"NORMATIVE DATA FOR CLINICAL AUDITORY BRAIN-STEM RESPONSE AUDIOMETRY: EFFECT OF SEX AND INTENSITY."

By
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DEDICATED

TO

ALL SERVING THE HANDICAPPED.

CERTIFICATE

This is to certify that the Independent Project entitled "NORMATIVE DATA FOR CLINICAL AUDITORY BRAIN-STEM RESPONSE AUDIOMETRY: EFFECT OF SEX AND INTENSITY", is the bonafide work in partial fulfilment for the degree of M.Sc. (Speech and Hearing) of the student with Reg. No.

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This is to certify that the Independent Project entitled "NORATIVE DATA FOR CLINICAL AUDITORY BRAIN-STEM RESPONSE AUDIOMETRY : EFFECT OF SEX AND INTENSITY", has been prepared under my supervision and guidance.

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DECLARATION

This Independent Project is my own work done under the guidance of Mr. M.N. VYASMURTHY, Lecturer in Audiology, All India Institute of Speech and Hearing, Mysore and has not been submitted earlier at any University for any other Diploma or Degree.

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CONTENTS.

CHAPTER I.

INTRODUCTION

(Auditory brain-stem response (ABR) audiometry is of great interest today, in the field of audiology, otology, neurology and neuro-otology and is probably one of the most exciting advances in Evoked response audiometry (ERA).

Assessment of hearing of the difficult-to-test child is crucial, challenging and rewarding. Many investigators have devoted themselves to developing procedures which do not require patient's co-operation. Thus, there is a need for objective audiometry. Shimizu (1981) concludes logically that ABR is one possible solution. Though ABR audiometry has not yet reached perfection, the results are satisfactory. Smith and Simmons (1982) tested 42 young multihandicapped children with ABR audiometry at the age of 34 months and could predict accurately the pure tone threshold (500 Hz and 2000 Hz) in 76%. Of the remaining 24%, 18% had error of - 10-12 dB. All these thresholds were confirmed later on through pure tone audiometry at the age of 71 months.

The ABR's are members of V (ventex) potential family, having a latency of 1 to 12 ms. They are approximately -26 dB low in amptitude than electrocochleography (E Coch G) potential detected by the transtympanic placement of the electrode and some -16 dB lower by extratympanic electrode placement (Davis, 1976). Table 1 shows the classification of ERA that is usually followed, from which it is clear that each category has a definite target, specific range in latency and amptitude of the response for the study of auditory system.

POTENTIAL	CLASSIFI-CATION	ORIGIN	LATENCY (MS)	AMPLITUDE (Microvolts)
ECOCHG	FIRST	ORGAN OF CORTI EIGHTH NERVE	0 1-4	
VERTEX	EARLY OR FAST	BRAIN STEM	2-12	.05-1
	MIDDLE	NEUROGENIC: CORTEX MYOGENIC : SONOMETER	12-50	0.7-3
	SLOW OR LATE	CORTEX II (WAKING) CORTEX III(SLEEPING)	50-300 200-800	8-20
	LATE OR VERY LATE	CORTEX IV (EXPECTATION)	250-600 DC SHIFT	10-20

TABLE 1: Classification of auditory evoked potentials, their origins and range of latencies and amplitude values.

The main reason for the distrust in the reliability and validity of ERA seems to lie in the following difficulties which confront the current technique for ERA scoring (Susuki et al.1976, The first difficulty is in setting up a criterion for interpreting the presence or Absence of the responses, which leads to a considerable variability of judgement in and between scorers. The second difficulty is the inevitable appearance of so called false-positive responses and the third is the lack of standard procedures for determining a response threshold from results of individual judgement.

The ABR stimuli are characterized by abrupt onset and decay and of short duration, unlike the sustained pure tone of conventional audiometry. This is necessitated by the diagnostic significance of response differences of less than 1 ms and the very rapid response of the cochlea by acoustic stimuli. Typically, the peak SPL of a ABR stimulus at hearing threshold is approximately + 25 dB greater than that of a sustained pure tone audiometry (Ward, 1981).

The patient's ABR to such stimuli is a minute electrical voltage, typically less than .00000025 volts or 250 nano volts. Thus relaxed state or often. sedation may be necessary (Davis, 1976). This voltage can be best measured at vertex (Terkildsen et al. 1978), but for clinical convenience high forehead placement is finding increased acceptance (Davis and Hirsh, 1977) with respect to the ipsilateral earlobe (Terkildson and Osterhammel, 1981). The actual intra-cranial voltages are much greater, but the intervening bone and tissue aitenuate these by several orders of magnitude at the skin surface, the only point of practical electrical connection.

At the instant of peak stimulus impact on the tympanic membrane, a shock wave is induced in the fluid of the cochlea. As this wave motion passes the hair cells, an electrical voltage is generated. The first vestige of this action is typically detected 1.6 milliseconds after the stimulus peak and is thought to be the response of the 8th or acoustia nerve. Approximately 4 milliseconds later this stimulus response reaches the inferior colliculus in the mid-brain and initiates a massive neuron discharge, Jewett's wave V. Figure 1 illustrates a typical ABR pattern to 100 dB HL logon stimuli. Lately, Biondi and Grandori (1978) have presented a mathematical model for ABR which can be basically helpful in (i) unifying the available data in a comprehensive description (ii) improving the fundamental knowledge of the mechanisms of response generation, transmission and recording (iii) maximizing the discrimination between normal and abnormal responses.

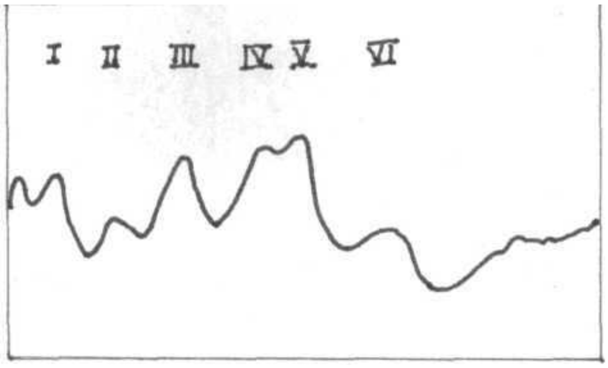

Figure 1: Typical ABR pattern at 100 dB HL logon stimuli.

The ABR audiometry is of great clinical value, besides threshold testing, if one understands the pathophysiological significance. Abnormalities along the auditory pathway result in temporal and morphological variations from the normal pattern, enabling reasonably accurate diagnosis of acoustic tumor, acoustic neuromas, cerebropantine angle tumors, brainstem tumors, demyelinating diseases, degenerating disorders, coma etc. The meticulously controlled recording technique, and establishment of the normal inter and intra subject variability are crucial because the interpretation of the results depends entirely upon them.

Many attempts have been made to establish norms for ABR but failed to, as each laboratory has different stimulus, starting point of recording, recording technique etc. More or less they can be compared if most of the variables are similarly controlled, hence there is the need for each laboratory or ABR recording system to have its own norm studies have been conducted by Jewett and Williston (1971), Lev and Sohmer (1972), Picton et al.(1974), Starr and Achor (1975), Stpckard and Rossiter (1977); Rosenhamer et al. (1978), Rowe (1978); Stockard et al. (1978); Beagley and Sheldrake (1978), Chiappa et al. (1979), Rosenhamer et al. (1980), Bergholtz (1981] and Hayers and Jerger (1982); to set norms. Almost all except Beagley and Sheldrake (1978) and Rosenhamer et al. (1980) have gone up to 80 dB stimulus to set the norms. Very few of these studies give data about amplitude and relative amplitude, though quite a few Stockard and Rossiter (1977), Gilroy and Lynn (1978); Rowe (1978), Chiappa et al.(1979),Rosenhamer et al. (1979), Bergholtz (1981), have talked about interwave latency and only Rosenhamer et al. (1978) have tested the reliability of ABR.

The available data have been controversial about the role of sex. Rowe (1978) did not find differences in sex, whereas Beagley and Sheldrake (1978) did find significant differences. They have found that females have shorter latencies than males.

Statement of the problem:

The present study was undertaken to see if different norms are necessary for different intensities and sexes and how closely the response was reproducible i.e. to see the test-retest reliability in the normal hearing subjects.

Null hypothesis:

1) There is no significant difference between ABR for
   i) two intensities (80 and 100 dB)
   ii) two sexes (males and females)
   iii) two sessions, in
      a) absolute latency
      b) absolute amplitude
      c) interwave latency
      d) relative amplitude

2) There is no significant correlation between
      a) absolute latency
      b) absolute amplitude
      c) interwave latency
      d) relative amplitude

   when individuals are tested twice at same intensities and at same frequency.

CHAPTER II

REVIEW OF LITERATURE

The present study aims to set norms for ABR for two intensities, two sexes and to see the reliability of response by test-retest method. The review of literature is discussed under the following headings:

1. Brief historical review of ERA and ABR.
2. Auditory Brainstem Evoked Response
    a) Anatomy and Physiology of ABR
    b) Recording of ABR
    c) Characteristics of ABR
3. Effect of intensity on ABR.
4. Effect of sex on ABR
5. Test/retest reliability of ABR.

1. Brief historical review of ERA and ABR:

> "It has been almost 200 years since Galvan discovered the electrical activity of the biological tissue. Today we are able to apply this fundamental discovery to the entire auditory system."
>
> ——GIBSON (1978).

The purpose of this section is to trace the significant people on the continuum of time whose efforts have brought us to the present status of knowledge about ABR. For details one can refer to Gibson (1978). The present section starts with ERA in general and goes on to ABR from the point it was engulfed in the ERA system.

1875 Caton first noticed presence of electrical potentials in the brain

1879 Vigowoux and later Fere in 1888 suggested exosomatic method, involving the application of electric current with a low voltage potential between the electrodes and measuring the change of resistance directly from the electrodes.

1890 Tarchanoff suggested endosomatic method of assessing the psychogalvanic reflex, measuring the difference in electric potential arising from current in the skin.

1929 Berger recorded first human electro encephalogram from electrodes placed on the scalp.

1930 Weaver and Bray obtained potentials from VIII nerve.

1934 Adrian and Mathew used a value amplifier and an accurate pen recording apparatus which left no doubt as to the authenticity of Berger's work.

1936 Loomi, Harvey and Hobart described diphasic or triphasic potentials which occured at the vertex of the head in response to tactile stimulation.

1939 Davis reported simpler responses to auditory stimuli to be definitely cortical in nature.

1948 Bordley, Hardy and Richter were the first to apply the phenomena of skin resistance changes to audiometry and for evolving a practical procedure for testing the hearing of young children.

1954 Wang established the level at which reflex accured to shock, whilst transection in cats at different levels, he established that auditory-sympathetic reflex must be somewhere between cortex and level of the inferior colliculi.

1956 Bordley believed that a postive PGSR response did not necessarily mean that the sound was being perceived.

1951 Hunt was the first to suggest the additive technique or electronic averaging and his coworker Dawson brilliantly exploited it.

1958 Clark developed an average response computer, this device converted analog data into a digital form, from which averages, amplitudes and time histogram could be easily computed and this was and is highly favored by ERA workers.

1958 Geister, Krishkosf and Rosenblith applied electronic averaging to the detection of auditory evoked responses, placing the electrodes on the surface of the scalp. They discovered responses with short latencies of 8-30 ms and believed that responses were mostly from the primary auditory cortex.

1963 Williams and Gralvan reported an electronic technique to average the V potential.

1965 Wipple published a volume entitled 'Sensory Evoked Responses in Man' (Ann. New York. Acad. Sci. 112, 1-546, 1964) which was a landmark event for ERA.

1967 History of ABR began when Sohmer and Feinmener succeeded in recording the VIII nerve action potential from an active electrode on the earlobe.

1970 Jewett confirmed the validity of above response.

1971 Jewett and Willston showed that acoustically generated 'early' potential could be detected from a wide area of the skull recording and proposed roman numbers from I to VII for seven peaks.

1973 Lev and Sohmer did similar work but concentrated on the V (Vertex) negative wave.

1973 Sohmer and Finmener demonstrated systematic variation in response on changing the electrode position in human subjects.

1974 Hecox and Galambos used the term Brainstem auditory evoked responses.

1978 Gibson altered this term to Acoustic brainstem electrical responses merely because the response can be obtained from a decerebrate animal, in which the term auditory seems inappropriate and because the International ERA study group favored the term 'Electric Response Audiometry', this argument is more academic than of clinical importance. The commonest abberations in recent literature are BER, ABR and BSER.

1978 Star and Achor from animal studies concluded that, ABR components recorded with scalp electrodes reflect composite activity of as many as six brainstem generators, contradicting the assumption - specific neural generator.

Thereafter information of various theoretical and clinical aspect of ABR in all its facets has increased to a large magnitude. A 'symposium on Brain stem response (ABR)' published by the Journal of Scandinavian Audiology, edited by Lundborg (1981) was a land mark event for ABR.

2. Auditory_Brainstem_Evoked_Response_(ABR).

ABR is a response, a potential, which is electrical in nature, picked up between two surface electrodes at the skull with 10 ms evoked in auditory pathway by a auditory stimulus the V peak is the prominent, reliable and the characteristic response of brainstem system.

There are many factors that affect the response characteristic - they can be grouped under three headings:

1. Recording parameters i) Averaging system, ii) Filtering system iii) electrode placement.
2. Stimulus parameters i) Dervied responses ii) intensity iii) rate of stimulus presentation iv) stimulus transduction v) polarity vi) binaural interaction vii) frequency - following responses viii) tone-onset responses ix) threshold.
3. Subject parameters i) age ii) sex iii) temperature iv) pharmacology v) psychological factors.

All the above parameters are not dealt with, for details one can refer Reneau and Hnation (1975); Gibson, (1978); Fria (1980); Lundborg (1981); Picton et al. (1981). As stated earlier some recording parameters and later on in section (3) stimulus parameter i.e. intensity and (4) subject parameters i.e. sex will be dealt with extensively.

2a. Anatomy and Physiology of ABR:

Attempt has been made to review the present state of knowledge about auditory evoked potentials generated in the auditory pathway and brainstem which are recorded from human subjects using surface electrodes. Wherever possible, attempt has been made to provide physiological and anatomical explanations for the reported findings.

The auditory pathways in the brainstem are characterized by multiple parallel connections. The primary afferent fibres divide immediately on entry into the central nervous system and connect to the dorsal, anterior ventral and posterior ventral cochlear nuclei. There is a multiplicity of cell types and cell firing patterns in the various areas of the cochlear nucleus. Some cells have firing patterns similar to those of the primary afferent fibres, whereas others have very different response patterns. For example, the octopus cell found in the posterior ventral cochlear nucleus has a simple onset response. The cochlear nucleus sends fibres through a variety of connecting pathways to the superior olivary complex of nuclei and to the lateral lemnisci. The superior olivary neurons are activated by both ears and project through the lateral lemnisci and their nuclei to both inferior colliculi. In the human brainstem the main nucleus in the superior olivary complex in the medial superior olivary nucleus. Although the onset of activity in the various auditory nuclei of the brainstem are sequential, the persistence of activity in each of the nuclei means that after the first 2 or 3 ms following a transient stimulus there is over lapping electrical activity in many different areas of the brainstem. More cellular details can be obtained from Harrison (1978).

Activation of the neurons in the brainstem auditory nuclei causes a separation of charge across the neuronal membranes. This causes a flow of current in the extracellular fluid. If the locations of the activated cells are randomly or circularly oriented, the flow of current is maintained within the nucleus and a 'closed field' occurs. If the cells are geometrically oriented to some degree an 'open field' dipole results. This is particularly true for the medial superior olivary nucleus. Fields may also be generated by the conduction of impulses along axons. There is a positivity recorded ahead of the impulse and a negativity laterally. The extent of the electrical field generated in the nervous system depends upon the amount of charge separated at the source and upon the geometry and impedance of the volume conductor.

Figure 2 gives the outline of the auditory pathway, local field potentials and single unit action potentials recorded from main relay station in the auditory pathway. To the right are principal patterns of nerve activity in different relays and the local field potentials. Above is the ABR vector sum of field components in volume conductor.

Many investigators have speculated and many have attempted to verify experimentally the neural generator of ABR component wave. The literature can be divided into two categories (Frid, 1981): i) Studies with animal subjects and 2) Studies with human subjects. But there are two main approaches to understand the origin of the early auditory evoked potentials. First, is to relate surface recordings to those obtained from depth-electrodes, and the second, is to study the effects of brain lesions on the surface-recordings.

Research with human subjects is more limited in extend and less precise in conclusion than animal experimentation. Intra-cranial recordings from human patients have not yet been studied extensively, although Hashimoto et al. (1980) have reported that wave II, III and IV were large in recordings taken from the floor of the fourth ventricle, and wave V very prominent in recordings from the quadrigeminal plate. Studies of human patients with localized pathological brain-stem lesions suggest origins for wave I in the acoustic nerve, for wave III in the pons and for wave V mainly in mid-brain (Sohmer et al. 1974; Starr and Hamilton, 1976; Stockard and Rossiter, 1977; Stockard et al. 1980; Rowe, 1981).

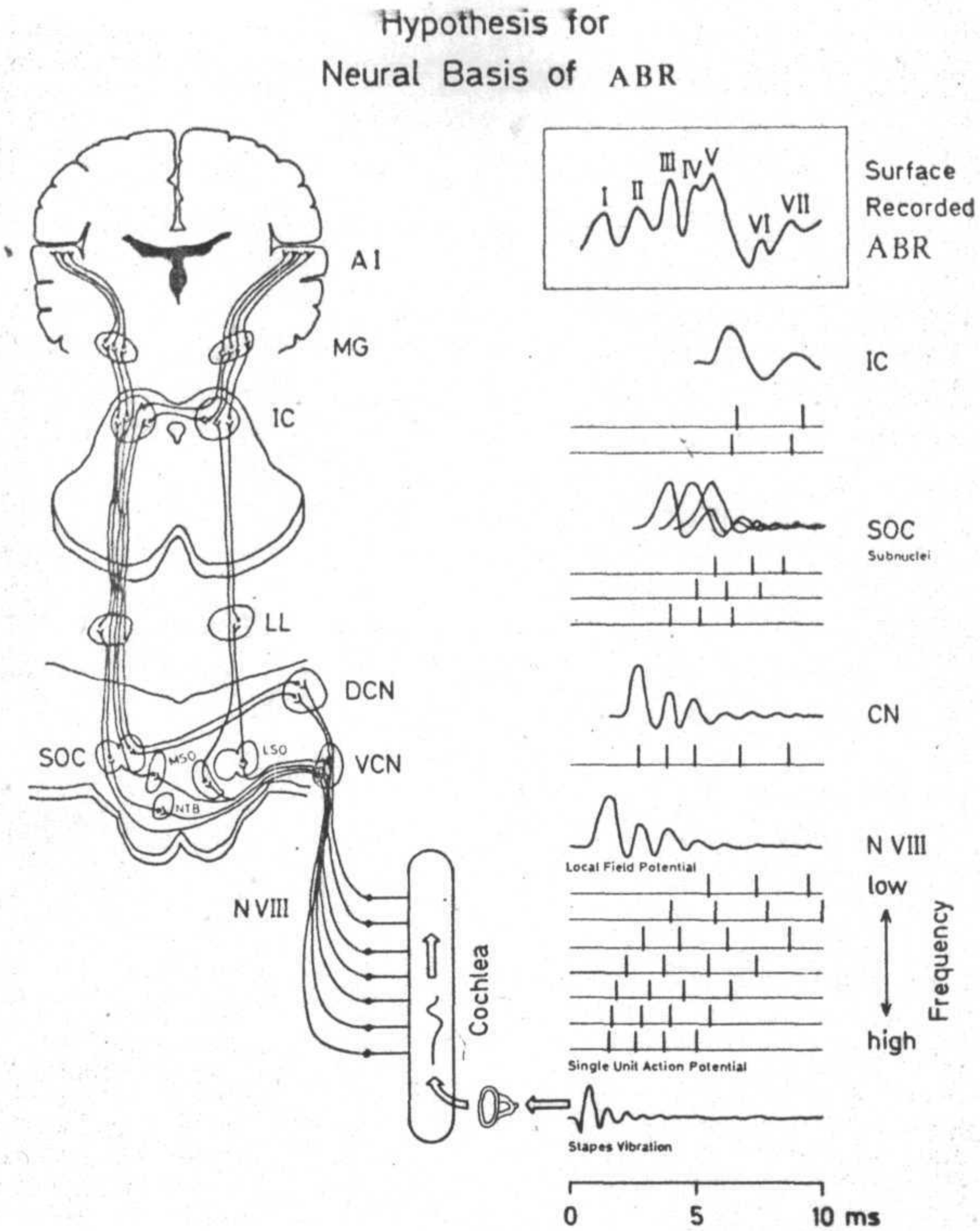

Figure 2. Outline of the auditory pathway, local field potentials and single unit action potentials recorded from main relay stations in the auditory pathway. To the right : principal pattern of nerve activity in different relays and the local field potentials. Above is the ABR Vector sum of field components in volume conductor.

There are two areas of controversy in the literature concerning the origins of the early auditory evoked potentials. One is whether the scalp- recording peaks represent distinct processes in the brain (Buchwald, 1981) or overlapping fields from several different generators (Achor and Starr, 1980 a & 1980 b). The second point of controversy is whether the major contribution to the surface recordings comes from graded post-synaptic potentials (Buchwald, 1981) or from synchronized action potentials (Picton et al. 1981).

There is general agreement that the first vertex-positive is generated by the auditory nerve fibers. Because of the latency differences between the peak recorded from the auditory nerve near the brainstem, Buchwald (1981) has suggested that wave I represents the generator potential in the dendrites of the auditory nerve fibers. Wave II appears to reflect activity in the cochlear nucleus although there may also be a contribution from activity in the auditory nerve. In the latency region of wave III there are probably overlapping generators, in the superior olivary complex, the trapezoid body, and the lateral lemnisci. Although it was originally hypothesized as deriving from the inferior colliculi, the wave IV-V complex now appears to be independent of those nuclei (Goldenberg and Derbyshire, 1975; Achor and Starr, 1980 b) and is probably generated in the axons and/or nuclei of the lateral lemnisci. In figure 2, the presumed correspondence between ABR component waves and the anatomical structures are correlated. In view of Lundborg (1981) the complex structure and connections of the auditory pathway and the inhomogenous electric properties of the surrounding volume conductor, their interpretation of ABR anatomical and physiological terms is hazardous, but the potential clinical benefits of a definition of the ABR in such terms is however great.

2b. Recording of ABR:

Four major components instrumental in recording and for proper understanding of latendy and amplitude functions are

i) the acoustic stimuli

ii) the preamplifier

iii) the averager
iv) the data presentation system

i) The acoustic stimuli:

Stimuli for ABR are characterized by abrupt onset and decay and short duration, necessitated by the diagnostic significance of response differences at less than one ms and by very rapid response of the cochlea to acoustic stimuli. Arlinger (1981) states, reporting of acoustic waveform is highly desirable if any discussion of absolute latencies of AER component is to be meaningful. There are many types of stimulus: raw clicks, filtered clicks, tone bursts, derived band clicks, tone pips and tone logon. Two general types of stimulus are employed, each for a specific purpose.

1. The CLICK stimulus is a brief, single polarity pulse. Its energy spectrum is comprised of a broad series of harmonics of the stimulus repetition frequency, limited in high-frequency region by the roll-off characteristics of the earphone and its driving amplifier. The click is useful in the ross evaluation of hearing function, where frequency specific information is not required.

2. The LOGON stimulus, used in this study, is a very brief tone pip with very specific rise and decay characteristics. The logon of Gabor (Davis, 1976) is defined as a pure sine wave modulated by a Gaussian distribution function. The stimulus is characterised by 3 peaks, in a 50% negative, 100% positive, 50% negative sequence, followed by a 50% positive, 100% negative, 50% positive sequence; reversing on each successive stimulus. Stimuli provided with 2,4 and 6 kHz center frequencies, stimulus repetition rates are 20 and 5 per second. The only disadvantage is that the starting point is not definite (iiadsen and Hansen, 1981).

The logon stimulus has been determined by controlled biological experiment, to be approximately -25 dB less effective than a pure tone of the same frequency, in terms of hearing threshold SPL. This is in fair agreement with textbook temporal integration, wherein threshold SPL is said to increase +3 dB for each halving of presentation time below 200 ms. The stimulus intensity is adjustable upto +100 dB HL at all frequencies.

Thus logon stimulus is a 1.5 cycle burst of the desired stimulus frequency, having onset and decay time equal to 0.75 cycles of that frequency. Its waveform is a single major peak, preceded and succeeded by minor peaks of opposite polarity. The logon's energy spectrum is approximately one octave in bandwidth, centered on that frequency determined by the inter-peak time of its waveform. The logon stimulus is more frquency specific and finds clinical application in the more detained exploration of hearing abnormalities.

ii) The Pre-amplifier system:

The problem of extracting useful information from sub-microvolt bio-electrical signals is a formidable one. The amplitudes of the evoked potential are in the order of 0.1 to 10uV which requires a very sensitive high gain, low noise amplifier, and at least with the total system gain yielding 1uV to the size of 2.3.cms on the display screen (Madsen and Hansen, 1981). Physical principles limit the minimum theoretical noise characteristics of amplifying devices.

Total electrical isolation between the pre-amplifier input and earth ground is the only practical way of meeting the various electrical codes and standards. This can be achieved by radio-frequency isolation. Recent instrument designs favour r-f isolation. In this design, a ground referenced oscillator supplies r-f power to an isolated amplifier and the signal is returned to the ground - referenced portion of the circuit as a modulated r-f carrier. When demodulated this is the original input, amplified and ground referenced. All connections to the subject are by r-f means achieveing total electrical isolation.

The equivalent preamplifier input noise for a device of the band width described is 0.4 uV or approximately 1.3uV s peak. The noise peaks greatly exceed the 0.2 uV ABR signal, making direct interpretation impossible. The relative quality of noisy signals can be expressed in terms of ratios (S + N)/N in dB. For conditions stated, this ratio is (0.2 + 1.3) / 1.3 or + 1.2 dB. (S + N)/N ratios in the order of + 12 dB can be intelligently interpreted, + 20 dB ratio's are essentially free of noise artifacts. Amplification does not alter the ratio, it simply increases the amplitude of the signal and noise components. The SLZ, 9794 used in this study fulfills this criteria.

iii) The Averager:

Averager as such performs only one job, namely to summate and store the incoming results from pre-amplifier. Fortunately, the ABR signal is synchronous, i.e. fixed in time with relation to the BSER stimulus, while noise is random. When a number of synchronous events are accumulated, they add in proportion to the number of events, when a similar number of random events are accumulated, they add in proportion to the square root of the number of events. For the condition stated, 380 samples result is accumulated signal of 76 uV and an accumulated noise of 25.3 uV results a +12 dB (S + N)/N ratio. Increasing the number of samples to 3422 results in a +20 dB ratio. It is a technique of sample accumulation, more commonly called signal averaging, which makes ABR audiometry possible.

The TA - 1000 digital averager divides the patients response, during the analysis window, into 250 small slices of time, and converts the instantaneous response amplitude into a 11-bit digital code, identifying 2048 discrete levels. Each time slice code is added to all other in the same time slice, which occured from previous sample responses, and the total, representing the average amplitude in that time slice, is accumulated in a 16-bit memory, from which it is read out, converted to a voltage amplitude and displayed on either oscilloscope or plotter. This is the ABR with the system noise suppressed.

iv) The data presentation system:

ABR data are in two forms, temporary and permanent. Temporary data are those that are displayed on an oscilloscope and represent on-going response accumulation. By observing the ABR as it increases in amplitude and quality with increased number of samples, the cliniciancan confirm the subjects ABR and the equipment performance. When sufficient samples have been accumulated to display a response of suitable quality, the permanent data can be recorded, usually by a dedicated X-Y plotter.

2c. Characteristics of AER:

Recognition of abnormal responses from the normal makes diagnosis possible. Generally three ABR parameters are looked for, they are morphology, latency and amplitude. Particular emphasis is placed on the description of parameter variation due to non-pathologic factors.

a) Morpphology:

There are wide individual differences in the morphology of the response (Rowe, 1978; Chiappa et al. 1979), that do not appear to be easily explained by any other parameters. In about 5% of normal subjects there is a double or bifid peak I and a similar incidence has been reported for a double peak III. These double peaks tend to occur of higher intensities. Chiappa et al. (1979) have described several patterns of peak IV - V morphology, Picton et al. (1981) have observed, similar patterns and gave combined incidence in both studies. In 15% of cases wave IV and V merge into a single peak, in 45% of cases wave IV is smaller than wave V, in 30% of cases wave V occurs with lower amplitude than wave IV and in 10%

cases waves IV and V are approximately equal. In about one third of the cases the IV -V pattern in one ear is not the same as that seen in the other, Stockard et al. (1979) have pointed out that many of these IV-V patterns can be caused by changing the polarity of the stimulus used in evoking the response. Although Chiappa et al. (1979) did not report the polarity of their click stimuli, Picton et al. (1981) state that by using clicks of one polarity there are definite individual differences in the response morphology that depends upon the ear, the polarity and the intensity of the stimulus.

b) Response latency:

Latency is time relationship between any response and the stimulus eliciting that response. For ABR this parameter is designated as absolute wave latency or interwave latency (Figure 3). Absolute latency is the time relationship between stimulus onset and associated response. Interwave latency refers to time difference between two component waves e.g. the I-V interwave latency, their values are typically specified in milliseconds (Fig 4). Clinically the most valuable interwave latencies are the I-II, III-V and I-V intervals. (Bergholtz, 1981).

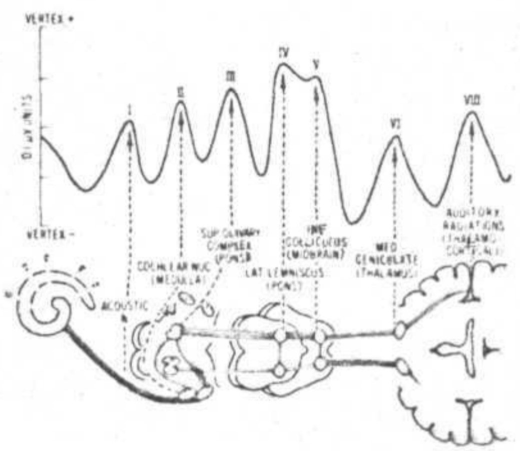

Figure 3. Presumed correspondence between ABR component wave (I through VII-upper portion of the figure) and anatomical structures in the primary (lower portion of the figure).

The mean absolute latency values for normal adults reported by different authors are shown in Table 2. These authors used a general technique, vertex-ear recording, stimulation with 60 to 70 dB SL unfiltered clicks and latencies measured from onset of the electric clicks except Jewett and Williston (1971) and possibly Lev and Snhmer (1972) who measured latencies from the arrival of the sound to the tympanic membrane. The variation between studies for the different latency values may be attributed partly to different latency zero references and different click intensities, but part of these are due to different delays in the equipments used.

Measures of the variability of normal absolute latencies, can be used for comparison between different reports. The SD of normal latency values reported by Lev and Sohmer (1972) and Amadeo and Shagass (1973) was greater for waves beyond III, but in these early papers the inherently inconsistent IV-V complex was labelled as one wave, and this might account for observed increase in variability. Later reports by (Starr and Achor, 1975? Rosenhamer et al. 1978; Rowe, approximately same SD for all ABR component waves ≤ 0.3 ms.

Normal interwave latency values have been reported for several combinations by Stockard and Rossiter, 1977; Gilroy and Lynn, 1978; Rowe, 1978; Beagley and Sheldrake, 1978; Chiappa et al. 1979; Rosenhamer et al. 1979 and 1980; Bergholtz, 1981. Table 3 presents a comparison of published findings for young adult subjects. As shown the I - V interwave

INVESTIGATIONS	N	Click Intensity	ABSOLUTE LATENCY (m sec.)					
			I	II	III	IV	V	VI
Jewett & Williston (1971)	11	60-75 dB	1.7			—	4.6-5.1	
Lev & Sohmer (1972)	10	65 dB	1.5	2.5	3.5	5.0	6.7	-
Amadeo & Shagass (1973)	4	60 dB	1.6	2.8	3.7	-	5.6	-
Picton et al. (1974)	20	60 dB	1.5	2.6	3.5	4.3	5.8	7.4
Starr & Achor (1975)	6	65 dB	1.6	2.8	3.8	4.8	5.5	7.1
Stockard & Rossiter (1977)		60 dB	1.9	3.0	4.1	5.2	5.9	7.6
Rosenhamer et al. (1978)	20	60 dB	1.7	2.9	3.9	5.2	5.9	7.6
Rowe (1976)	25	60 dB	1.9	2.9	3.9	5.1	5.8	7.4
Rowe (1978)	25	60 dB	1.96	-	4.01	-	6.01	-
Stockard et al. (1978)	50	60 dB	1.8	2.9	3.9	5.2	5.8	-
Beagley & Sheldrake (1978)	20	60 dB	2.4	-	4.6	-	6.4	-
Chiappa et al. (1979)	50	60 dB	1.7	2.8	3.9	5.1	5.7	7.3
Rosenhamer et al. (1979)	41	60 dB	1.76	-	4.03	-	6.03	-
Bergholtz (1981)		65 dB	1.8	2.9	4.0	5.2	5.9	-
Present study	20	80 dB	1.20	2.2	3.2	4.3	5.0	-
		90 dB	0.92	1.9	2.9	4.1	4.8	

TABLE: 2: Normal ABR latency values from 15 studies. The number of subjects and click intensity used are also stated.

INVESTIGATIONS	INTENSITY	I-III	III-V	I-V
Stockard and Rossiter (1977)	60 dB	2.10 (0.20)	1.9 (0.20)	4.00 (0.20)
Gilroy and Lynn (1978)	15 dB	2.05 (0.15	—	3.83 (0.13)
Rowe (1978)	25 dB	1.97 (0.16)	1.97(0.20)	3.94 (0.22)
Chiappa et al. (1979)	50 dB	2.10 (0.15)	1.9 (0.16)	4.00 (0.23)
Rosenhamer et al. (1979)	60 dB	2.26 (0.15)	2.00(0.20)	4.27 (0.22)
Bergholtz (1981)	65 dB	2.21 (0.25)	1.85(0.15)	4.09 (0.26)
Present study	80 dB	1.92 (0.23)	1.80(0.18)	3.52 (0.27)
	100 dB	1.97 (0.19)	1.87(0.20)	3.85 (0.19)

TABLE: 3: The mean and standard deviation (in parenthesis) interwave latency values from several investigations.

latency approximates 4.0 ms and slightly more than half of this time can be attributed to the I-III interwave latency.

The I-III value estimates transmission time through the panto-medullary junction and lower pans, and III-V values estimates transmission time from caudal pons to caudal midbrain levels. The I-V latency estimates the time needed for impulses to travel the entire system and is sometimes called 'central' or 'brainstem' transmission time. These estimates are of great value for clinical purposes.

C. Response amplitude:

In ABR, response amplitude refers to the height of the given wave component, and it is usually measured in microvolts (uV) from the peak of the wave to the following trough (assuming that vertex positive wave are displayed as upward deflection). This measurement is called absolute amplitude. The absolute amplitudes of ABR component waves can also be expressed in relation to one another, and these are called relative amplitudes (Figured).

The variation of normal values of ABR amplitude have been observed substantially by Amadeo and Shagass, 1975; Starr and Achor, 1975; Chiappa et al. 1979: Stockard et al. (1978) reported the mean amplitude in response to high intensity clicks to be 0.15 and 0.38 uV for wave I and V respectively.

Since there is great variability in absolute amplitude measurement, relative amplitude is suggested by Starr and Achor, 1975. In 50 normal subjects, they found that ratio of V:I always exceeded 1.0 in response to click intensities below 65 dB. Similar ratios for 60 dB clicks evoked ABR's were reported by Stockard et al. 1978; Chiappa et al. 1979; who found mean V:I ratio 2.53 in 100 normal ears.

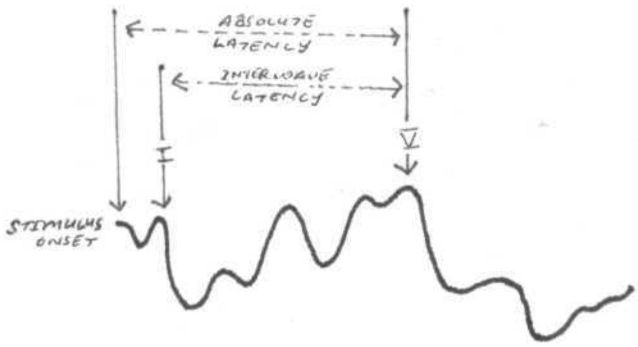

Figure 4: The distinction between absolute and interwave latency for components of the ABR. Absolute latency is the time (in ms) from stimulus onset to the occurance of a given peak, in this figure the absolute latency of wave V is represented. Interwave latency is the time difference (in ms) between the absolute latencies in two ABR waves, in this figure I to V (I-V) interwave latency is depicted.

3. Effect of intensity. on ABR:

Auditory brainstem responses, the morphology, the latency and the amplitude changes with changes in intensity of the click stimulus,

The latency of all components increases with decreasing intensity. The peak-latency of wave changes from 5.6 ms at 80 dB HL to 8.2 ms at 10 dB (Hecox and Galambos, 1974; Starr and Achor, 1975; Zollner et al. 1976; Picton et al. 1977; Beagley and Sheldrake, 1978; Coats, 1978; Galambus and Hecox, 1978; Rosenhamer et al. 1980; Picton et al. 1981). The standard deviation of the latency measurements increases somewhat with decreasing intensity. At 70 dB the standard deviations for V-latency have been reported between 0.20 and 0.25 whereas at 30 dB the standard deviations have

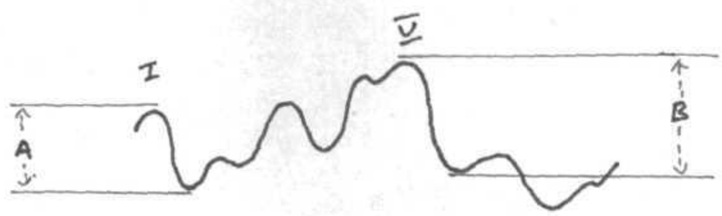

Figure 5. The distinction of absolute and relative wave amplitudes for ABR. Host often, absolute amplitude is the height (in microvolts) of the wave from its peak to the following trough, as shown above for waves I and V (A & B) respectively); but relative amplitude is the ratio of the absolute amplitudes for two ABR waves. For example, in this figure, the relative amplitude of wave V to wave I would be B divided by A.

increased to about 0.30 ms. The latency-intensity data can be fitted reasonably well by a linear regression line with an average slope of -38 us/dB and with a baseline value of 8 25 ms at 0 dB. The normal values for the slope of this line ranges between 20 and 50 us/dB (Pratt and Sohmer, 1977; Galambos and Hecox, 1978; Narillaud, 1980) although at high intensity, slopes as low as 10 us/dB and at lower intensities slooes of upto 60 us/dB may be seen. The relationship is not really linear and a somewhat better fit can be obtained using a power function such that log 10 (v-latency in ms)= -0.0025 (click intensity in dB) + 0.924. The other peaks of the response have approximately equal slopes to that of wave V

(Starr and Achor, 1975; Pratt and Sohmer, 1977). However as noted by Stockard et al. 1979, Wave i may actually show a slightly larger latency shift with decreasing intensity than wave V, particularly over the middle intensity range. Thus the 1-V inter-peak latency decreases from an average of 4.02 ms at 70 dB SL to 3.68 ms at 30 dB SL.

The changes in amplitude of the brainstem response components with intensity have been the subject of study of very few people Starr and Achor, 1975; Zollner etal. 1976; Pratt and Sohmer, 1977; Picton et al. 1981. Furthermore, because many different high-pass filter settings are used it is difficult to compare data across laboratories. Using high-filter setting of 100 Hz or lower, the amplitude of wave V measured relative to the succeeding vertex-negative wave decreases from about 0.6 uV at 70 dB to 0.3 uV at 20 dB nHL with the average curve being approximately linear over this region. The amplitude decreases much more rapidly between 20 dB and increases somewhat more slowly above 70 dB. When high-pass filter-setting of greater than 100 Hz are used the amplitude of wave V is smaller and may reach a maximum value at lower intensities. The amplitude is far more variable than the latency measurement and individual subjects may show quite consistent steps in the amplitude - intensity function that do not show up in the average data over a population of subjects. The earlier components of the brainstem response show a more rapid decline in amplitude than wave V. At 30 dB nHL, the amplitude of wave V in response to a 10/s click stimulus, is about 60 per cent the amplitude at 70 dB, whereas the amplitudes of wave I and III have been reduced to about 30 percent of their respective amplitudes at 70 dB. Wave V is easily recognizable in normal subjects to within 20 dB of threshold whereas the earlier waves of the response become difficult to identify below 50 dB nHL.

Interwave latencies do not follow the logic of intensity-latency function. Rowe (1978) and Stockard et al. (1978) observed minimal changes in interwave latency when stimulus intensity was decreased. Stockard et al. (1978.) reported one subject who showed a .07 ms increase in the I-V interwave latency when responses to 70 and 20 dB SL clicks were compared.C1ose examination of this subjects wave-forms, however, reveals that they measured the I-IV latency at 70 dB SL and perhaps the I-V latency at 20 dB SL. Hence slight increase in interwave latency for the 20 dB SL stimulus is not surprising. In a later paper Stockard et al. (1979) reported that wave I latency increased more than wave III and V when stimulus intensity was decreased. Consequently interwave latency values involving wave I-III and I-V were shorter at lower stimulus intensities. The average decrease I-III latency was 0.19 ms and for I-V was 0.34 ms. For one subject the I-V latency decreased 0.73 ms when responses to 70 and 30 dB SL clicks were compared. For some subjects, the transition (decrease) in interwave latencies was most prominent for responses to 40 or 50 dB SL clicks.

The relative amplitude ratio V:I increases with decreasing intensity (Fria, 1981). Thus intensity related changes in relative amplitude confirmed the original observation of Starr and Achor (1975).

4. Effect of Sex on ABR.

The latency and the amplitude of the ABR is significantly related to the sex of the subject. Adult female subjects have significantly shorter latencies for wave III and V. For clicks the difference in V-latency has been reported as between 0.05 and 0.36 (on average 0.22) ms (Beagley and Sheldrake, 1978; Kajar, 1979; McClelland and Mcbrea, 1979; Jerger and Hall, 1980; Michalewski et al. 1980;

Jacobson et al. 1980). The difference in III - latency is slightly less, on average about 0.15 ms. Wave I is little affected and therefore the I-V inter-peak latency is about 0.21 ms shorter in female subjects (Stockard et al. 1979). The sex related latency differences persist at lower intensities and at faster presentation rates (Kjaer, 1979% Jacobson et al. 1980). The amplitude of all components are larger in the adult female than in male (Kjaer, 1979; Michalewski et al. 1980). Wave I appears to be about 30% larger in females, wave III 23% and wave V 30%.

The sex differences noted in the latency measurements do not occur in normal young children. The occasional sex differences noted in neonatal studies (Seitz et al. 1980; Cox et al. 1981) are probably related to the increased perinatal risk in male infants and do not persist (Cox et al. 1981). There is some controversy in the literature about when the adult difference begins. McCelland and McCrea (1979) found no significant sex-related latency differences in a group of 9-13 year old children but noted difference related to adolescence and its attendant hormonal changes. 0'Donovan (1980), however, found significantly different latencies from the age of eight years onwards. Anatomical differences between the sexes might therefore underlie the differences in recording brainstem-responses. At present it is futile to speculate the causes for these differences. The only intelligible explanation seems to be based on spatial diamension of the wave generating system and volume conductor embedding it, than electrophysiological diversity. Shorter pathways would give an earlier latency and might also increase synchronization so as to give a larger amplitude.

Another factor that is specific to the adult female is the menstrual cycle. Picton et al. (1981) have reported that I-v inter-peak latency changes slightly during the menstrual cycle, being on average 3.81 ms between the days 12 and 26 and 3.92 ms on the other days. This is probably related to temperature changes during the menstrual cycle. Temperature differences cannot although explain the overall male female differences since males in general have slightly higher core temperature than female.

5. Test/retest_reliabilitv_of_ABR.

The test reliability of BSER is excellent. The N V peak can be used confidently to estimate the hearing status. The latency of this peak is remarkably constant even from subject to subject, and in normally-hearing adults, it occurs at 4.9 - 5.5 ms using an 80 dB HL click stimuli (Gibson, 1978). The N V peak, nearly always follows the N I by exactly 4.0 ms unless the subject has some disorder affecting the brainstem.

For audiometric purposes, the N V can usually be identified at 10 dB SL or less usually click stimuli or tone burst of 2.8 K Hz (Davis, 1976). Some subjects do not yield an identifiable N V within 10 dB but this never happens at 30 dB SL using 4 K Hz stimuli. The older subjects over 40 years of age seemed to be most difficult to test for threshold purposes. At lower stimulus frequencies the N V becomes broader and more difficult to identify (Davis and Hirsh, 1977). Antonelli (1976) reported ABR threshold between 10-30 dB for 75% of his 39 adult subjects. At 500 Hz the N V is very difficult to identify (Davis and Hirsh, 1979). The test-retest reliability is good. The BSER wave form does not show any change on repeated or prolonged testing. Thornton (1975) tested the same subjects on different occasions and found no significant changes in either the amplitude or latency of the BER. The SD of the amplitude data were proportionally much larger than those obtained from the latency data.

"This suggests that despite the averaging procedure, a considerable proportion of the measured response amplitude variance is attributable to the remaining variance of the background noise process" (Thornton, 1975). Rosenhamer et al. (1978) determined test-retest reliability in 6 subjects. The time gap in testing was 6 months and he used two sided t-test with equal latency, hypothesis rejection probability set at 5%. The results showed good test-retest reliability.

CHAPTER III

METHODOLOGY

I. Subjects:

Twenty normal hearing (20 dB HL ANSI 1969) subjects with the age range of 18 to 25 years (mean age - 20.5 years) ten males with mean age 20.3 years and ten females with mean age 19.8 years were selected for this study.
Only one ear i.e. right ear was tested in all these subjects. The subjects were selected on the following criteria:

1) They should not have had any history of chronic ear discharge, tinnitus, giddiness, earache or any other otological complaints.
2) They should not have had any history of epilepsy or other neurological complaints.
3) They should be able to relax and feel comfortable with electrodes on, within 10-15 minutes after their placement.
4) Their electrophysiological input should come below 500 microvolts within 10-15 minutes after electrode placement.
5) Their hearing sensitivity should be within normal limits i.e. within 20 dB HL (ANSI 1969).

II. Equipment:

The equipment used was, Electric Response Audiometer, model TA-1000.
Brief description of the instrument:

The TA-1000 system consists of the SLZ 9793 desk-top console, the SLZ 9794 preamplifier and an accessory group.

The SLZ 9793 console containsall of the operating controls, indicators and read-outs for the system. It provides the patients an auditory stimulus and accepts patient's electrical responses from the preamplifier. Signal conditioning and digital averaging extract the patient's BSER 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 an isolated EEG preamp. with frequency response and gain specifically designed for ERA. Patient's electrical response is sensed by a set of three electrodes and after amplification, is conducted to the console by an inter connecting cable.

Accessory group used was

a) A binaural air-conduction head-set with cord set.
b) Inter connecting cables, chart paper and pens.
c) Sets of electrodes, electrolyte get and electrode adhesive pad (which was exhausted and substituted by Johnsonplast).

CONTROLS_and_their_FUNCTION.

The TA-1000 is operated with only (i) four knobs and (ii) nine push button switches. All knobs are clearly marked to indicate their functions. Push-button switches are of two types; alternate-acting i.e. push-ON, push-OFF; and momentary acting i.e, push-to-indicate. All push-buttons indicate, by means of internal Tamps, the active state of the selected function. Unwanted or illogical function are internally inhibited.

(i) F0UR_KN0BS:

1) The stimulus function switch permits selection of 2 KHz, 4 KHz or 6KHz acoustic logon stimulus equivalent frequencies, at repetition rates of 5 or 20 stimuli per second and patient response intervals of 10 ms or 20 ms immediately following the acoustic logon stimulus.

2) The stimulus attenuator establishes the presentation level, permits selection of acoustic logon stimulus from 0 to + 100 dB HL.

3) The scale function switch permits selection of system sensitivity and number of averaged response samples. For 1024 samples, 0.5 uV, 1 uV, 2uV and 5uV/division sensitivities are available. For 2048 samples 0.2 uV, 0.5uV, 1 uV and 2 uV/division sensitivities are available. For 4096 samples, 0.1 uV, 0.2 uV 0.5 uV and 1 uV/ division sensitivies are available.

4) The latency control position a curson mark on the oscilloscope display for precise determination of time delay from stimulus peak to any point on the averaged patient response. Readout of latency, in milliseconds, to 0.1 ms resolution is displayed in digital form directly above this control.

(ii) PUSH_BUTTON_SWITCHES:

1) POWER switch energizes the system and indicate the system status.
2) SCORE switch controls the oscilloscope display.
3) CLEAR push-button clears the micro-processor averager memory, resets the sample display counter and corrects the micro-processor operating mode to correspond to the current control status.

4) START/STOP push-button initiates the micro-processor average function. As the 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, or when any averager memory channel is full; automatic termination requires a clear, to permit restart.

5) RECORD push-button initiates the platter readout, if the averager is not active.

6) MASK push-button applies broad-band noise masking to the contra-lateral ear only when either Air left or Air Right stimulus is active.

7) AIR LEFT applies the stimulus to the desired earphone.

8) AIR RIGHT applies the stimulus to the desired earphone.

9) BONE push-button applies the stimulus to the bone-vibrator transducer.

Besides these there is (1) paper advancer thumb wheel, when rotated downward advances the plotter chart paper. (2) The limit indicator, in the samples window, will light briefly to indicate the presence of excess input to the system. At high sensitivities i.e. 0.1 uV, 0.2 uV and 0.5 uV/division, this indictor will be relatively active, depending on the individual patient. Patient responses, occuring when the limit light is on, are rejected from the averaged responses and are neither accumulated nor counted. (3) The TWF/RUN/EEG switch should be in RUN for normal operation. When in the TWF position, after a CLEAR, the oscilloscope will display a characteristic test waveform to confirm oscilloscope operation. In the EEG position, after a CLEAR, the oscilloscope will display the ongoing patient EEG activity, the raw signal from which the averaged response is derived. Figure 6 shows the flow chart of the system.

III. Test environment:

The experiment was carried out in sound treated room at the Audiology department, All India institute of Speech and Hearing, Mysore.

a) POWER SOURCE: The main A-C current was cannalized to I.T.L. Model SVS - 200L stabilizer with input 170-270 volts and output of 230 volts, this was stepped down by Kardio S.No.101 to 110 volts which is the requirement of the instrument to function properly.

b) LOCATION of the instrument: The instrument was placed inside a larger sound tested room.

i) Humidity was neither too high or low to the point where either the subject or clinician were uncomfortable.

ii) It was away from noisy drafty or excessive vibration area.

iii) Away from high brightness areas, curtains were drawn to control direct sunlight in the room.

iv) It was away from electrically noisy areas i.e. large motors, copying machine etc.

IV. PROCEDURE:

Prior to every test the stabilizer output was checked to ensure a constant voltage of 200 volts. The chart papers in the plotter was also checked for its proper position. The tubular pen holder was uncaped.

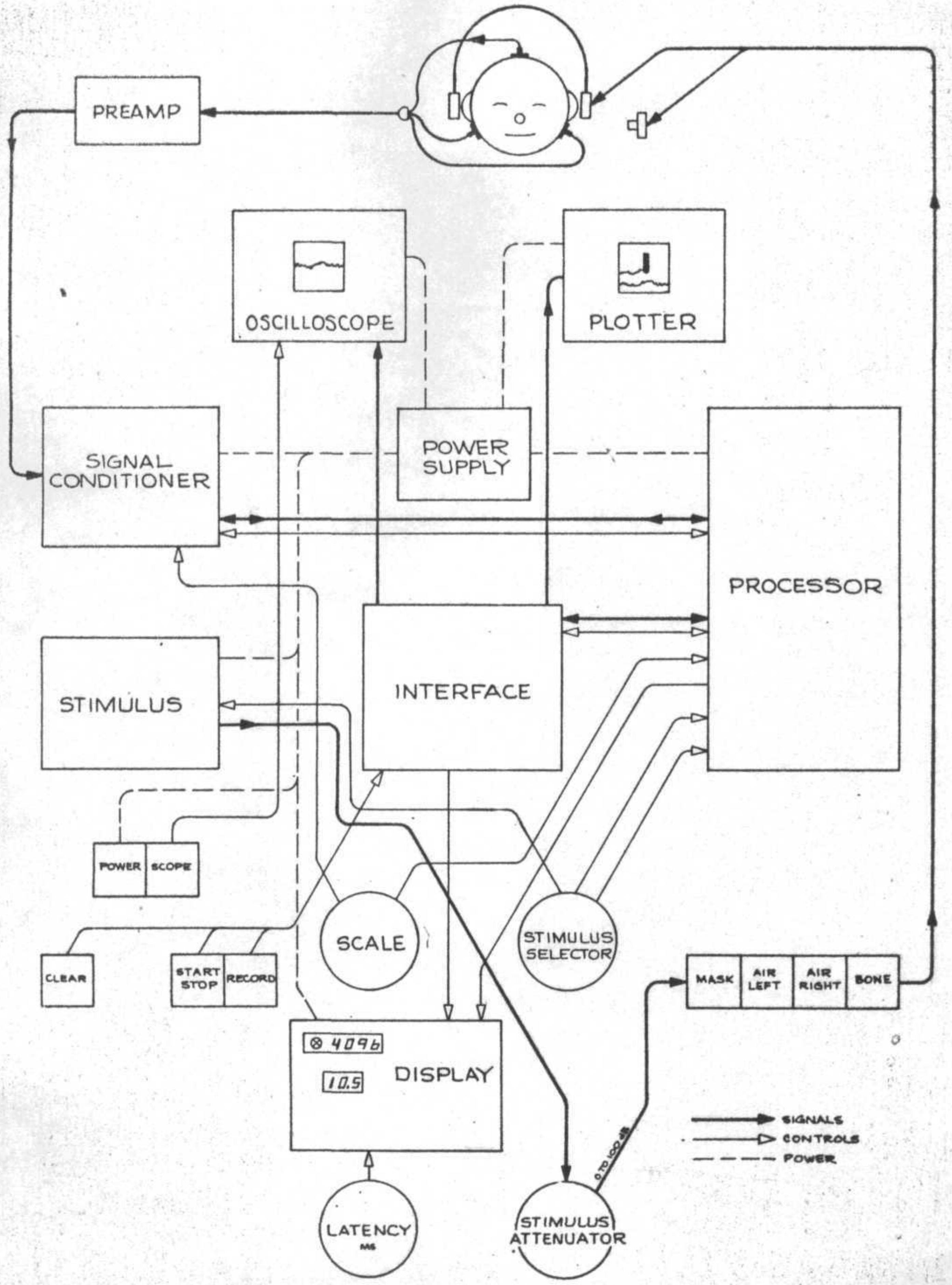

Figure 6: Flow chart of ERA: TA-1000 used in the present study.

The subject was to lie in relaxed, recumbent position on a medical examination table. Option was given for pillow to avoid head, neck tension and to make muscle artifact negligible. Subject was briefed with the information that, there electrodes would be placed and then an earphone from which he could hear click like sound in the right ear. He was told to be in a relaxed state and he could go to sleep.

Electrodes were checked with a gentle tug on both ends. They were cleaned with cotton soaked in rectified spirit (electrodes are of solid sterling silver). Thus, there was no danger of wearing of any plating.

Cotton soaked in rectified spirit was briskly rubbed on the skin area where the electrodes were to be placed, till pinkish colour indicative of increased vascularity appeared. This was then wiped with dry cotton.

Sufficient quantity of Beckman electrode electrolyte (electrolyte gel) was placed on the electrodes to fill the recess in the electrode to the 'slightly rounded' condition and to get applied to the skin. Electrode was placed on the previously cleaned area, pressing slightly. The excess of paste which oozed out from the electrode holes and sides was cleaned with dry cotton. Then Johnson adhesive of 2 x 2 cms approximately was used to hold the electrode into firm contact all around.

Electrode placement was as follows:-

Red : (+) signal, to high forehead.
White:(-) reference, at right mastoid of the test ear.
Black: Ground, at left mastoid of the nontest ear.
The electrode end of the preamplifier patient electrode cable was attached to the bed surface near the head and held in position with adhesive plaster. Each electrode was plugged into the correspondingly coloured receptacle on the patient electrode cable from the preamplifier.

Preamplifier was positioned in a convenient location and was plugged with the 3-pin patient electrode cable plug into the corresponding preamplifier receptacle (they have blue colour code).
Preamplifier and the ERA were interconnected by means of the cable and receptacles which are colour coded (Yellow).

Headphones were placed and the head set was positioned in such a way that it was comfortable to the patient. Power and scope buttons were pressed. The preamplifier high input light was checked. If the red light was on continuously, the various factors such as improper electrode attachments, excess muscular activity on the part of the patient (if he was uncomfortable), possible neck muscle strain and swallowing, were checked to eliminate the preamplifier high input light.

ERA was set as follows:

* TWF/RUN/EEG was kept on RUN.
* Stimulus frequency on 2 KHz, 20 pulses per second and 10 MS sample time.
* The scale switch on 2048 samples and 0.2 uV/DIV.
* Stimulus Intensity 80 dB HL (Subsequent tests were done at 100 dB HL, 80 dB HL and 100 dB HL).
* CLEAR was pressed and then AIR RIGHT.

Preamplifier was rechecked, when there was no indication of high input START/STOP was initiated for operation.

The sample was rejected when
1) an automatic stop occured before 2048 samples.
2) When rapid averaging of amplitude was observed, a four division marker was observed at the left side which as test progresses and trace reaches full oscilloscope amplitude, a two division marker and finally one division was observed. If one division was observed before 500 samples or not observed even when 2048 samples were achieved.

When adequate samples and divisions were observed, the final recording was done by pressing RECORD button (the oscilloscope trace, representative of the patient's BSER for test parameter was recorded on the plotter by tubular pen).

I to V peak latency readings were noted down with the help of latency cursor.

By pressing the CLEAR button sad changing the intensity to 100 dB HL, after adequate sampling and averaging, next recording was done. Similarly, averaged brain stem responses were recorded at 80 and 100 dB HL for the second time. Amplitude of BSER was determined from the plotter. To determine the amplitude of the subjects BSER in microvolts, the marker amplituder N, was noted in division of 1, 2 or 4. For finer analysis each was further divided into 10 divisions with the help of traveling microscope. Scale switch amplitude is noted i.e. .2 /lV/div. For example a trace feature is 2.5 division high and the marker is 1 division high and the scale switch is set to .2 /lV/div.
T = 2.5

$$M = 1 \qquad S = .2 \qquad \text{BSER} = \frac{TS}{M} = \frac{2.5 \times .2}{1} = .500 \text{ uV}$$

All the subjects were tested in the above manner. In a pilot study 15 ears were tested and 109 recordings done, of which 50.46% were fulfilling the criterion set to accept as sample, 38.53% were not averaged and 11.01% showed rapid averaging. Besides this, the morphology and other stimulus parameters were not consistent. Instrument was calibrated time and again, earthing was checked, the only problem seemed to be power fluctuation, the Keltron Stabilizer did not seem to be strong enough to absorb the fluctuation, as whenever there was fluctuation, it was seen on the oscilloscope representation of the response. A high power stabilizer was then utilized to give a steady flow and it was ensured that a constant flow of 230 volts was coming, and stepped down to 110 volts for the TA - 1000 ERA. Then the responses were consistent. Finally 28 ears were tested, of which 8 were rejected as they did not fulfil the required sample or other criterion set. Of the 8 rejected, 45 recordings were done, 33.33% did not get averaged. 13.33% were arranged properly and 53.34% showed rapid averaging, 2 showed abnormal morphology and 3, predominantely females, showed high input despite ruling out all possible factors which could lead to this, like loose contract, bad earthing etc. Of the 20 ears taken as sample, 122 recordings were done. 65.57% were adequately sampled and averaged, 12.20% were not averaged, 10.65% were rapidly averaged and 11.58% were not adequately sampled.

The data was analysed using appropriate statistical methods. ANOVA. 2 (intensities) x 2 (sex) x 2 (sessions) was used to see the significant differences and Test-retest reliability was found using product moment co-efficient of correlation. For data analysis DEC system a -10 Forton computer system at Tata Institute of . Fundamental Research, Bombay (which has integrated SPSS program) was used. Statistical Package for the Social Sciences (SPSS) is an integrated system of computer programs designed for the analysis of social science data (Nie et al. 1981). The system provides a unified and comprehensive package that enables the user to perform many different types of data analysis in a simple and convenient manner as well as flexibility in the format of data. The workspace is 2688 words, transpace 384 words, and allows 14 transformations, 59 record values plus Lag variables, and 238 IF/complete operations.

Following programs for analysis were utilized from SPSS computer programs.

1) ANOVA : LAT 1 to LAT 5 BY SEX (1,2), SESS (1,2), INT(1,2),
   INPUT FORMAT: FIXED (12, 3F 1.0, 6F 5.0).

2) ANOVA : AMP 1, AMP 2, AMP 3 BY SEX (1,2), SESS (1,2) INT (1,2).
   INPUT FORMAT: FIXED (12, 3F 1.0, 6F 3.0).

3) ANOVA : IWL 1, IWL 2, IWL 3 BY SEX (1,2), SESS (1,2) INT (1,2). and

4) ANOVA : RAMP 1, RAMP 2, RAMP 3 BY SEX (1,2), SESS (1,2), INT (1,2).

- INPUT FORMAT: FIXED (I2, 3F 1.0, 6F 4.0).

5) PEARSON CORR: LATA1 TO LATA6 with LAT B1 to LAT B6
   INPUT FORMAT: FIXED (I2, 3F 1.0, 6F 5.0/.5 x, 6F 5.0)

6) PEARSON CORR: AMP A1 to AMP A3 WITH AMP B1 to AMP B3
   INPUT FORMAT: FIXED (I2, 3F 1.0, 3F 3.0/5x, 3F 3.0)

7) PEARSON CORR: IWL A1 TO IWL A3 WITH IWL B1 TO IWL B3.

8) PEARSON CORR: RAMP A1 TO RAMP A3 WITH RAMP B1 to RAMP B3

   INPUT FORMAT: FIXED (I2, 3F 1.0, 3F 4.0/5 x, 3F 4.0).

CHAPTER IV

DATA. ANALYSIS. RESULTS AND DISCUSSION

The present chapter is discussed under the following headings.

1) The Raw data
2) The Means
3) The Range
4) 2 x 2 x 2 ANOVA:
   Relationship between
   i) two intensities
   ii) two sexes
   iii) two sessions for
      a) Absolute latency
      b) Absolute amplitude
      c) Interwave latency
      d) Relative amplitude
5) Correlations:
   Test-Retest reliability of
      a) Absolute Latencies
      b) Absolute amplitudes
      c) Interwave latencies
      d) Relative amplitudes
6) Standard deviation, cross-product deviation and covariance.
7) Comparison of the present results with the results of previous studies.

1) The_Raw_data:

Tables 4 to 9 give the values for absolute latency (ms), interwave latency (ms), absolute amplitude (cm), and relative amplitude (mm) for different intensities, sexes and sessions.

SL.No. of Subjects	SESSION	INTENSITY 80 dB I	II	III	IV	V	VI	100 dB I	II	III	IV	V	VI
1	ONE	1.2	2.1	3.2	4.3	5.2	6.2	.9	1.8	3.0	4.1	5.1	6.0
2	''	1.3	2.0	3.1	4.3	4.8	6.2	1.1	2.2	2.8	4.1	4.7	5.9
3	''	1.2	2.2	3.1	4.3	4.9	6.3	1.0	1.9	2.9	4.0	4.8	5.9
4	''	1.2	2.1	3.2	4.3	5.0	6.5	.8	1.8	3.0	4.2	4.8	6.2
5	''	1.0	2.2	3.1	4.3	5.0	6.0	1.0	1.4	3.0	4.0	4.7	5.6
6	''	1.4	2.1	3.2	4.4	4.9	6.3	.9	1.7	2.8	3.9	4.5	6.0
7	''	1.1	2.1	3.3	4.5	5.3	6.3	.7	1.7	3.0	4.2	5.1	6.4
8	''	1.1	1.9	3.1	4.3	4.6	5.9	.8	1.6	2.9	4.2	4.6	6.2
9	''	1.5	2.4	3.5	4.5	5.0	6.5	1.0	2.0	3.2	4.6	4.9	6.7
10	''	1.1	2.2	3.2	4.4	5.1	6.5	1.0	1.9	2.9	4.1	4.8	6.2
1	TWO	1.0	1.8	3.0	4.1	5.1	6.2	1.0	1.4	2.9	4.1	5.0	6.7
2	''	1.4	2.3	3.1	4.3	4.8	6.3	1.1	2.0	2.8	4.2	4.7	6.0
3	''	1.3	2.1	3.1	4.3	4.9	6.1	1.0	1.9	2.9	4.0	4.7	6.0
4	''	1.2	2.2	3.2	4.3	5.0	6.5	.9	1.9	3.0	4.3	4.9	6.2
5	''	1.2	2.2	3.2	4.2	5.1	5.9	1.0	1.9	3.0	3.9	4.8	5.7
6	''	1.3	2.0	3.2	4.5	4.9	6.2	.9	1.8	2.8	4.2	4.8	6.1
7	''	1.2	2.1	3.3	4.6	5.4	6.2	0.8	1.7	3.1	4.3	5.2	6.5
8	''	1.0	1.9	3.0	4.3	4.5	6.1	.8	1.6	2.9	4.2	4.6	6.1
9	''	1.4	2.4	3.4	4.6	5.1	6.5	1.0	2.2	3.1	4.6	4.9	6.4
10	''	1.1	2.3	3.2	4.5	5.1	6.4	1.0	1.9	3.0	4.2	4.9	6.2

Table 4: Latency values for males in Sessions I and II for 80 and 100 db stimuli.

SL.NO. OF SUBJECTS	SESSION	INTENSITY 80 dB						100 dB					
		I	II	III	IV	V	VI	I	II	III	IV	V	VI
11	ONE	1.3	2.5	3.0	4.4	5.1	6.5	1.1	2.2	3.0	4.2	4.9	6.3
12	''	1.4	2.3	3.2	4.2	4.8	6.2	.9	1.8	3.0	4.0	4.6	5.7
13	''	1.2	2.2	3.0	4.3	4.9	6.3	.9	2.0	2.8	4.0	4.9	6.2
14	''	.9	2.5	3.2	4.4	5.1	6.4	1.0	2.2	2.4	4.0	4.8	6.2
15	''	1.3	2.3	3.3	4.2	4.8	6.5	.9	2.0	2.9	4.3	4.7	6.1
16	''	1.1	2.0	3.0	4.1	4.6	6.1	.8	1.7	2.7	3.8	4.6	6.0
17	''	1.3	2.2	3.3	4.5	5.0	6.3	1.0	1.7	3.0	4.3	4.8	6.0
18	''	1.1	2.0	3.0	4.0	4.5	5.6	.8	1.7	2.7	3.4	4.2	5.8
19	''	1.2	2.6	3.3	4.6	5.1	6.7	.8	1.9	3.0	4.3	4.7	6.2
20	''	1.2	2.2	3.1	4.3	4.9	6.2	.8	1.9	2.9	4.2	4.8	6.0
11	TWO	1.3	2.4	3.2	4.4	5.2	6.8	1.0	2.3	2.9	4.2	4.9	6.4
12	''	1.3	2.3	3.3	4.3	4.9	6.3	.9	1.9	3.0	4.0	4.5	5.8
13	''	0.9	2.4	3.0	4.2	5.0	6.4	.8	2.2	2.8	4.0	4.8	6.1
14	''	0.9	2.6	3.2	4.4	5.2	6.6	1.0	2.2	3.0	4.2	4.9	6.3
15	''	1.4	2.4	3.3	4.3	4.9	6.5	1.0	2.0	2.9	4.1	4.9	6.1
16	''	1.1	2.0	3.0	4.2	4.7	6.2	.7	1.7	2.7	3.9	4.4	6.0
17	''	1.5	2.3	3.3	4.6	5.2	6.4	.9	2.4	3.2	4.2	4.7	5.7
18	''	1.1	1.9	2.9	3.9	4.5	5.7	.8	1.7	2.7	3.4	4.4	5.7
19	''	1.2	2.5	3.3	4.4	5.1	6.8	.9	2.0	3.0	4.3	4.8	6.7
20	''	1.1	2.3	3.1	4.2	4.8	6.2	.9	1.4	2.4	4.2	4.8	6.8

Table 5: Latency values for females in session I and II for 80 and 100 dB stimuli.

SL. NO. OF SUBJECTS	SESSION INTENSITY / SEX	SI						S II					
		80 dB			100 dB			80 dB			100 dB		
		I	III	V	I	III	V	I	III	V	I	III	V
1	MALE	.6	.8	.9	.8	.5	1.0	.8	.4	1.3	.8	.3	1.3
2	''	.5	1.1	1.5	.7	1.0	1.6	.5	1.1	1.7	.3	1.2	1.1
3	''	.5	.3	1.4	.9	.5	1.3	.3	.3	1.4	.7	.7	1.9
4	''	.8	.7	1.8	1.2	.8	1.7	.7	.7	1.3	1.0	.8	1.3
5	''	.3	.3	1.4	.4	.4	1.9	.4	.3	.8	.4	.5	.7
6	''	.4	.7	1.5	.7	.9	1.9	.4	.8	1.5	.4	1.1	1.4
7	''	.8	.9	1.5	.5	.6	1.3	.6	1.1	1.2	.6	.7	1.4
8	''	.5	1.2	1.6	.9	1.5	2.6	.6	1.0	1.8	1.1	1.5	2.5
9	''	.2	.7	1.6	1.0	.5	1.3	.5	1.1	1.4	.4	1.0	1.8
10	''	.3	.7	1.6	.4	.7	1.3	.3	.8	1.3	.4	.7	1.2
11	FEMALE	.4	.5	0.7	.5	.4	1.0	.4	.3	1.1	.5	.4	0.9
12	''	0.8	0.9	1.8	1.0	1.2	1.9	.6	.5	1.5	0.8	.9	2.0
13	''	1.0	1.0	1.3	0.8	1.1	1.2	1.1	1.3	0.8	0.9	1.0	1.3
14	''	.6	.5	1.3	.6	.7	1.3	.5	.8	1.6	.5	.6	1.3
15	''	1.2	1.8	2.4	1.6	2.2	2.0	1.0	1.6	1.6	.8	1.4	1.9
16	''	1.1	1.5	1.4	1.4	2.3	1.7	1.3	1.7	1.5	1.9	2.3	2.1
17	''	.5	1.1	.7	.5	.9	1.4	.4	.9	.9	.3	.8	.9
18	''	.4	.4	1.1	1.1	.5	2.4	.5	.6	2.3	1.3	.4	2.1
19	''	.7	1.0	1.7	1.0	1.1	1.7	.9	.9	1.7	.7	1.2	1.8
20	''	.5	.8	1.6	1.0	1.2	1.6	.4	1.2	1.6	.9	1.0	1.3

Table 6: Absolute Amplitude value for males and females at 80 and 100 dB in sessions I and II

SL. NO. OF SUBJECTS	SESSION - INTENSITY INTERPEAK	I						II					
		80 dB			100 dB			80 dB			100 dB		
		I-III	III-V	V-I	I-III	III-V	V-I	I-III	III-V	V-I	I-III	III-V	V-I
	SBX MALE												
1	''	2.0	2.0	4.0	2.1	2.1	4.2	2.0	2.1	4.1	1.9	2.1	4.0
2	''	1.8	1.7	3.5	1.7	1.9	3.6	1.7	1.7	3.4	1.7	1.9	3.6
3	''	1.9	1.8	3.7	1.9	1.9	3.8	1.8	1.8	3.6	1.9	1.8	3.7
4	''	2.0	1.8	3.8	2.2	1.8	4.0	2.0	1.8	3.8	2.1	1.9	4.0
5	''	2.1	1.9	4.0	2.0	1.7	3.7	2.0	2.1	4.1	2.0	1.8	3.8
6	''	1.8	1.7	3.5	1.9	1.7	3.6	1.9	1.7	3.6	1.9	2.0	3.9
7	''	2.2	2.0	4.2	2.3	2.1	4.4	1.1	2.1	4.2	2.3	2.1	4.4
8	''	2.0	-1.5	3.5	2.1	1.7	3.8	2.0	1.5	3.5	2.1	1.7	3.8
9	''	2.0	1.5	3.5	2.2	1.7	3.9	2.0	1.7	3.7	2.1	1.8	3.9
10	''	2.1	1.9	4.0	1.9	1.9	3.8	2.1	1.9	4.0	2.0	1.9	3.9
11	FEMALE	1.7	2.1	3.8	1.9	1.9	3.8	1.9	2.0	3.9	1.9	2.0	3.9
12	''	1.8	1.6	3.4	2.1	1.6	3.7	2.0	1.6	3.6	2.1	1.5	3.6
13	''	1.8	1.9	3.7	1.9	2.1	4.0	2.1	2.0	4.0	2.0	2.0	4.0
14	''	2.3	1.9	4.2	1.4	2.4	3.8	2.3	2.0	4.3	2.0	1.9	3.9
15	''	2.0	1.5	3.5	2.0	1.8	3.8	1.9	1.6	3.5	1.9	2.0	3.9
16	''	1.9	.1.7	3.4	1.9	1.9	3.8	1.8	1.9	3.7	2.0	1.7	3.7
17	''	2.0	1.8	3.7	2.0	1.8	3.8	1.8	1.6	3.4	2.3	1.5	3.8
18	t!	1.9	1.5	3.5	1.9	1.5	3.4	1.1	1.8	3.9	2.1	1.8	3.9
19	''	2.1	1.8	3.9	2.2	1.7	3.9	2.0	1.7	3.7	1.5	2.4	3.9
20	''	1.9	1.8	3.7	2.1	1.9	4.0	2.1	1.9	4.2	1.9	1.7	3.8

Table 7 : Interwave Latency values for males and females at 80 and 100 dB in session I and II

SL.NO. OF SUBJECTS	SESSION INTENSITY WAVE	I 80dB III/I	V/III	V/I	100 dB III/I	V/III	V/I	II 80 dB III/I	V/111	V/I	100 dB III/I	V/III	V/I
1	SEX MALE	1.33	1.13	1.50	.63	2.00	1.25	.50	3.25	1.63	.36	4.33	1.63
2	''	2.20	1.36	3.00	1.43	1.60	2.29	2.20	1.55	3.40	4.00	.92	3.67
3	''	.60	4.67	2.80	.56	2.60	1.44	1.00	4.67	4.67	1.00	2.71	2.71
4	''	.88	2.57	2.25	.67	2.16	1.42	1.00	1.87	1.86	.80	1.63	1.30
5	''	1.00	4.67	4.67	1.00	4.75	4.79	.75	.24	2.00	1.25	1.40	1.75
6	''	1.75	2.14	3.75	1.29	2.11	2.71	2.00	1.86	3.75	.28	1.27	3.50
7	''	1.13	1.66	1.86	1.20	2.17	2.60	1.83	1.09	2.00	1.17	2.00	2.33
8	''	2.40	1.33	3.20	1.67	1.73	2.89	1.67	1.80	3.00	1.36	1.67	2.27
9	''	3.50	2.29	8.00	.50	2.60	1.30	2.20	1.27	2.80	2.50	1.80	4.50
10	''	2.33	2.29	5.33	1.75	1.86	3.25	2.67	1.63	4.33	1.75	1.71	3.00
11	FEMALE	1.25	1.40	1.75	.80	2.50	2.00	.75	3.67	2.75	.80	2.75	1.8
12	''	1.13	2.00	2.25	1.20	1.58	1.90	.83	3.00	2.50	1.13	2.22	2.50
13	''	1.00	1.30	1.30	1.38	1.09	1.50	1.18	.77	.73	1.11	1.30	1.44
14	''	.83	2.60	2.17	1.67	1.85	2.17	1.60	2.00	3.20	1.20	.78	2.60
15	''	1.50	1.33	2.00	1.38	.91	1.25	1.60	1.00	1.60	1.75	.64	1.13
16	''	1.36	.93	1.2 7	1.64	.74	1.21	1.31	.85	1.15	1.21	.91	1.11
17	''	2.20	.63	1.40	1.60	1.56	2.80	2.25	1.00	2.25	2.67	1.31	3.00
18	''	1.00	2.75	2.75	.45	4.80	2.18	1.20	3.83	4.60	.31	5.23	1.62
19	''	1.43	1.70	2.43	1.10	1.55	1.7	1.00	1.89	1.89	1.71	1.50	2.57
20	''	1.60	2.0	3.20	1.2	1.33	1.6	3.00	1.33	4.00	1.11	1.30	1.44

Table 8: Relative amplitude values for males and females at 80 and 100 dB in session I and II.

2) The_Means:

Means reflect the central tendency of the data. From table 9 it is clear that there is hardly and differences between the mean values, but females on the whole show shorter latencies than males, and with increase in intensity there is decrease in latency. Reverse is seen in amplitude behavior table 10, the females have higher amplitudes than that of the males. With the increase in intensity there is a tendency for the increase in amplitude. Here again, sessions do not make much of difference for peak III.

The interwave latency (Table 10) though showing similar picture as Table 9, the differences are minimal except for V-I interwave latency. For relative amplitude also variations are less.

Breaking the main factor for two way (Table 11 and 12) and three-way interaction (Table 13) the picture is similar as above (Table 9 and 10) but the mean differences become smaller and smaller.

3) The_Range:

Table 14 shows that for absolute latency, there is no overlap except for upper limit of peak IV and lower limit of peak V, for males and females at 80 dB. Males at 100 dB have wider interwave than interwave latencies. In case of amplitude there does not seem to be any pattern, unless one considers the upper limits which show there is distinction, there is overlap hut to a lesser extend when compared to lower limits. There is not much difference in the range of peak I and III whereas V does show a marked increase from these two.

ABSOLUTE LATENCY	SEX		SESSION		INTENSITY	
	MALE	FEMALE	I	II	80 dB	100 dB
I	1.08	1.04	1.06	1.06	1.20	0.92
II	1.97	2.12	2.03	2.06	2.21	1.88
III	3.07	3.00	3.03	3.03	3.17	2.90
IV	4.27	4.17	4.21	4.23	4.33	4.11
V	4.91	4.81	4.84	4.87	4.95	4.76

Table 9: Means of Absolute Latency I to V for main effects sex, sessions and intensities (N = 40).

	SEX		SESSION		INTENSITY	
	MALE	FEMALE	I	II	80 dB	100 dB
ABSOLUTE AMPLITUDE						
I	0.59	0.81	0.74	0.67	0.61	0.80
III	0.77	1.02	0.90	0.90	0.86	0.94
V	1.48	1.51	1.53	1.46	1.43	1.56
INTERWAVE LATENCY						
I-III	1.97	1.95	1.96	1.93	1.92	1.97
III-V	1.84	1.82	1.81	1.85	1.80	1.87
V-I	3.84	3.79	3.78	3.84	3.52	3.85
RELATIVE AMPLITUDE						
I/III	1.45	1.34	1.34	1.45	1.52	1.27
III/V	2.16	1.80	2.06	1.90	1.98	1.97
V/I	2.91	2.07	2.48	2.50	2.77	2.20

Table 10: Means of Absolute amplitude I, III and V ; Interwave latency of I-III, III-V and V-I; and Relative amplitude I/III, III/V and V/I; for main effects sex, sessions and intensities (N = 40).

	SESSION				INTENSITY				INTENSITY			
	I		II		80 dB		100 dB		80 dB		100dB	
ABSOLUTE LATENCY	MALE	FEMALE	MALE	FEMALE	MALE	FEMALE	MALE	FEMALE	SESSION. I	SESSION. II	SESSION I	SESSION II
I	1.07	1.05	1.09	1.04	1.22	1.19	0.94	0.90	1.20	1.20	0.91	0.92
II	1.97	2.09	1.98	2.15	2.13	2.29	1.81	1.95	2.21	2.22	1.85	1.91
III	3.08	2.99	3.06	3.01	3.19	3.15	2.95	2.85	3.17	3.16	2.89	2.91
IV	4.25	4.18	4.29	4.17	4.36	4.30	4.17	4.05	4.33	4.33	4.10	4.12
V	4.89	4.79	4.92	4.83	4.99	4.91	4.82	4.70	4.93	4.97	4.75	4.78
ABSOLUTE AMPLITUDE												
I	0.63	0.84	0.56	0.78	0.50	0.71	0.69	0.91	0.60	0.61	0.87	0.73
III	0.73	1.05	0.80	0.99	0.75	0.96	0.80	1.08	0.85	0.87	0.96	0.92
V	1.55	1.57	1.42	1.51	1.42	1.43	1.54	1.59	1.44	1.42	1.62	1.51

Table 11: Means of Absolute latency I to V and Absolute amplitude I, III, and V for two way interaction sex x sess, INT x SEX and INT x SESS (N= 20).

	SESSION I		SESSION II		INTENSITY 80 dB		INTENSITY 100 dB		INTENSITY			
									SESSION		SESSION	
INTERWAVE LATENCY	MALE	FEMALE	MALE	FEMALE	MALE	FEMALE	MALE	FEMALE	I	II	I	II
I - III	2.01	1.97	1.93	1.94	1.93	1.92	2.02	1.93	1.97	1.96	1.88	1.99
III- V	1.82	1.81	1.87	1.83	1.81	1.79	1.88	1.86	1.77	1.86	1.86	1.88
V-I	3.83	3.74	3.85	3.84	3.79	3.76	3.89	3.82	3.73	3.82	3.84	3.87
RELATIVE AMPLITUDE												
I/III	1.39	1.30	1.51	1.39	1.65	1.40	1.26	1.28	1.52	1.53	1.17	1.37
III/V	2.38	1.73	1.93	1.87	2.17	1.80	2.15	1.80	2.04	1.93	2.08	1.87
V/I	3.02	1.94	2.81	2.19	3.29	2.26	2.53	1.88	2.84	1.72	2.11	2.29

Table 12: Means of Interwave latency I-III, III-V and V-I in m sec and Relative amplitude I/III, III/V and V/I in mm, for two way interaction sex x sess, INT x sex and INT x SESS (N = 20).

INTENSITY		80 dB				100 dB			
SESSION		I		II		I		II	
SEX		MALE	FEMALE	MALE	FEMALE	MALE	FEMALE	MALE	FEMALE
ABSOLUTE LATENCY	I	1.21	1.20	1.23	1.18	0.92	0.90	0.95	0.89
	II	2.13	2.28	2.13	2.31	1.80	1.91	1.83	1.98
	III	3.20	3.14	3.17	3.16	2.95	2.84	2.95	2.86
	IV	4.36	4.30	4.37	4.29	4.14	4.04	4.20	4.05
	V	4.98	4.88	4.99	4.95	4.80	4.70	4.85	4.71
ABSOLUTE AMPLITUDE									
	I	0.49	0.72	0.51	0.71	0.79	0.95	0.61	0.86
	III	0.74	0.95	0.76	0.98	0.74	0.85	1.61	1.00
	V	1.48	1.40	1.37	1.46	1.62	1.62	1.46	1.56

Table 13: Means of Absolute latency and Absolute amplitude for threeway interaction sex x SESS X INT. (N = 10).

ABSOLUTE LATENCY

INTENSITY	PEAK	I	II	III	IV	V
	SEX					
80 dB	MALE	1.0-1.5	1.8-2.4	3.0-3.5	4.1-4.6	4.5-5.4
	FEMALE	0.9-1.5	1.9-2.5	2.9-3.3	3.9-4.6	4.6-5.2
100 dB	MALE	0.7-1.1	1.4-2.2	2.8-3.1	3.9-4.6	4.6-5.2
	FEMALE	0.7-1.1	1.4-2.3	2.4-3.0	3.4-4.3	4.4-4.9

ABSOLUTE AMPLITUDE

	PEAK	I	III	V
	SEX			
80 dB	MALE	0.2-0.8	0.3-1.2	0.8-1.8
	FEMALE	0.4-1.2	0.3-1.8	0.7-2.4
100 dB	MALE	0.3-1.2	0.3-1.5	0.7-2.6
	FEMALE	0.5-1.9	0.4-2.3	0.9-2.4

Table: 14: Range of Absolute latency and Absolute amplitude over two sessions for 80 and 100 dB stimuli in males and females (N = 40).

4) 2_x_2_x_2_AN0VA_and_significant differences:

To test the differences between the means whether significant or not, 2 (sexes) x 2 (sessions) x 2 (intensities) ANOVA was applied. Tables 15 and 16 give the summary of the analysis for main effect, two-way and three-way interactions for absolute latency and absolute amplitudes respectively.

For absolute latency, all main effects taken together are significant, P < .0001. Each main effect like sex was significant for peak II, P < .005; III and IV, P < .05; and V, P<.01; thus for these peaks means of females do have significantly shorter latencies. Differences between mean latency values for two intensities 80 dB and 100 dB, for peaks I to V are significant, P < .001. Thus with increase in intensity there is significant decrease in latency. The main effect of sessions are not significant, thus indicating homogeneous sample. Besides this none of the two-way and three-way interactions were significant.

Absolute amplitude values when taken together, the main effects, are not as significant as latencies except amplitude I, P<.01. For main effects, the amplitudes of I and III peaks for the two sexes are significant, P<.01; thus the females have significantly larger amplitudes than the males for peak I and III. Considering intensity as main effect, only amplitude 1 was seen as significant, P < .05. Thus with increase in intensity amplitude of I peak only shows significant increase. Sessions main effect as two-way and three-way interaction were not significant.

As observed in Table 10 and 12, the mean values for interwave latencies and relative amplitudes are small, thus only the main effects were studied. Table 17 gives the summary of the analysis of variance. Considering the main effect intensity only interwave latency V-I is significant, P<.0001, thus with increase in intensity there is statistical significant decrease. Relative amplitude V/I was significant for main effect with regard to sex, $P < .001$, i.e. females have significantly shorter relative amplitude V/I was significant $P < .025$ i.e. with increase in intensity there was significant decrease in relative amplitude V/I.

SOURCE OF VARIATION	df	LAT I		LAT II		LAT III	
		MS	F	MS	F	MS	F
MAIN EFFECTS	3	0.57	28.93*	0.89	19.09*	0.51	21.99*
SEX	1	0.03	1.25	0.44	9.34+	0.09	3.94**
SESS	1	0.00	0.03	0.02	0.45	0.00	0.01
INT	1	1.68	85.53*	2.21	47.48*	1.43	61.81*
2-WAY INTERACTION	3	0.00	0.15	0.01	0.13	0.01	0.41
SEX X SESS	1	0.00	0.41	0.01	0.13	0.01	0.27
SEX, X INT	1	0.00	0.03	0.01	0.13	0.02	0.91
SESS X INT	1	0.00	0.03	0.01	0.13	0.00	0.05
3-WAY INTERACTION	1 ,	0.00	0.00	0.00	0.00	0.00	0.05
SEX X SESS X INT	1	0.00	0.00	0.00	0.00	0.00	0.05
EXPLAINED	7	0.25	12.47	0.38	8.24	0.22	9.58*
RESIDUAL	72	0.02		0.05		0.02	
TOTAL	79	0.04		0.08		0.04	

* P< 0.0001, II P< 0.001, + P < 0.005 ++ P< 0.025, ** P< 0.05   P <: 0.01

Table 15 a: Analysis of variance: Summary table for Absolute latencies I, II and III

	LAT IV		LAT V	
SOURCE OF VARIATION	MS	F	MS	F
MAIN EFFECTS	0.38	9.52 *	0.30	6.84 *
SEX	0.18	4.47 **	0.18	4.17 ++
SESS	0.01	0.11	0.02	0.57
INT	0.97	23.97*	0.69	15.80 *
2-WAY INTERACTION	0.01	0.21	0.00	0.10
SEX X SESSION	0.01	0.20	0.00	0.01
SEX X INT	0.01	0.31	0.01	0.29
SESS X INT	0.00	0.11	0.00	0.01
3-WAY INTERACTION	0.00	0.05	0.01	0.29
SEX X SESS X INT	0.00	0.05	0.01	0.29
EXPLAINED	0.16	4.15"	0.13	3.02 +
RESIDUAL	0.04		0.04	
TOTAL	0.05		0.05	

Table 5 b: Analysis of variance: Summary table for Absolute latencies IV and V.

		AMP I		AMP III		AMP V	
SOURCE OF VARIATION	df	MS	F	MS	F	MS	F
MAIN EFFECTS	3	0.57	6.10	0.45	2.28	0.16	0.87
SEX	1	0.89	9.40	1.21	6.08	0.02	0.09
SESS	1	0.08	0.84	0.00	0.00	0.09	0.49
INT	1	0.74	7.81 **	0.14	0.68	0.37	2.05
2-WAY INTERACTION	3	0.03	0.35	0.04	0.19	0.05	0.25
SEX X SESS	1	0.00	0.04	0.08	0.40	0.09	0.50
SEX X INT	1	0.00	0.00	0.02	0.11	0.01	0.05
SBSS X INT	1	0.10	0.01	0.01	0.07	0.03	0.20
3-WAY INTERACTION	1	0.12	0.19	0.09	0.47	0.01	0.03
SEX X SESS X INT	1	0.12	0.19	0.09	0.47	0.01	0.03
EXPLAINED	7	0.26	2.79	0.22	1.13	0.08	0.49
RESIDUAL	72	0.09		14.06		0.18	
TOTAL	79	0.11		15.62		0.17	

Table 1b: Analysis of variance: Summary table for Absolute amplitude I, III and V.

		INTERWAVE LATENCY					
		I-III		III-V		V-I	
SOURCE OF VARIATION	df	MS	F	MS	F	MS	F
MAIN EFFECT							
SEX	1	0.04	2.0	0.03	0.75	0.05	0.83
SESS	1	0.05	1.0	0.03	0.75	0.07	1.17
INT	1	0.02	2.5	0.09	2.25	72.75	121.50 *
ERROR (RESIDUAL)	72	0.02		0.04			
TOTAL	79	0.03		0.04			

		RELATIVE AMPLITUDE					
MAIN EFFECT		I/III		III/V		V/I	
SEX	1	0.25	0.50	2.61	2.09	14.21	11.58"
SESS	1	0.23	0.46	0.50	0.40	0.01	0.01
INT	1	1.29	2.61	0.00	0.00	6.53	5.32 ++
ERROR (RESIDUAL)	72	0.50		1.25		1.23	
TOTAL	79	0.49		1.20		1.44	

Table 17: ANOVA summary table for Interwave latency in milliseconds and Relative amplitude I-III, III-V and V-I and I/III, III/V and V/I

5) Correlations and Test re-test reliability:

Test re-test reliability was established by Pearsons product moment correlation coefficients, N= 40, 20 subjects were retested for two intensities on different sessions.

Absolute latencies were found to be more reliable than the interwave latencies (Table 18). All the absolute latencies I to V obtained in the two sessions have good correlation. The latencies of peaks III, IV and V have correlation values of 0.74, 0.90 and 0.89 respectively. All are significant at P<.0001. On the other hand, interwave latencies, though on face value show greater reliability, have less correlation values r = .62, P<.0001, for I-V, r = 35, P <.001 for I-III and r = .49, P<.001 for III-IV. Cross correlation between I and II, III, IV and V show successive decrement in correlation- showing that each wave is an independent factor but the same is not true of interwave latencies.

Absolute amplitude is less reliable than the latencies. Relative amplitude is less reliable than the absolute amplitude. Absolute amplitude for peak III (r = .85, P < .001) is more reliable than the absolute amplitude of Peak I (r = .74, P <.0001) and absolute amplitude of peak V (r = .47, P<.001) (Table 19). Relative amplitude have poorer reliability, of them I/III (r =.48, P<.001) is more reliable than III/V (r = .41, P < .004) and I/V (3 =.37 P <.01).

6) Standard_deviation._cross_Product_deviation_and_covariance:

Standard deviation for all dependent variables was computed across sex and intensity. N = 40, for sessions I and II. It is clear from Table 20, that SD except for relative amplitude does not exceed .50 - indicating there is not much variation in the results when tested twice.

Cross product deviation and covariance values were also computed across sex and intensity for all dependent variables (Table 21 and 22).. Covariance reflects the homogenity among the variables or of regression. The values are very low-reflecting that the data is homogeneous. Also, the cross product deviation reflects the deviation between the two sessions, here again the values are low.

Low values of standard deviation, cross product deviation and covariance reflects that the sample is homogeneous and can be pooled together - this was to counter-check the main effect of session in ANOVA.

ABSOLUTE LATENCY

SESS II / SESS I	I	II	III	IV	V
I	0.873 p<.0001	0.604 P <.0001	0.650 P <.0001	0.476 P <.001	0.330 P <.019
II	0.597 P <.0001	0.737 P<r.0001	0.550 P< .0001	0.533 P<.0001	0.556 P<.0001
III	0.635 P <.0001	0.454 P <.002	0.742 P<.0001	0.651 P<.0001	0.538 P<.0001
IV	0.527 P<.0001	0.5401 P <.0001	0.672 P<.0001	0.895 P<.0001	0.688 P<.0001
V	0.358 P <.012	0.387 P<.007	0.563 P <.0001	0.661 p<.0001	0.8939 P<.0001

INTERWAVE LATENCY

SESS II / SESS I	I-III	III-V	V-I
I-III	0.347 p <.001	0.374 P< .009	0.783 P<.0001
III-V	0.312 P<.025	0.493 P<.001	0.449 P<.002

V-I	0.675 P<.0001	0.475 P<.001	0.623 P<.0001

Table 18: Pearson correlation coefficients of Absolute latency and Interwave latency for I to V, I-III, III-V and V-I between session I and II in ms (N = 40).

ABS0LUTE AMPLITUDE

SESS II / SESSI	I	III	V
I	0.744 P<.0001	0.559 P<.0001	0.413 P <.004
III	0.617 P <.0001	0.851 P <.0001	0.368 P<.010
V	0.367 P<.10	0.407 P <.005	0.470 p<001

RELATIVE AMPLITUDE

SESS II / SESS I	I/III	III/V	I/V
I/III	0.484 P < .001	-0.430 P < .003	0.153 P<.173
III/V	-0.250 P <.060	0.417 P <.004	0.255 P<.056
I/v	0.270 P <.046	-0.126 P < .219	0.370 P<.010

Table 19: Pearson correlation coefficient of Absolute amplitude and Relative amplitude for I,III and V; I/III, III/V and I/V between session I and II (N = 40).

ABSOLUTE LATENCY	SESS I	SESS II
I	0.20	0.21
II	0.26	0.29
III	0.20	0.20
IV	0.23	0.22
V	0.22	0.23
ABSOLUTE AMPLITUDE		
I	0.32	0.34
III	0.47	0.43
V	0.42	0.42
INTERWAVE LATENCY		
I-III	0.20	0.20
III-V	0.20	0.24
V-I	0.24	0.23
RELATIVE AMPLITUDE		
I/III	0.61	0.79
III/V	1.06	1.15
I/V	1.34	1.05

Table 20: Standard deviation for Absolute latency in ms, Absolute amplitude in cm, Interwave latency in ms, and Relative amplitude (N = 40).

VARIABLES SESS I	SESS II	CROSS-PRODUCT DEVIATION	COVARIANCE
LAT I	I	1.37	0.04
''	II	1.35	0.04
''	III	1.01	0.03
''	IV	0.84	0.02
''	V	0.59	0.02
LAT II	I	1.26	0.03
''	II	2.21	0.06
''	III	1.14	0.03
''	IV	1.26	0.03
''	V	1.33	0.03
LAT III	I	1.03	0.03
''	II	1.05	0.03
''	III	1.19	0.03
''	IV	1.18	0.03
''	V	0.99	0.03
LAT IV	I	0.96	0.02
''	II	1.40	0.04
''	III	1.21	0.03
''	IV	1.83	0.05
''	V	1.42	0.04
LAT V	I	0.63	0.02
	II	0.97	0.03
	III	0.98	0.03 .
	IV	1.31	0.03
	V	1.79	0.05

Table 21: Cross-product deviation and covariance of absolute latencies I to V between session I and II in msec.

VARIABLES SESS I	SESS II	CROSS PRODUCT DEVIATION	COVARIANCE
ABSOLUTE AMPLITUDE			
I	I	3.18	0.08
''	III	3.02	0.08
''	V	2.16	0.06
III	I	3.81	0.10
''	III	6.64	0.17
''	V	2.78	0.07
V	I	2.02	0.05
''	III	2.83	0.07
''	V	3.17	0.08

Table 22: Cross-product deviation and covariance of absolute amplitude I, II and V between session I and II in cm.

7) Comparison_of_the_present_results with results of previous studies:

Comparison in true sense of the word is not possible unless, if not same, similar environment i.e. test condition, stimulus variable, subject variables etc., are maintained.

The absolute latency of all components decrease with increase in intensity. The following ABR latency V/S intensity table is from starr and Achor (1975). It represents latency, for monoaural stimulus, at various sensation levels to an 0.2 ms pulse through TDH -39 earphone, which results in a short damped oscillation having essential characteristics of brief 250 Hz tone pip - similar to the one used in present study.

	dB	I	II	III	IV	V
Starr and Achor (1975)	45	2.7	3.6	4.3	5.4	6.0
	55	1.8	3.0	3.9	5.0	5.8
	65	1.6	2.8	3.8	4.8	5.5
	75	1.4	2.4	3.7	4.6	5.4
Present study	80	1.2	2.2	3.1	4.3	5.0
	100	.9	1.9	2.9	4.1	4.8

This the present study abides with the rule that latency decreases with increase in intensity.

The interwave latency behavior in a smilar manner - a study by Rosenhamer et al. 1978, gives the following results for males and females.

INTERWAVE LATENCY	MALE 60	80 dB	FEMALE 60	80 dB
I - III	2.31	2.31	2.21	2.23
III - V	2.02	2.03	1.98	1.93
V - I	4.33	4.34	4.21	4.17

PRESENT STUDY	80	100 dB
I - III	1.92	1.80
III - V	1.80	1.87
V - I	3.85	3.52

Stockard et al. (1979) found I-V interpeak latency decreases from 4.02 ms at 70 dB SL to 3.68 ms at 30 dB. Rowe (1978) also observed minimal changes in interwave latency when stimulus intensity was decreased. Stockard et al. (1979) found interwave latency values for wave I-III and I-V shorter at lower stimulus intensity than wave III-V - this was not observed within the study probably because Stockard referred to 30 dB and 70 dB sensation levels. In the present study higher intensity stimulus was used.

Absolute amplitude changes with intensity. Picton et al (1982) states that the absolute amplitude decreases below 20 dB and increases more slowly above 70 dB. They report that with high pass filter of 100 Hz, Wave V amp decreased from 0.6 uV at 70 dB to 0.3 uV at 20 dB. In the present study it decreased from .312 uV at 100 dB to .286 uV at 80 dB.

Stockard (1975) observed that 30 dB reduction in stimulus intensity was associated with a 33% decrease in amplitude at the IV-V complex while the same reduction in intensity was associated with a 90% decrease in wave I amplitude - consequently relative amplitude (V/I) ratio increased with decreased stimulus intensity. Rosenhamer et al. (1978) found V/I to be between 1.5 and 2.53 and V/III to be between 1.40 and 1.72 for 80 and 60 dB SL. In the present study, the relative amplitude viz. V/I and V/III for 100 dB stimulus have been found to be 2.2 and 1.97 respectively- the relative amplitude viz. V/I and V/III for 80 dB stimulus have been found to be 2.77 and 1.98 respective-

Adult female subjects have significantly shorter latencies for wave III and V for clicks. Many studies (Kjaer 1979; Jerger and Hall 1980, Mecleans et al 1980) have reported a latency difference (difference between males and females regarding peak V latency) ranging from 0.05 to 0.36 ms. Rosenhamer et al (1980) found significant latency differences between males and females of the order of 0.15 ms (wave I), 0.25 ms (wave III) and 0.30 ms (wave V). In the present study the values are: .03 ms (wave I), .06 ms (wave III) and .08 ms (wave V). Beagley and Sheldrake (1978) have found the difference for wave V between males and females ranging from 0.2 ms to 0.4 ms. Thorton et al. (1978) have reported a latency difference of 0.25 ms (wave V) between males and females.

Interpeak latency is about .21 shorter for female subjects (Stockard et al. 1979); whereas Rosenhamer et al. (1980) found interwave difference of .8, .10 and .17 and 80 dB for I-III, III-V and I-V respectively. In the present study interwave difference values are: .20, .20 and .50 for I-III, III-V and V-I respectively.

The higher values of the present study may be due to the high intensity of the stimulus used.

Test-Retest reliabiiity:

Thorton (1975) and Rosenhamer (1978) showed good test-retest reliability for latency. The present study also shows good test-retrest reliability for absolute latency. All the correlations were above +.73, P <.0001, ranging from .73 to .89. But the same is not true of absolute amplitude, their range is from .47 to .85. This though significant above P < .001, they are not as reliable as absolute latencies.

CHAPTER V.

SUMMARY AND CONCLUSION

Several clinics use ABR audiometry in audiological and otoneurological diagnosis. Abnormalities along the auditory pathways result in temporal and morphological variations from the normal pattern, enabling reasonably accurate diagnosis of acoustic neuroma, cerebropontine angle tumour etc. The meticulously controlled recording technique and establishment of the normal interwave and intrawave subject variability are crucial because the interpretation of the results depend upon them.

The present study was undertaken with the aim of establishing accurate norms for the patient's ABR data, considering intensity of the stimulus and sex of the patient. Interest was focused on absolute latency, interwave latency, absolute amplitude and relative amplitude. The study also included the establishment of test-retest reliability of these response parameters.

Latency is relatively an easy measurement especially in clinic oriented ABR audiometry, as compared to amplitude measurement which is more vague. To be more precise about the amplitude measurement, an easy method was developed. The graph paper which is scaled in cms. each cm representing 0.200 uV, was further divided into 10 mm and the data was analysed in the same unit (mm). Convertion into uV is possible by using the convertion table (Appendix l).

Regarding the effect of intensity of the stimulus . on the latency of ABR, it is clear that there is consistent and significant lengthening of latency of all the five waves with the reduction of stimulus . intensity. This is in coherence with the studies done by Hecox and Galambog, 1974; Starr and Anchor, 1975; Toller et al. 1976 Picton et al. 1977; Galambos and Hecox, 1978; Beagley and Sheldrake, 1978; Coats, 1978; Rosenhamer et al. 1980. The above relationship was also true for interwave latency. This is in agreement with studies done by Stockard and Rossiter, 1977; Gilroy and Lynn, 1978; Rowe, 1978; Chiappa et al. 1979; Rosenhamer et al. 1979; Bergholtz, 1981. In general, amplitude and relative amplitude tended to increase with intensity though the intensity - amplitude function was not as consistent and significant as that of latency - intensity function. This is in consonance with the studies of Starr and Achor, 1975; Tollner et al. 1976; Pratt and Sohmer, 1977 and Picton et al. 1981.

In the present study, sex did not yield significant differences at intensity level, though when intensities were pooled they did. Females at both intensity level do yield shorter latency values, which is in accordance to findings of Beagley and Sheldrake, 1978; Kjaer, 1979; Micha et al. 1980 and Rosenhamer, 1980; though significant differences were observed by Beagley and Sheldrake (1978) in sex-latency function.

Good test-retest reliability is indicated by Thorton (1975) and Rosenhamer et al. (1978) for latencies. In the present study similar findings were obtained. The correlation coefficients for reliability of interwave latencies and relative amplitudes were however not very high.

The study was carried out in a sound treated room at Audiology Department, AIISH, Mysore. Twenty (10 males and 10 females) normal hearing subjects were tested. As stated in methodology, subjects were in supine position and three electrodes were used - active, ground and reference. ERA - TA - 1000 was used, logon tone was fed through right earphone of 2 K Hz, 20 pulses per second, with 10 ms sample time and 2048 samples were collected. The intensity of tone was 80 dB, then 100 dB, this comprised one session, then again the same intensities were repeated for second session with no time interval inbetween.

The response characteristics studies were Absolute latencies I to V, Absolute amplitude I, III and V, Interwave latencies I-III, III-V and V-I, and relative amplitudes I/HI, III/IV and I/V.

Data was analysed using DEC system-10, a Forton computer system, with integrated SPSS programs, ANOVA and correlation programs were used for this study (cf, pg.36).

Following norms were obtained, and can be used for TA-100-ERA, at 2000 Hz for 2048 samples.

1) For Absolute Latencies:

INTENSITY dB		PEAKS IN MS I	II	III	IV	V
80 dB	X	1.20	2.21	3.17	4.33	4.95
	SD	.15	.20	.13	.16	.21
100 dB		0.92	1.88	2.90	4.11	4.76
	SD	.10	.24	.17	.23	.19

2) For Absolute Amplitude.

INTENSITY (dB)		PEAKS IN CMS. I	III	V
80 dB	X	0.61	0.86	1.43
	SD	.27	.39	.36
100 dB	X	0.80	0.94	1.56
	SD	.35	.49	.43

3) For Interwave Latencies.

INTENSITY (dB)		WAVES IN MS I-III	III-V	V-I
80 dB	X	1.92	1.80	3.52
	SD	.23	.18	.27
100 dB		1.97	1.87	3.85
	SD	.19	.20	.19

4) For Relative Amplitude.

INTENSITY dB		WAVES I/III	III/V	I/V
80 dB	X	1.52	1.98	2.77
	SD	.68	1.10	1.38
100 dB	X	1.27	1.97	2.20
	SD	.67	1.08	.88

Following conclusions are drawn from the study:

1) There are significant differences between the absolute latencies of peaks I to V obtained at two intensities. The differences are as follows: .28 ms (I), .33 ms(II), .27 ms(III), .22 mst.IV) and .19 ms(V). The latencies obtained for 100 dB stimulus are shorter than the latencies obtained for 80 dB stimulus.

2) There are significant differences in absolute latecies II to V between two sexes when intensities and sessions pooled. The differences are as follows: .04 ms(I), .15 ms(II), .07 ms(III), .10 ms(IV), and .10 ms(V). Females have shorter latencies than the males.

3) There are no significant differences between absolute latencies obtained in two sessions. The differences are nil for wave I and III, minimal in II (.03 ms), IV (.02 ms) and V (.03 ms). The latencies are prolonged in second session.

4) There are no significant differences in absolute latencies I to V between males and females at 80 dB and 100 dB. The differences between males and females are as follows: .04 ms and .04 ms (I), .16 ms and .16 ms (II), .04 and .10 ms(III), .06 ms and .12 ms (IV) .08 ms and .12 ms (V) at 80 and 100 dB respectively. . Females show shorter latencies than males at both the intensity levels.

5) There are no significant differences between absolute latencies I to V. The difference between two sessions at 80 dB and 100 dB respectively are .003 ms and .01 ms (I), .01 ms and.06 ms (II), .01 ms and .02 ms (III), .00 ms and .02 ms (IV) and .04 ms and .03 ms V, The latencies are prolonged in second session (though very

minimal) except wave III at 80 dB where it is reversed, and no changes are seen in wave I and IV at 80 dB between sessions.

6) There are no significant differences for absolute latencies I to V between males and females in two sessions. The differences are as follows: .02 ms and .04 ms (I), .11 ms and .07 ms (II), .09 ms and .05 ms (III), .07 ms and .12 ms(IV) and .10 ms and .09 ms (V). The latencies are prolonged for males (except wave II). There is no systematic change in the two sessions. The differences are more in absolute latencies of session two for wave I and IV, whereas inverse is true for the remaining.

7) There are no significant differences in absolute latencies between males and females, at 80 dB and 100 dB in session one and two. The differences are as follows: .01 ms and .05 ms (1), .14 ms and .18 ms (II), .06 ms and .01 ms (III), .06 ms and .08 ms (IV), .08 ms and .04 ms (V) at 80 dB, between sexes. At 100 dB the differences are: .02 ms and .06 ms (I), .11 ms and .15 ms (II), .09 ms and .11 ms (III), .10 ms and .15 ms (IV), .10 ms and .14 ms (V) between two sessions. On the whole, females have shorter latencies and this difference is more in session II at both intensity levels, except wave II, where inverse is true.

8) There are significant differences in interwave latencies obtained at two intensities. The differences are as follows: .33 ms (V-I), .05 ms (I-III) and .07 ms (III-V), the latter two are not significant. At higher intensities interwave latencies are decreased.

9) There are no significant differences in interwave latency I-III, III-V and V-I between two sessions. The differences are as follows: .03 ms (I-III), .04 ms (III-V) and .06 ms (V-I). The interwave latencies are larger in session two for III-V and V-I and shorter for I-III.

10) There are no significant differences in interwave latencies I-III, III-V and (V-I) between males and females. The differences are as follows: .02 ms, .02 ms and .05 ms respectively. The interwave latencies are shorter for females.

11) There are no significant differences between interwave latencies for males and females at 80 dB and 100 dB. The differences between sexes are as follows: .01 ms and .09 ms (I-III), .02 ms and .02 ms (III-V) and .03 ms and .07 ms (V-I) for 80 dB and 100 dB respectively. Females show shorter interwave latencies than the males at both intensity levels.

12) There are no significant differences in interwave latencies between sessions at 80 dB and 100 dB. The differences between two sessions at 80 dB and 100 dB are as follows: .01 ms and .09 ms (I-III), .09 ms and .02 ms (III-V) and .09 ms and.03 ms (V-I). The interwave latencies are larger in second sessions at both intensities levels except for I-III.

13) There are no significant differences for interwave latencies between males and females in two sessions. The differences are as follows: .04 ms and .01 ms (I-III) .01 ms and .05 ms (III-V) and .08 ms and .10 ms (V-I) between males and females for session one and two. The interwave latencies are larger for males in both the sessions.

14) There are significant differences in absolute amplitudes of wave I, II and III obtained at two intensities. The differences are: .19 cm (I), .05 cm (III) and .13 cm (V). On the whole with increase in intensity there is increase in absolute amplitude.

15) There are no differences in absolute amplitudes of wave I, III and V between two sessions. The differences are as follows: .07 cm (I), .07 cm (V) and nil for wave III. The amplitudes are depressed in session two.

16) There are significant differences in absolute amplitudes of waves I and III between two sexes. The differences are: .22 cm (I) and .25 cm (III); wave V is .03 cm, which is not significant. Females have higher amplitudes than the males.

17) There are no significant differences in absolute amplitudes between males and females at 80 dB and 100 dB. The differences between males and females are: .21 cm and .22 cm (I), .21 cm and .28 cm (III) and .01 cm and .05 cm (V) at 80 dB and 100 dB respectively.

18) There are no significant differences in absolute amplitude between the two sessions at 80 dB and 100 dB. The differences between sessions are: .01 cm and .10 cm (1), .02 cm and .04 cm (III) and .02 cm and .09 cm (V) at 80 dB and 100 dB respectively.

19) There are no significant differences in absolute amplitude between males and females in two sessions. The differences are as follows: .21 cm and .22 cm (I) .32 cm and .19 cm (III), .04 cm and .03 cm (V) between males and females for session one and two. Females have larger amplitudes in both the sessions except wave V in session one (where the inverse, true).

20) There are no significant differences in absolute amplitude between males and females, at 80 dB and 100 dB in two sessions. The differences are as follows: .23 cm and .20 cm (I), .21 cm and .22 cm (III), and .08 cm and .09 cm (V) at 80 dB and .16 cm and .25 cm (I), .09 cm and .61 cm (III), .00 cm and .10 cm (V) at 100 dB between males and females in two sessions. In all instances females have larger amplitudes except wave V of session one at 80 dB where reverse is true and at 100 dB no differences were observed.

21) There is significant difference between relative amplitude I/V obtained at two intensities, the difference obtained is .57. Similar behavior is seen in relative amplitudes I/III (.25) and III/V (.01) but they are not significant. Relative amplitude decreases with increase in intensity.

22) There are no significant differences in relative amplitude I/III, III/V and I/V obtained in two sessions. The differences are as follows: .11 (I/III), .16 (III/V), and.02 (I/v). There is increase in relative amplitudes I/III and I/V in session two and decrease in relative amplitude

23) There is significant differences between relative amplitude I/V obtained between two sexes, the difference obtained is .84. Similar behavior in relative amplitude is seen in I/III (.36) and III/V (.11) which is not significant, but males have higher ratios than females.

24) There are no significant differences in relative amplitudes between males and females at 80 dB and 100 dB. The differences between sexes obtained for 80 dB and 100 dB are as follows: .25 and .14 (I/III), .03 and .35 (III/V) and 1.03 and .65 (I/V). Males have higher ratios at both intensity levels.

25) There are no significant differences in relative amplitude obtained in the two sessions at 80 dB and 100 dB respectively. The differences between two sessions for 80 dB and 100 dB are as follows: .01 and .10 (I/III), .11 and .21 (III/V) and .13 and .18 (I/V). The relative amplitude ratios are higher in session one for components III/V, I/V at 80 dB and 111/V at 100 dB; in the remaining reverse is true.

26) There are no significant differences in relative amplitudes between males and females in two sessions. The differences are as follows: .09 and .12 (1/111), .65 and .06 (Iil/V), .08 and .62 (1/V) between sexes for session one and two. The relative amplitude ratios are larger for males in both the sessions.

27) There are significant correlations for the response parameters, viz. absolute latency, absolute amplitude, interwave latency and relative amplitude. The test-retest reliability is good for absolute latencies and absolute amplitudes, and not so good (though significant) for interwave latency and relative amplitude.

Limitations of the study:-

1) Although the number of samples selected for averaging was 2048, the system used to reject the samples whenever there was high input. There was no access to note the number of samples rejected by the system during a test run.

2) Stimulus parameters like derived responses, stimulus transduction, tone-onset responses etc. could not be determined.

3) There was no objective way of measuring the amplitudes.

4) The normative data established in this study is limited to 20 subjects with age range.

5) The subjects who were willing to undergo the test were included in the study, and hence randomization was not possible.

Recommendations:

1) It would be desirable to collect more data using different intensities andfrequencies of logon stimulus.

2) It may be worthwhile to study the effects of different samples viz. 1024 and 4096.

3) Norms of ABR for different age groups need to be established.

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APpendix - I

millimeter	Microvolts
.01	.002
.02	.004
.03	.006
.04	.008
.05	.010
.06	.012
.07	.014
.08	.016
.09	.018
0.10	.020
.11	.022
.12	.024
.13	.026
.14	.028
.15	.030
.16	.032
.17	.034
.18	.036
.19	.038
.20	.040
.30	.060
.40	.080
.50	.100
.60	.120
.70	.140
.80	.160
.90	.180
1.00	.200
1.50	.300
2.00	.400
2.50	.500
3.00	.600
3.50	.700
4.00	.800
4.50	.900
5.00	.1000

Conversion table from millimeter (mm) to microvolts (uV). Illustration: Converting 156mm into microvolts.

156 = 100 + 50 + 6 = 156 mm

= .200+.100+.012 = .312 uV.

APPENDIX II

TA - 1000 Electric Response Audiometry System used in the present study.