the cortical activity evoked by a click is more diffuse than with a pure tone.

Devis (1970) used tone pips which are filtered clicks at different frequencies. Recently he pointed out that although agreement between voluntary thresholds for pure tones and tone pips is generally good, it tends to be poorer for persons with steeply sloped hearing loss.

It is seen that the spectral shape of a signal is intrinsically related to the electrically generated signal. Also currant (1982) says that the final stimulus arriving at the cochlea will be influenced by the mode of delivery (i.e. earphones vs. speaker) and the acoustics of the auricle, ear canal, and the middle ear space.

A 'click' can be generated using a number of electrical equivalents, such as one or two cydes of sine wave, the triangular wave, the square wave, a positive sawtooth wave (ramp), a positive or negative-going pulse, a short tone burst, the so-called haversine and various form of wide-band and band-limited noise.

In the 1970s, the theoretical treatment of Gabor'a(1947) elementary signal or "logon" theory (Davis,1976) was consi-dered. Here the emphasis was on striking a compromise between an abrupt rectangular wave and a continuous, pure tone.

The logical sequal to these efforts was a desire to have a signal that is abrupt enough to synchronize primary auditory units, yet long enough to maintain frequency specificity. Thus, the interest arose in tone pip (Davis, 1976), the 1/3 octave click (Naunton and Zerlin, 1976) and the short tone burst (Bausch, Rose and Hairner, 1980; stockard et al., 1979; wood Leitz and Jacobson, 1979, etc).

II. Effect of Stimulus Intensity:

The most striking characteristic of the ABR is its sensitivity to the intensity of the acoustic stimulus. Stimulus intensity is related to the spatial configuration of neural aggregates and the number of active neural elements present.

A decrease in stimulus intensity results in an increase in response latency of all ABR component waveforms. For a click stimulus, the latency of the most robust wave (V) increases monotorically as stimulus intensity decreases from 90dB nHL down toward visual detection threshold of the response. (Fig.V - See page No.27).

Intensity of stimulus influences the frequency of firing and the number of neural elements capable of firing (Moore, 1978).

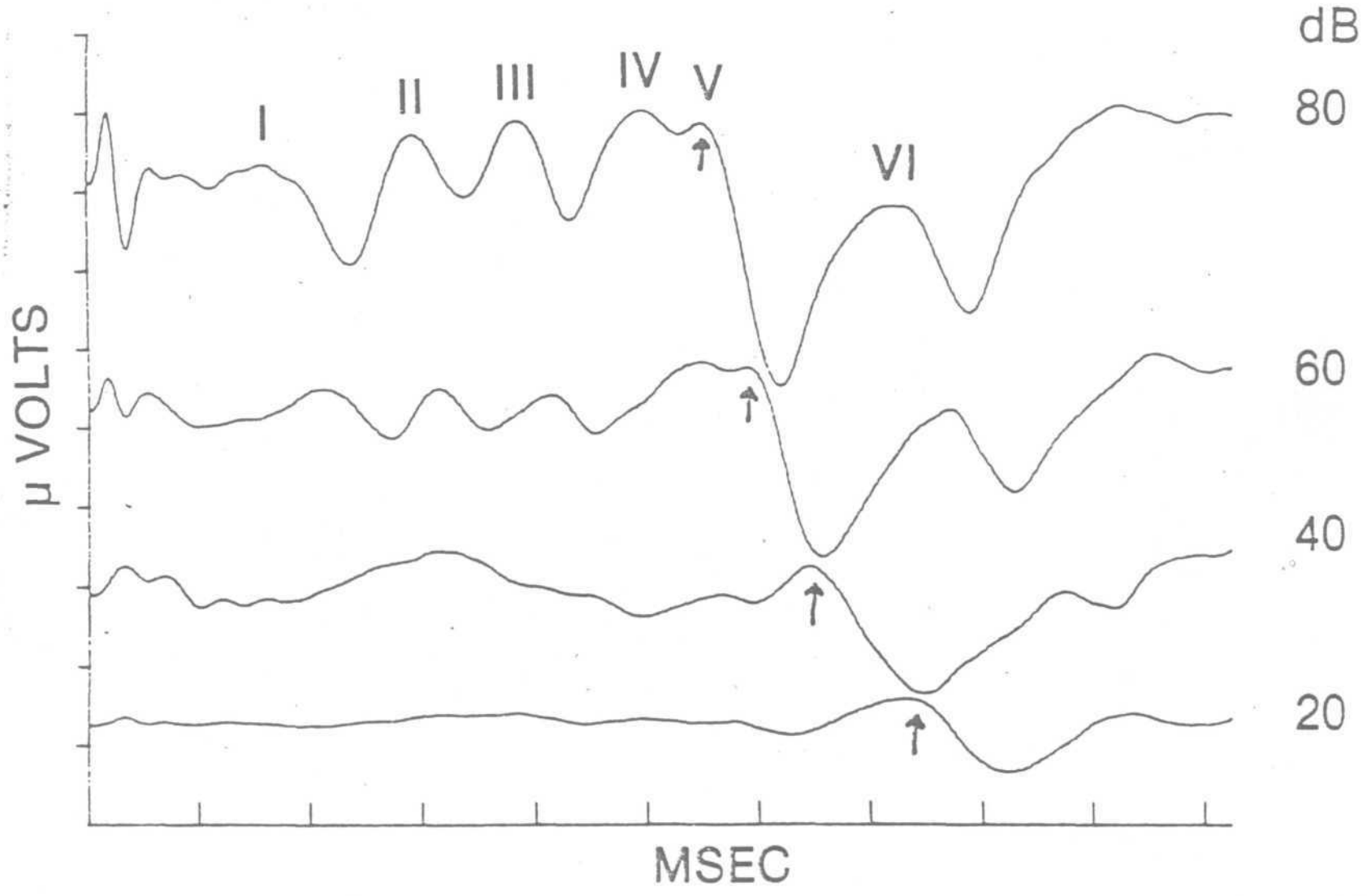
We use nH1 designation wherever levels are referred to the threshold of a panel of normal hearing young adults. And dBsL is used when levels refer to individual's threshold for that stimulus (Moore, 1978).

At the intensities below 40dBnHL (approximately) waves I and III are seen more frequently than II and IV. But V is often the only remaining wave in response to stimulus intensities that approximate threshold levels (Rowe, 1978).

When wave V is fused into an undistinguishable IV-V complex, its resolution is improved at lower stimulus intensities (Rowe, 1978; stockard, et al., 1978).

Latency is supposed to have an approximately linear relation to the log of the stimulus intensity (Moore, 1979).

FIGURE V
Effect of decreasing stimulus intensity on wave V latency, amplitude, and morphology. Time window is 10 ms.



A decrease in stimulus intensity is associated with the increase in the component wave latencies. (Jewett and Williston 1971; Jawatt et al., 1970; Hecox and Galambos, 1974; Picton et al., 1977; Starr and Achor 1975; Yamada at al., 1975).

Wave I is latency was found to increase more than waves III-V, when stimmlus intensity was decreased. Also ABR amplitude was found to decrease with decreasing stimulus intensity (Stockard at al., 1979).

To explain the response to various intensity changes, Rosenblith (1964) used a statistical model of nervous system and noted that recording from an electrode in the nervous system is really a sample of summated activity from a neural population at that particular spot in the auditory system and the number of neural units involved depends on intensity. He also observed that clicks presented in an ascending order of intensity were associated with raised threshold responses having reduced amplitude, as compared to responses presented in a descending order of intensity.

The magnitude of latency shift for wave V is on the order of 40 μs/dB. They have studied the probability of detecting various peak components as a function of stimulus sensation level for the normal hearers. Visual detection of wave V was possible in 75% of cases at intensities between 10 and 20dB SL and approached 100% at higher stimulus levels.

Wave III, was identifiable at levels of approximately 30dBSL in 50-60% of the subjects. For wave I, a response rate of 75% was seen at 50dBSL (Schwartz and Barry, 1984; D.E.Rose, 1984; Worthington and Peters, 1980).

Wave V is high rate of detectability or near the visual detection threshold provides a basis for deriving a latency-intensity series as an aid to estimating hearing threshold in those individuals with whom routine behavioral measurements are precluded. It was also recommended that each individual facility develop its own normal latency-latensity template, for comparision with patient's suspected of hearing loss.

Starr and Achor (1976) found that V:I relative amplitude ratio increased with decreased stimulus intensity.

stockard et al (1978) observed that a 50dB reduction in stimulus intensity was assoicated with a 33% decrease in amplitude of the IV-V complex, while the same reduction of intensity waw associated with a 90% decrease in wave I amplitude.

Wolfe et al., (1978) investigated relation between peak amplitude and latency to signal intensity for the ABR. Responses were obtained to clicks presented to sensation levels of 15, 20, 30, 40, 50, 60 and 70dB and the latency and amplitudes for various wavelets were plotted against signal I.

A consistent tread of decreased peak latency was seen with increased intensity. Also wavelet V showed a linear growth with increased signal intensity.

10dB decrease in click intensity was seen to result in a measurable increase in absolute latency. Mean latency for wava-I in normal adults increases from approximately 5.5msec at 80dBHL, to slightly greater than 8.0 msec. at 10dBHL (Chiappa et al., 1979; Hecox and Galambos, 1974) Starr and Achor, 1975; Yamada, et al., 1975).

Stockard et al (1978) reported one subject who showed a 0.07 msec. increase in the I-V interwave latency when responses to 10 and 20 dBSL clicks were compared.

In newborns, wave I shows an average amplitude reduction of 66%, when intensity is decreased from 70 to 30dBHL, white wave IV-V is only reduced by 33% (Moore, 1982).

At high intensities waves I, III and V stand out more prominently than others, and as intensity drops their amplitudes diminish and their latencies increase. Near threshold only wave I is consistently identifiable.

When click intensity is reduced from 70 to 30dBSL in adults, the magnitude of the latency shift is greatest in wave-I and least in wave-V. The largest shift appears between 50 and 40dBSL where amplitude dominance is transferred from the

first and second major peak of the eighth nerve action potential (AP), causing a sudden jump in latency (Eggermont and Odenthal, 1974). This jump is not paralleled by the shift in vave-V. An abrupt decrease inthe I-V IPL occurs at this point. Smaller but significant decreases are seen an IPL is involving wave-I between 70 and 60dB SL (I-III, $P < 0.02$), 60 and 50 dBSL (I-III, $P < 0.02$; I-V $P < 0.001$) and 40 and 30dBSL (I-V. $P < 0.01$).

The amplitude of the IV-V complex is also less affected by stimulus intensity than are earlier components (Terkildnsen. Osterhammel, ang Huisin't Veld, 1973; Pratt and Sohmer, 1976).

The Change in mean amplitude from 0.49 μv at 70dBSL to 0.28 μv at 30dBSL in adults represents an average 41% reduction in amplitude over the 40 dB range. Wave I amplitude over the same range is reduced by 81%. The most abrupt change in amplitude is seen between 60 and 70dB, where wave I doubles in amplitude is both newborns and adults (Moore, 1983).

In many wave-I amplitude is lower at the "transitional" intensity (usually 45-55 dBSL) than at 30dBSL (Moore, 1983).

III. Effect of stimulus loudness on the evoked responses:

Loudness is the psychological parameter of intensity.

Allen (1969) found that the amplitude of the response to binaural stimulation was about 21% greater than monaural stimulation regardless of frequency or intensity level. He interpreted this as binaural stimulation of loudness.

Antinoro and Skinner (1969) - described the relationship of amplitude increments to intensity increments as linear function.

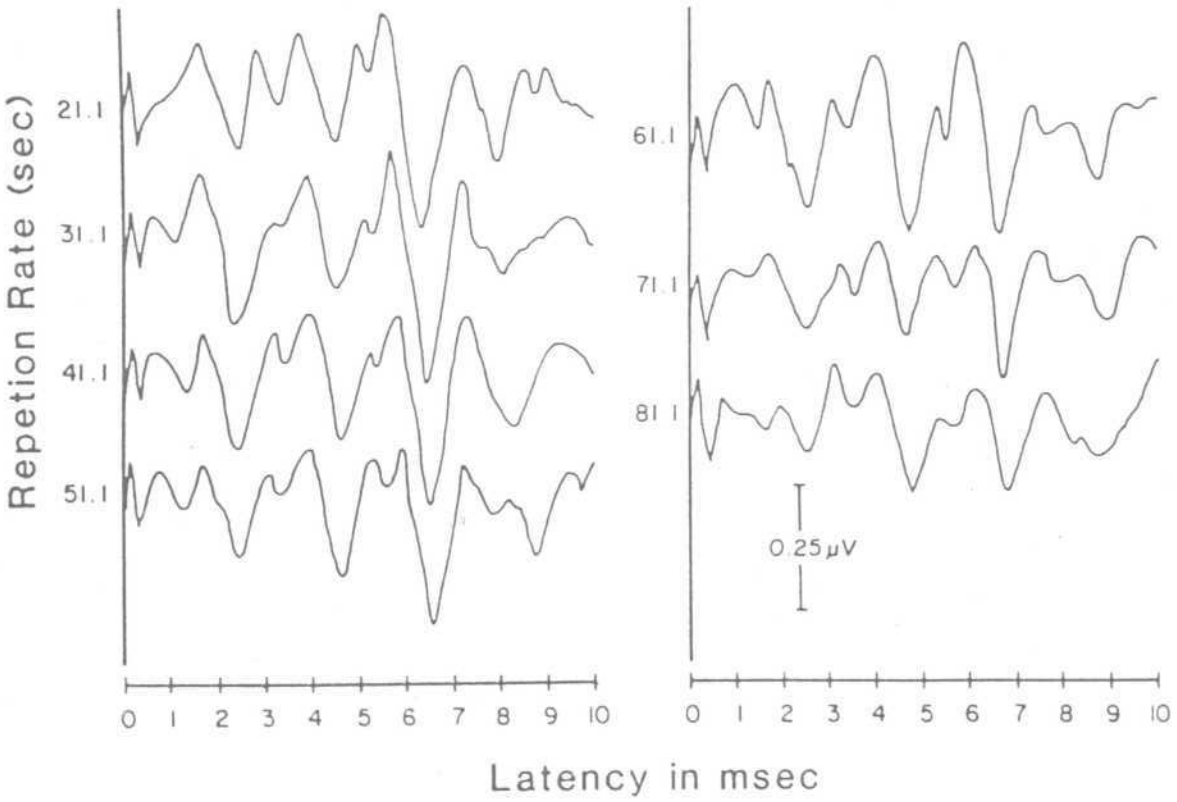
IV. Effect of stimulus duration on Evoked Response:

As duration is increased from 30 to 100 msec. the latency of all components increased. Also the amplitude of various components decreased and became indistinct. But all the waves can readily be identified at the longest duration, though double peaked wave IV-V complex merge into one broad identifiable peak (Haskins, McEvoy and Scott, 1979).
Fig.VI (See page No.33).

Satisfactory vertex response could he obtained from normal hearing subjects by using tone pulses having a duration of 6-64 m.sec. presented at a rate of one per two seconds.

While the duration is increasing the various BSER waves are less distinct and show an increase in latency but a decreased in amplitude. It has been seen that when stimuli

FIGURE VI.
Changes in ABR characteristics secondary to increasing repetition rate.



of 30 m.sec and 200 m.sec were employed clinical accuracy was better at stimulation rate of one per two seconds, as compared to one per second (Cody and Buckford, 1980).

It was hypothesized that with the presentation of each stimulus, a neural memory trace is set up in the brain. The watch between the memory trace and actual stimulus improves with each successive presentation of the stimulus. The evoked response amplitude is a measure of the amount of mis-match which is present, and habituation can be defined in this match.

Skinner and Jones (1968) observed a maximum peak-to-peak voltage when the stimulus duration was 25-50 m.sec. They agree with Davis and zerlin (1966), that an increment in response to amplitude at this point is probably due to interaction of the on - and - off effects. The amplitude of off-effect is seen to increase with stimuli of longer duration just as amplitude of the on-effact is increased by using longer interstimulus intervals.

V. The effect of stimulus rise:-

- Decay time on the Evoked Response.

The neural impulses that make up the BSER are best excited by fast rising stimuli. The latency of various components are also seen to shift to a later time of occurrence for longer

rise-decay times. Distinctive BSER potentials depend upon a synchronous discharge of auditory nerve fibers (Kimmelman, Marsh and Yamada et al., (1979); Koder, Hink and Yamada et al., (1979); Suzuki and Horiuchi (1981).

Cody and Kliss (1968) found that a decrease in rise time was associated with a decrease in response latency and generally with an increase in amplitude.

VI. The Effect of stimulus Polarity on the Evoked Response:

This is the effect of stimulus when presented in a condensation or a rarefaction phase starting from time zero.

It has been seen that the first firing of the auditory nerve coincides with most of the basilar membrane towards the scala vestibuli, which corresponds to the rarefaction phase of the acoustic stimulus and lateral displacement of the tympanic membrane (Kiang, Watanabe and Thomas, et al., 1965). This fact alone would predict a wave-I latency delay of one-half of the cycle of the stimulus to condensation (c), as compared to rarefactioa(R), stimuli.

Changing of click polarity from rarefaction to condensation influences morphology of IV-V complex. There is shortening of Wave-V in the order of 0.4 - 0.8 ms to rarefaction versus condensation (Coats and Martin, 1977; Ornitz and Walter, 1980).

Stockard et al (1979) found that wave-IV was more prominent than wave-V in 70% of subject's responses to rarefaction clicks. Alteration of click polarity can affect morphology of wave-I due to possible cancellation of out of phase components when responses to the separate polarities are summed.

Studies by Berg et al., (1982); Rosenhamer, Lindstrom and Lundberg (1978 and Ruth et al., (1982) fail to reveal any systematic alteration in the peak latency of Wave-V with click phase inversion. It is often seen that signal generated electrically at an instrument does not guarantee a similar acoustic polarity when transduced through an earphone. So, it is necessary to determine acoustic phase of the stimulus prior to collecting of normative data. This can be done by an earphone phase tester (EPT).

In some individuals, BSER vertex-positive peaks II-IV may also be altered by phase, in either direction. This is particularly true in infants (Stockard, stockard and Westmoreland at al., 1979) and Children (Ornitz and Walter, 1975).

The magnitude of C-R (Condensation-rarefaction) wave-I differences is also greater in newborns resulting in rather large interpeak latency C-R differences.

Stimulus phase also influences the magnitude of the rate effect on wave I latency (and on IPLs involving that components). At 70dB SL, wave I latency is either unlatered or decreased by high rates of rarefaction click presentation. These is significantly (P 0.001) greater I-III, and I-V IPLr ate related change for rarefaction clicks than for condensation clicks.

VII. The Effect of stimulus Presentation and Interstimulus Interval:

Increasing the rate of stimulation also increases the latency, bat decreases the magnitude of BSER waves. The effect is more for rates greater than 10/sec, but the effect does not go unnoticed at rates below 10/sec (Campbell, Picton and Wolfe et el., 1961; Moore, 1971; Picton at al., 1981).

Increase in stimulus rate significantly decreased the definition of waves I through IV. This was quite noticeable at 20 clicks per second as compared to 10/second. Wave V seems to be least resistant to rate effects (Jewett and Williston, 1977).

In general, an increase in absolute latency of all ABR component waves is associated with an increase in stimulus repetition rate. The I-V interwaves latency was seems to be increased. (Chiappa et al., 1979; Rosenhamer et al., 1978; Stockard et al., 1979; Weber and Fuzikawa, 1977).

Optimal rate lies probably between one per 3 seconds and one per second according Rapin (1964).

According to Hyde et al., (1976) latency of wave-V is not seriously affected until rate exceeds approximately 30/sec.

Increases in rate of stimulation above approximately 20Hz result in a dimunition in amplitude for the early components of the ABR (waves I-II) with little effect on the more rostral component (Wave-V) until stimulus rate exceeds approximately 30/sec. Also, the latency of essentially all ABR components appears to increase by a magnitude of approximately 0.4 ms as repetition rate increases from 10-80Hz.

Due to possible compromising effects of repetition rate on response clarity and magnitude of waves I and III, which are important to otoneurologic diagnosis, repetition rates less than 12/sec are recommended for evaluating auditory neural integrity. It may be desirable to employ fast rates of presentation to detect incipient abnormalities in the brainstem pathway (Gerling and Finitzo, Hieber (1983); Robinson and Rudge (1977); Stockard, Stockard and Shorbrough (1980).

VIII. Filter Characteristics:

With most of the bioelectric potentials in the ABR too is embedded in a background of competing electrical activity

(EMG). Sometimes amplitudes of the electromyographic events 100 times greater than those of the ABR. So, the morphology of the averaged evoked potential will loose considerable resolution unless the frequency response of the recording system is set to reject the maximal amount of electrical interference.

One method of optimizing response clarity by reducing the signal-to-noise ratio is that of bandpass filtering. The choice of filter settings should be predicted on the frequency composition of the derived bioelectric potential as well as on interfering myogenic noise.

Several investigators have indicated that the constituent frequencies that compose the ABR range from 50 to 1000Hz (Laukil and Muir, 1981; Thornton, 1978, etc).

Kevanishike and Aphonchenko (1982) have suggested that the main spectral components of Waves-I and II are distributed between 400 Hz and lKHz; Wave-III between 100 and 900 Hz. and Wave IV -VI from 100 its 500Hz. Hence, it is apparent that the frequency content of ABR is critical to the selection of appropriate bandpass filtering since the characteristics of the response can be affected by filter bandwidths and roll-off rates.

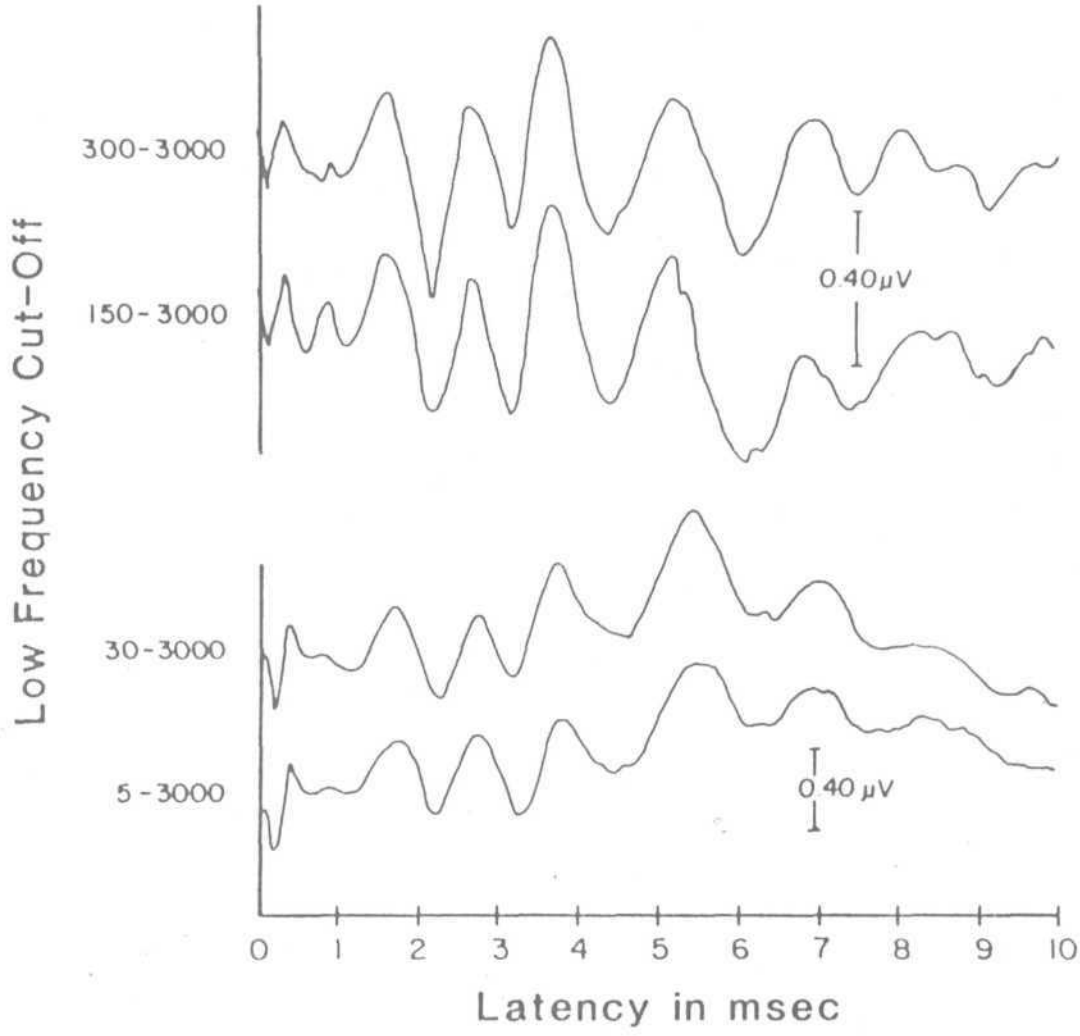
Most commercially available instruments employ analog filters that are known to cause latency shifts due to phase distortion (Boston and Ainslie, 1980).

Jewett and Williston (1971) reported latency changes following reduction in bandwidth from 1.6 to 100 Hz and concluded that the high pass setting should be a nominal l000Hz.

Stockard et al (1976) saw that increasing the low frequency filter settings from 100 to 300Hz resultant in a progressive decrease in wave latency. They also noticed that the amplitude of IV/V complex decreased rapidly between low-frequency filter settings of 100 and 300Hz. Absolute wave latency was shown to decrease as a result of increasing the high-frequency cut-off from 300 to 10,000 Hz with the most optimal waveform reduction occurring at a high frequency filter setting of 3KHz (Fig.VII. See page No. 41).

Raising the low frequency cut-off from 2 to 100Hz results in a closs of the slow component of the response and a decrease in peak latencies, lowering the high frequency cut-off from 5000 to l000Hz produced uniform latency increases across wave components. So, they concluded that analog filtering produced significant and complex changes in latency, amplitude and morphology which could result in diagnostic

FIGURE VII
Effect of changing the low-frequency filter cutoff on ABR measurement parameters.



interpretation unless normative data was gathered against which individual clinical patient responses will be compared under the same filter conditions. As per them, clearest responses are determined at filter settings between 150 and 1500Hz (Laukli and Mair, 1981)

Fig.VIII (See page No.43)

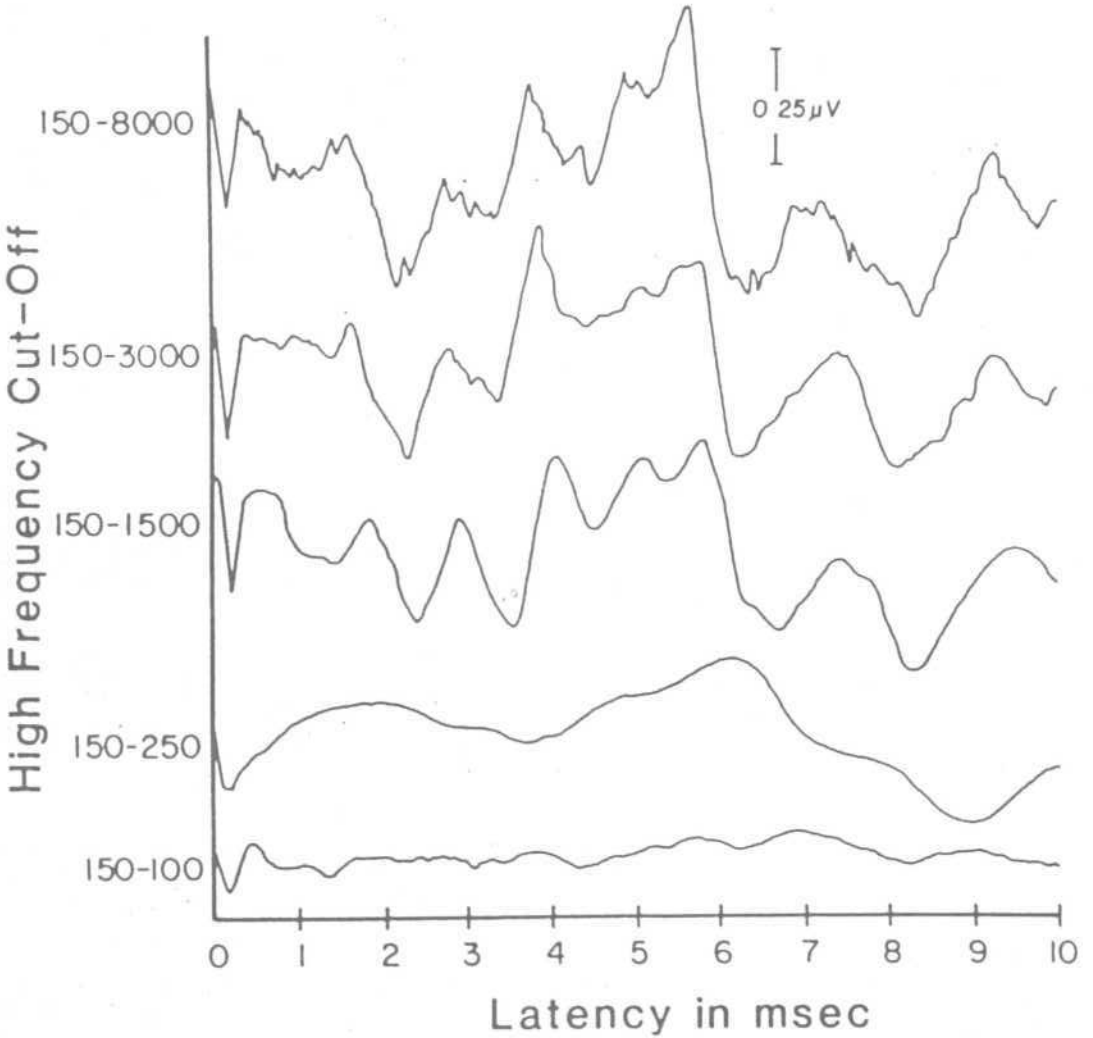
B.Procedure related Effects on ERA:

Jewett and Williston (1971). Martin and Moore (1977), Picton et al (1974), Plantz at al (1974), Stockard at al., (1978) studied ABR components mapping in normal hearing subjects. The scalp distribution of the highest electrical activity of ABR components on the scalp were as follows:

- (1) The highest electrical activity of wave-I was most significantly detected on the parietal to the ipsi-laterel occipital area;
- (2) For the wave-III, the highest area was not inform, but tended to distribute to the contralateral hemisphere;
- (3) Wave-v revealed; the high amplitude area at the parietal portion (fairly contralateral).

The measurement of latency requires both stimulus and response reference points and the choice of reference points varies from one investigation to another. Latency measurement

FIGURE VIII.
Effect of changing the high-frequency filter cutoff on ABR measurement parameters.



referred to stimulus. Onset have slightly longer value than when reference is computed time of arrival of stimulus at the ear (stockard at al., 1978).

I. The Number of Samples: Time Domain Averaging -Effects of ERA:

The absolute voltages of the surface recorded ABR are quite small (Less than μv) and are measured from an area with significantly larger neurogenic and myogenic activity. ABR is only 1% of the amplitude of the ongoing EEG activity. So, the desired response remains concealed within this back-ground activity.

There are many ways of eliminating the unwanted electric activity. The source to noise ratio can be increased by (1) bandpass filtering; (2) artifact rejection; (3) electrode placement; (4) common mode rejection; (5) time domain averaging (Thornton, 1982).

The absolute number of averages needed for clear response resolution is dependent upon the amplitude of the ABR and amount of unwanted noncerebral electrical activity.

Decrease in intensity, results in decreased waveform amplitude, necessiates an increase in the number of averages to maintain a favourable signal to noise ratio.

This is important when (1) ABR is elicited to low level stimulation for threshold estimation; (2) Recording ABR in

environments having relatively high electrical ambience, as in the neurological or neonatal intensive care units.

So, it is recommended that at least two averager of 2000 response be obtained with greater averaging (4000-6000 sweeps) required for threshold measures and myogenically noisy subjects. A control trial should be performed (i.e. no stimulus input) as a baseline for comparison with the actual response, Artifact rejection of events that exceed the limits of the A-D converter should be employed.

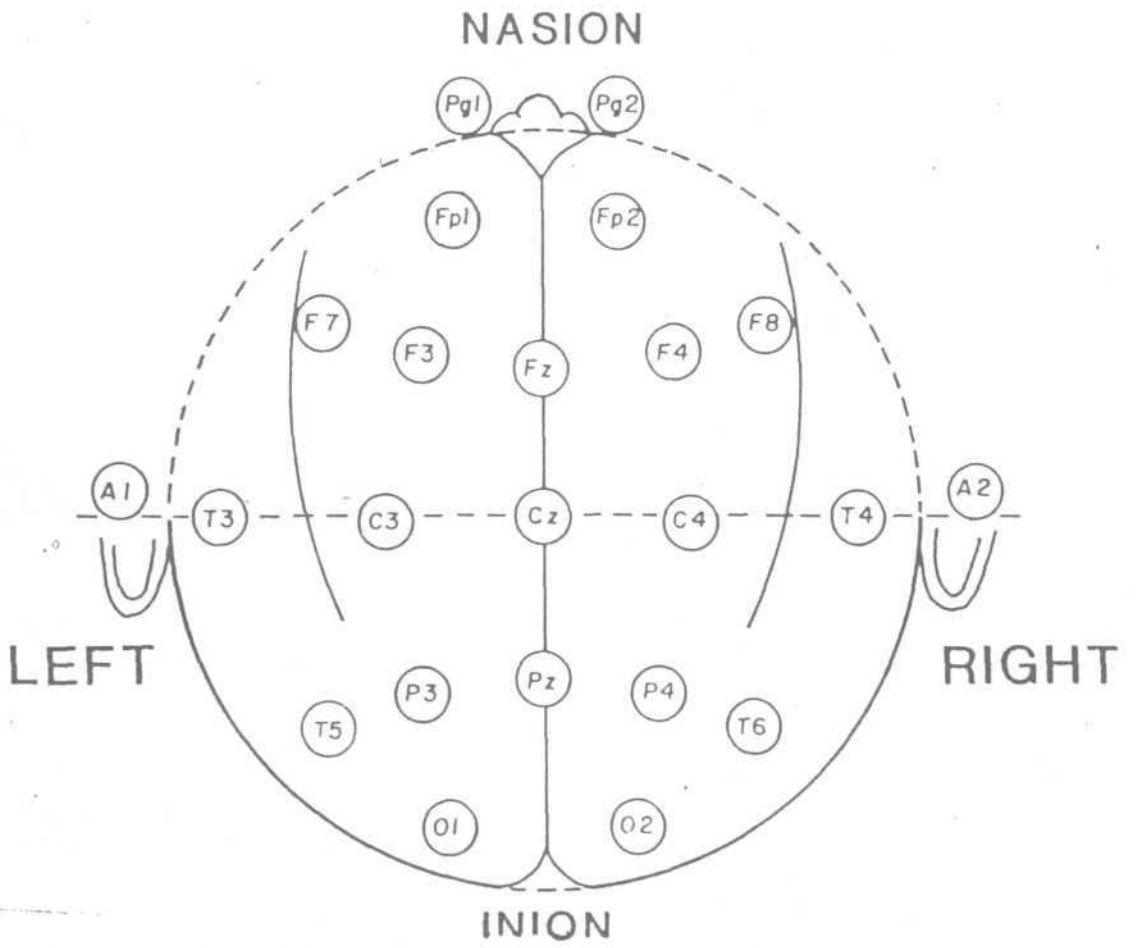
II. Effect of Electrode Location on ABR:

The international 10-20 system proposed by Jasper (1958) in which electrode placements are based on measurements from four standard position on the head; namely, the nasion ionion and right and left preauricular sites.
Fig.IX (See page No.46)

In ABR testing, the electrodes are arranged such that the electrical potential difference is measured between pairs of scalp electrodes (bipilar deviation). In the single channel ABR recordings requires placement of three surface electrodes two of Which are connected to preamplifier inputs with the third serving as ground.

The active or positive electrode as placed on the vertex (Cz) or high forehead (Fz). The reference or negative electrode

FIGURE IX.
International 10-20 system for electrode placement. Landmarks most commonly used in ABR recording are A1-A2, Pz, Cz, and Fz.



is placed as assumed inactive site; i.e., the ipsilateral earlobe (A_1, A_2) or mastoid (M_1, M_2). The ground electrode is placed on the contralateral counterpart (earlobe or mastoid).

Terkildson, Osterhammel and Huis in't Veld (1974) called the active electrode as 'positive' and reference electrode as 'negative'.

According to Martin and Moore (1977) and Terkildsen and Osterhammel (1981) the best location for the positive electrode is considered to be the vertex.

Parker (1981) said that the optimal was to measure at a perietal site or Pz to ipailateral mastoid, with the Cz or positive to ipsilateral mastoid as the record best site.

Use of various atrumatic intrameatal electrodes tends to double the amplitude of Wave-I (Walter and Blegaud, 1981) without change in latency.

Lenget al (1981) observed some decrease in amplitude of wave V and VI.

Stockard et al (1978) found wave I amplitude to be 1.5 times greater with an earlobe versus a mastoid site for the reference electrode. Thus, yet another way in present for wave I amplitude to be increased.

III. Transducer Types Effect on ERA:

Earphone:

In routine ABR testing, the brief duration (eg.100 MS) rectangular wave electric pulse is transduced through some type of standard electrodynamic audiometric earphone (eg. TDH-39, and TDH-49) housed in either circumaural or supra-aural cushions. But, the differences between click spectra produced by different earphones may be significant.

Most earphones exhibit two primary resonant peaks between 3KHz and 6KHz. So, if the earphone is damped insufficiently about the resonant frequencies, then the application of a transient signal with an instantaneous rise time will result in 'ringing' that can interact with the stimulus of interest. Fig. X (See page No.49).

Thus, it is essential for the clinician to define the spectral content of the particular earphone to be used in ABR testing. Or latency prolongation may reflect the physical properties of the transducer and not those of the auditory system.

Also these electrodynamic earphones having low input load impedance often impart stray electromagnetic fields which are passed through the recording electrodes only to contaminate

the early portion of the ABR in the form of electromagnetic artifact. One common method for reducing this is enclosing the earphone in a conductive material as mu-metal and to connect the shield to ground.

Sound-field:

ABRs have been recorded for signals transduced through a loudspeaker in the sound field.

We should not only take care with the frequency response of the speaker, but also with the time delay that is introduced as a result of the distance between the tympanic membrane and the transducer. For example, speaker at the distance of 0.5 meters, means there will be a delay of 0.0015 MS.

Jacobson, Seltz, Mencher and Parrott (1981) compared binaural earphone - to - sound field generated ABRs and found absolute latencies for all wave components to be prolonged by a significant amount when unfiltered clicks were transduced through a loudspeaker placed one meter from the tragus.

Bone conduction:

Bone conduction is useful to assess sensorineural hearing loss, and also for congenital atresia or microtia.

Bone conducted ABRs reveal wave-V latency delays on the order of 0—5MS. This is probably due to effective spectrum or

the bone conducted signal which showed primary acoustic energy below 2500 Hz.

So, it is rrecommended to subtract 0.5 MS from measured bone conduction wave latency in an effort to provide direct comparisons to the derived air conduction latency values. The average separation in decibels between air conducted and corrected bone conducted latency-intensity functions, therefore, yields an estimate of the average air-bone gap from 1000 to 4000Hz.

On studying the bone-conducted latency-intensity functions developed for Radioear B-70, B-71, and B-72 bone conduction oscillators placed on 'the' mastoid. It was found that earliest wave V latency was obtained for the B-70 followed by B-71. The differences in wave-V latency between the B-70 and air conducted responses were minimal across intensities.

IV. Effect of Monaural Vs. Binaural Mode of Presentation:

In normals binaural stimulation usually results in a response of increasing amplitude.

Also binaural stimulation increases ratio of Wave I to Wave-V amplitude, but the ratio of amplitude of waves I and II.

V. Bilateral recording of ABR - Effect on ABR:

Terkildsen and his group (1973) showed the variation of the response to a unilateral stimulation according to whether it was recorded from the ipsilateral or contralataral mastoid. Fig.XI (See page No.53).

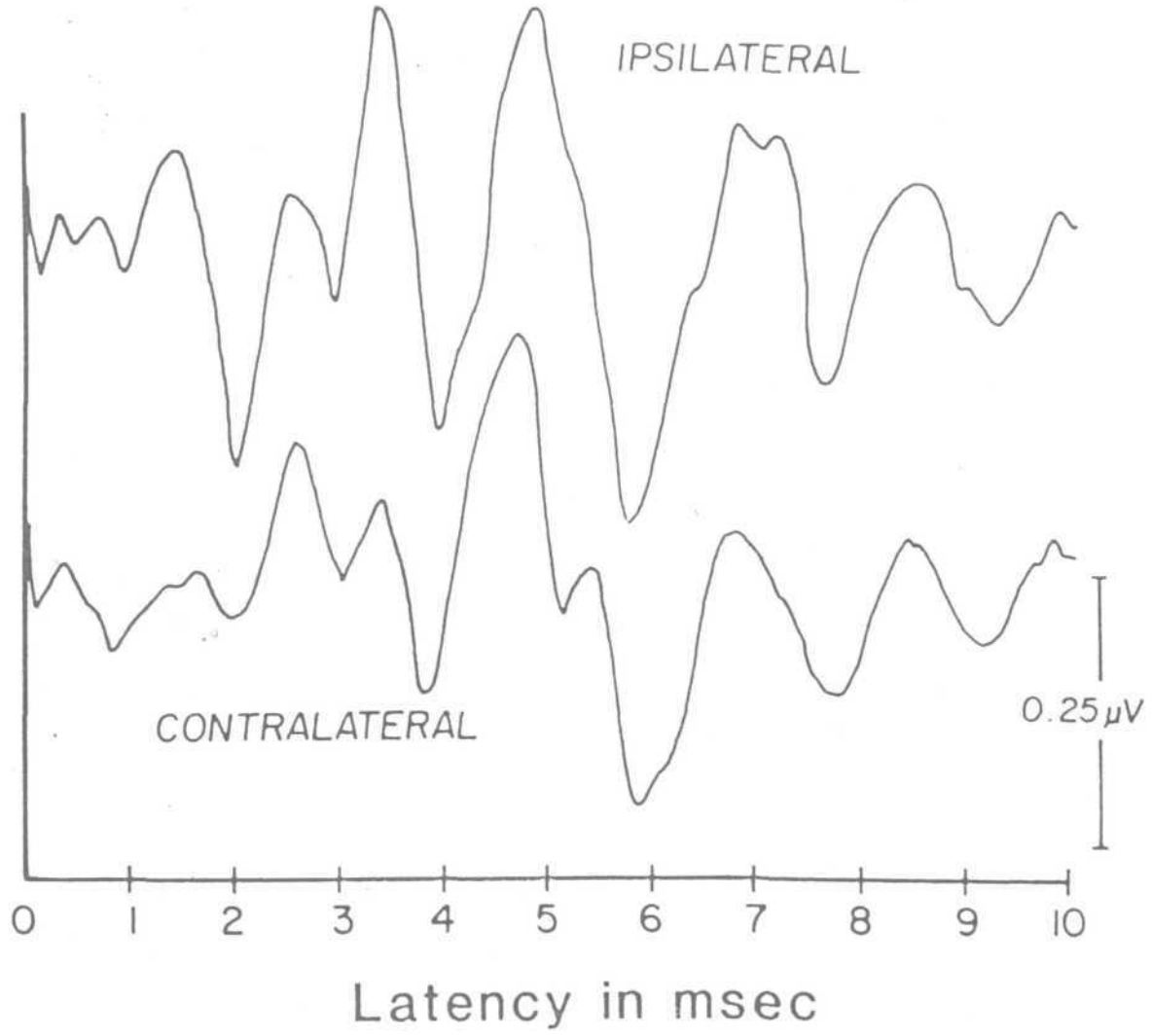
Recordings from the ear opposite to that of stimulation show that wave-I is often either diminished in amplitude or absent whereas wave-III can be more attenuated than wave-II. For latency measures, there is a tendency for wave-III to have a faster latency with wave-V being slightly prolonged on the order of 0.15 MS relative to its ipsilateral counterpart. Also the I-III IPL is shortened and the I-V IPL increased for recordings obtained on the ear contralateral to click stimulation.

Also simultaneous ipsilateral or contralateral recording has ability to separate the IV-V complex into two distinct waves, when morphologic ambiguity exists.

VI. Effect of Masking on ABR:

Masking occurs when one sound makes another sound difficult or impossible to hear or when the threshold of the signal (maskee) has been elevated by a second signal or none (the masker).

FIGURE XI .
Comparison of ipsilateral and contralateral recording of the ABR.



'Temporal masking' as a masking effect in which two sounds are not simultaneously presented.

If a signal (A) occurs before say a masker (B), a "backward masking" paradigm is noted. If signal (A) is presented after signal (B) a "forward masking" paradigm is noted. "Simultaneous masking" occurs if signal (A) and masker (B) are on at the same time.

Ananthanarayana and Gerkin (1976) used a tone-on-tone forward masking paradigm. Wave-V latency was prolonged. Wave-III showed a general reduction in amplitude for the simultaneous masking condition and a tendency towards recovery of amplitude values with increasing t. Wave-V also showed reduced amplification, but showed an increase in forward masking condition. This was t dependent. This is attributed to peripheral masking effect. Temporal sequence resulting in wave-V enhancement was compared to the manner in which rapid spectral change affects medial geniculate evoked responses.

Reid and Thornton (1983) - the stimulus and masker follow different afferent pathways with in the auditory system, so there is lack of interaction between them. So, broad band noise limits participation of non-test ear without affecting the desired test ear response.

Reid and Thornton (1983) - the interaural attenuation for click from 50-75dB.

Humes and Ochs(1982) found the contralateral masking for non-test ear, when there is a 50dB or greater difference between the intensity level of click stimulus to the test ear and the bone conduction thresholds between 1KHz and 4KHz in non-test ear. another method is to measure interaural latency differences and this when exceeding 1.5 MS.

C. EFFECT OF SUBJECT PARAMETERS:

I. Effect of sleep on ERA:

Mendel and Goldstein (1971) found that the latencies of the major peaks remained constant across the different stages of sleep and that the amplitudes were larger during stages of rapid eye movement (REM) and II, than during 3rd and 4th stages.

Mendel and Kupperman (1974) reported ao significant amplitude difference between REM and non-REM.

Brown and Shallop (1982) and Shallop and Osterhammel (1983) reported that the response during sleep was approximately one-third that during wakefulness. During sleep the transient (middle latency responses have been recorded within 10 or 20 dBSL.

Linden, Campbell, Hamel and Picton (1985) found that although the amplitude of the response is smaller during sleep, the

maximum amplitude is still recorded when stimuli are presented at rates of 30 to 50 tones per second. Effect of stimulus rate on the phase of the response did not change daring sleep.

The amplitude of the response increases as the intensity of stimulus increases. A similar stimulus intensity response amplitude function occurs across all stages of sleep, but the slope of the suprathreshold intensity-amplitude relationship is lower during sleep. The phase of the responses decreases as the suprathreshold intensity of the stimulus increases.

These findings are probably related to the decreased level of background EEG noise during sleep and the consistency of the phase relationship despite the decreased amplitude.

II. Effects of Drugs on ERA:

Cody, Klass and Buckford (1967) used 20 grains of chloral hydrate with adult subjects and did not observe any effect of this drug on the evoked auditory potential.

Suzuki and Taguchi (1968) in a study with children, administered 3 mg of pentobarbital sodium per kilogram of body weight. They concluded that the sleep induced by this drug was similar to natural sleep.

Brain and Casting (1971) found chloropromazine; triflorpromazine, moprobamli valuum and chloroprothizen did not effect ERA.

III. Effect of Anaesthesia on ERA:

The effect of halathane and sodium thiopental on the brain-stem response was assessed and no effect on BER were deserved.

IV. Gender/Sex Difference on ERA:

Studies demonstrated that the absolute latency of Wave I was essentially the same for male and female subjects, but wave III and wave V latency, that is, III-V and I-V latencies were longer in male subjects.

Both normal and hearing impaired subjects, females, showed consistently shorter latency and longer amplitude at all age levels. Wave-V latency was about 0.2 MS shorter and wave V amplitude was about 25% larger in femeal subjects.

v. Body Temperature and ERA:

Stackard, Sharbrough and Tinker (1978) reported six neuro—logically and audiologically normal patients subjected to hypothermic during cardiopulmonary bypass surgery who displayed IPLs that exceeded the 99% confidence limit by 0.7 - 0.9 MS since temperatures of about $20—32^{0}$ C are a common occurrence during such surgical procedures allowances for possible IPL prolongation should be made if the ABR is recorded intra-operatively.

VI. The effect of Age on Evoked Potentials:

A study by Rowe (1978) showed that on comparing old and young adults about 0.2 MS increase with I-III interwave latency was found with increase in age. Both infant and geriatric subjects display abnormal BSER more rapidly for a given increment in repetition rate than is normal.

Schulmann, Galambos and Galambos (1978) reported that Wave-V latency decreased by 0.3 MS to 0.5 MS with each week of gestational age.

A decrease in absolute latency with increased age has also been observed through the second year of life (Hecox and Galambos, 1974; Salamy and McKean, 1976; Salamy et al., 1975). Wave-V latency approaches adult values much later in the infants life than the values for wave-I.

McKean (1976) reported a depression in the latency of waves-I through VI in infants ranging in age from 20 hours to 12 months. The change in mean latency with age, however, was greater for wave V (1-12 M.sec)than for wave-I (0.41 m.sec.) Also only a slight decrease in wave-I latency was observed after 6 to 8 weeks of age, but wave V latency continued to decrease through 12 months of age .

Another study found that I-V interwave latency decreased with maturation, in premature and full-term newborns from

7.2 m.sec at 25 weeks gestational age to 5.2 m.sec at 40 weeks gestational age (Starr, et al. 1979).

The decrease in wave latency in the first two years of the human infant life is suggests that both peripheral and central auditory structures are maturing. The differential effect on early versus later waves implies that peripheral maturation precedes central maturation.

Age related changes are observed in morphology and amplitude of ABR waves (Leiberonan and Salamy et al., 1973).

It was observed that waves II and III began to appear as separate waves in 6 week old infants, and the pronounced negative wave was still seen in 62% of these babies. Waves I It and III were clearly resolved in 3 month old infants and the general waveform closely resembled that of the adult. Stability of these responses increased with age.

Starr et al (1977) also reported that wave-V amplitude increased with maturation.

Thus, we can see how a number of stimulus, subject and procedure parameters can affect the ABR. Thus, special care has to be taken to control as many of these variables as is possible before we can rely on our ABR results for diagnosis and research purposes.

METHODOLOGY

METHODOLOGY

Subjects:

20 subjects (14 females and 6 males) in the age range of 17 years to 26 years were selected for the purpose of this study.

The subjects had to satisfy the following criteria:

1. They should have audiometrically and otologically normal ears, i.e.:
   (a) Hearing sensitivity within 20dB KL (ANSI, 1969) in the frequencies 500Hz, 1KHz, 2KHz, 4KHz.
   (b) Have no history of any ear ache, eardischarge, headache, giddiness, tinnitus, brain-damage or have been exposed to loud sounds.
2. Negative history of any neurological complaints and epilepsy.
3. No family history of hearing loss.

Equipment:

In order to measure the auditory brain stem evoked responses, an electric response audiometer TA-1000 was used.

TA-1000 is a clinical diagnostic system incorporating the essential precision versatality and reliability in a simple, compact and convenient instrument.

The instrument consists of a stimulating system (a stimulus generator which feeds the stimuli to a transducer

earphone or a bone conductor) and a recording system (- it consists of electrodes, amplifiers, filters, averager and display together with some device for obtaining a permanent record).

Brief Description of the Equipment:

TA-1000 system (from the Teledyne Aviontcs) consists of the SLZ 9793 desk-top console; the SLZ 9794 preamplifier and an accessary group.

The SLZ 9793 console contains all of the operating controls, indicators and read-outs for the system. It provides the patient with auditory stimuli, and accepts patients electrical response from the preamplifier. Signal conditioning and digital averaging extract the patient's brain stem evoked response or EcochG responses from the background noise. Oscillographic display and ink -on - paper recording provide an on-going monitor as well as a permanent record of responses.

The SLZ 9794 preamplifier is a totally isolated EEG preamplifier with frequency response and gain specifically designed for ERA.

Patient's response is sensed by a set of 3 electrodes, and after amplification is conducted to the console by an interconnecting cable.

There is also a set of standard silver chloride electrodes. TDH-39 earphones and circumaural cushions MX-41/AR calibrated paper for recording the responses, electrolyte gel, adhesive tape and spirit to conduct the experiment are available.

Functions of the controls:

The TA-1000 is operated with push-button switches and 4 knobs.

(A) The push-button switches:

Push-botton switches are of two types.

1) alternate acting i.e. push ON and push OFF and
2) momentary acting i.e. push to initiate.

All push buttons indicate, by means of internal lamps, the active state of the selected function. Unwanted or illogical functions are internally inhilated.

The various push-buttons are:

1. The alternate acting POWER switch energizes the system and indicates the system status.
2. The alternate acting SCOPE switch controls the oscilloscope display.
3. The all acting AIR - LEFT and AIR - RIGHT push-button apply the stimulus to the desired earphone.

4. The alternate acting MASK push botton applies broad-band noise masking to the contralateral ear only when either AIR-LEFT or AIR-RIGHT stimulus is active.
5. The alternate acting BONE push-buttons applies stimulus only 2KHz and 4KHz stimulus to tone vibrator transducer.
6. The momentary acting CLEAR push-button clears the micro-processor averager memory, resets the sample display counter and corrects the microprocessor operating mode to correspond to the current control status.
7. The momentary acting START/STOP push-button initiates the micro-processor averages function. Averages function is automatically terminated when the selected number of samples has accumulated, or when any average memory channel is full; automatic termination requires a CLEAR to permit restart.
8. The momentary acting RECORD push-button initiates the plotter readout, if the averages is not active.

(B) The various knobs are:

– Clearly marked to indicate their function.

1. The STIMULUS functions switch permits selection of 2KHz. 4KHz or 6KHz logon equivalent frequencies at 5 or 20 stimuli per second and patients response intervals of 10 MS or 20 MS Immediately following stimulus.

2. The SCALE function switch permits selection of system sensitivity and number of averaged response samples. For 2048 samples 0.2 uV, 0.5 uv, luV and 2uV per division sensitivities are available. Readout of the accumulated number of samples is displayed in digital form, directly below this control.

3. The STIMULUS ATTENUATOR establishes the presentation level of the stimulus, in dBHL (from 0dB HL to 100dB HL).

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 ia m.sec. to 0.1 m.sec is displayed in digital from directly above this control.

TEST ENVIRONMEMT:

The study was carried out in a room away from noise sources and electrical appliances as fans etc. were put off. The room was away from excessive vibration producing sources.

For good results the subject was made to recline relaxed, comfortable and isolated from disturbing influences. The room was Sept dimly lighted and cool.

Sedation was not used, as the subjects were cooperative and relaxed enough for the test to be carried out smoothly. Sedation is used only in cases of young or active children.

Test Procedure:

The subject was asked to lie down on a bed with a pillow ender his head and neck to relax the neck muscles. Using a pillow was made optional as some subjects felt more relaxed without it. The subject was asked to make himself comfortable and relax.

Surface electrodes were then placed. Before placement of the electrodes the skin and the electrodes was cleaned with spirit. Electrode gel was smeared on the electrode in sufficient quantities. Each electrode was fixed to the skin with the help of adhesive tape.

The subjects were required to feel relaxed and comfortable with electrodes within 10-15 m.sec. after their placement.

The placement of the electrodes were as follows:

1. White or reference electrode on mastoid of the ear, i.e. right ear.
2. Black or ground electrode on mastoid of the non-test ear.
3. Red or signal electrode on high forehead.

After the red light on the preamplifier, beside the sample counter disappeared, the earphones for AC logon stimuli were placed.

The power switch was put on. The TWF/RUN/EEG switch was put on "RUN " position. The scale switch waa set to 2048 samples and 2uV/division.

The 20 subjects were tested at the frequency 2KHz at the intensities 30dB HL, 40dB HL, 50dB HL and 60dB HL. The subject's response interval of 10 m.sec was used. Response latencies of the third and fifth peak were notad as they were most consistent at these presentation levels.

Subjects were tested in a single session letting for about half an hour each. At each level readings were taken twice to get more reliable values. They were tested only with presentation of the stimuli in the right ear.

The test data was rejected when:

1) The limit light flickered often during the testing; and
2) The computer stopped before reaching 2048 samples.

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

The present study had aimed at obtaining the normative data of peak latencies for the presentation levels - 30dBHL, 40dBHL, 50dBHL and 6OdBHL, presented through air-conduction, at 2KHz, for the peaks - third and fifth, as they are consistently present at the levels being studied here.

Treatment of Data:

The following were determined –

a) The total of the peak latencies of the 20 subjects and them from this the mean latency values - at all the levels for the third and fifth peak were calculated separately.

b) Standard deviations were determined using the means obtained for each peak at each of the presentation levels.

From the above data obtained results were inferred and discussed.

In Table-I, the latencies of the third and fifth peaks, at each of the presentation levels of 30dBHL, 40dBHL, 50dBHL and 60dBHL - are tabulated.

In Table-II, the mean value of latencies of the 20 subjects is given at each of the presentation levels of the third and fifth peaks, calculated from Table-I.

In Table-III the standard deviation values obtained by the use of data from Table-II at different presentation levels for the third and fifth peak are tabulated.

DISCUSSION:

It is seen that a lower presentation level (eg. at 30dBHL, we have 6.07 m.sec for V peak latency) the mean peak latency is prolonged as compared to higher presentation levels (eg. at 60dBHL, we have 5.31 m.sec. for V peak latency).

Maximum variation is seen to be at low presentation levels (30dB HL and 40 dB HL) in terms of 0.3 to 0.5 standard deviation values. At 50 dB HL and 60 dB HL, the standard deviation values are around 0.2 only.

The third and fifth peaks are seen to be the most consistent at low presentation levels of the stimulus.

The instability of peaks I, II, IV and VI is due to the inability of these areas to perceive stimulation levels at or below 60dB HL.

Thus, using the information available through the present study, adult patients can be tested at presentation levels of 30dB HL, 40dB HL, 50dB HL and 60dB HL and keeping the standard deviation values or the variability of the values in mind, any deviation from the norms can be detected in order to determine a disorder.

Table-I:Peak latency values at 30dBHL, 40dBHL, 50dBHL and 60dBHL for the third and fifth peaks (values in milliseconds)

Subj. No.	30dBHL		40dBHL		50dBHL		60dBHL	
	III	V	III	V	III	V	III	V
1.	5.0	6.4	4.0	6.4	3.9	5.6	3.3	5.4
2.	5.0	6.5	4.5	5.1	3.9	5.4	3.6	5.2
3.	4.4	5.7	4.1	6.3	3.8	5.6	3.6	5.4
4.	4.6	6.0	3.9	6.2	3.8	5.5	3.3	5.3
5.	4.3	5.6	4.6	5.9	3.8	5.4	3.2	5.3
6.	5.0	6.5	4.6	5.9	4.3	6.0	3.6	5.3
7.	5.1	6.1	4.0	6.0	3.8	5.5	3.6	5.1
8.	5.3	6.5	4.1	6.2	3.8	5.6	3.7	5.4
9.	5.1	6.5	3.9	6.5	3.9	5.8	3.7	5.4
10.	4.4	5 9	3.7	5.7	3.7	5.9	3.6	5.0
11.	4.8	6.6	3.7	6.0	3.6	5.9	3.8	5.4
12.	4.0	6.0	4.0	5.7	4.2	5.6	3.5	5.2
13.	4.1	N.R	4.2	5.6	4.3	6.5	3.3	6.0
14.	4.0	5.8	4.0	5.6	3.7	5.8	3.3	5.4
15.	3.8	5.4	3.6	5.7	3.8	5.8	3.6	5.4
16.	4.8	6.5	3.6	5.8	3.6	5.5	3.6	5.3
17.	4.0	5.9	4.1	5.6	3.8	5.8	3.4	5.2
18.	3.9	6.0	3.8	5.9	3.7	5.7	3.6	5.2
19.	3.5	5.6	4.2	6.1	3.7	5.8	3.3	4.8
20.	4.1	6.0	3.7	5.8	3.6	5.9	3.8	5.5

(N.R = No Response)

Table-II: Mean value of latencies of the subjects at different presentation levels.

Presentation Level (dBHL)	III Peak	V Peak
30dBHL	4.46 m.sec.	6.07 m.sec.
40dBHL	4.01 m.sec.	5.95 m.sec.
50dBHL	3.83 m.sec.	5.73 m.sec.
60dBHL	3.52 m.sec	5.31 m.sec.

Table-III: Standard deviation values at different presentation levels.

Presentation Level (dBHL)	III Peak	V Peak
30dBHL	0.5122	0.4479
40dBHL	0.3168	0.2655
50dBHL	0.2032	0.2471
60dBHL	0.2513	0.2256

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

Summary:

The study aimed at establishing norms for low intensity stimuli (30dBHL, 40dBHL, 50dBHL and 60dBHL) presented via air conduction, for the most consistent peaks.

Twenty subjects with normal hearing in the age range of 17 years to 26 years were selected for the purpose of the study. They were thus, tested at 2KHz, at the levels 30dBHL, 40dBHL, 50dBHL and 60dBHL.

It was seen that the latencies prolonged at lower levels, more the prolongation lower the level. Variability in the latency was found to be more at 30dBHL and 40dBHL, than at 50dBHL and 60dBHL.

These norms can be used in identifying any problem, When the presentation levels are the above given, keeping in mind the extent of their variability.

Implications of the study:

As can be inferred from the results, the norms thus obtained can be used in diagnosis of the presence of a disorder, when only low intensity sounds can be presented and also to find the threshold of hearing as near to the pure tone

threshold as is possible. These values give is important information about the condition of the most reliable fifth peak at low intensity levels.

Limitations:

1) As the first peak is the most stable and prominent one in infants, these values are of no use to infants.

2) Values of latency or such norms vary from instrument to instrument, population to population and environment to environment. Thus, what is required is separate norms for each clinical set-up, to eliminate the effect of such variability.

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