EFFECTS OF MONTAGES ON ABR
IN ADULTS AND CHILDREN

Reg. No.M9707

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

All India Institute of Speech and Hearing
Mysore 570006
1998

CERTIFICATE

This is to certify that this Independent Project entitled *EFFECTS OF MONTAGES ON ABR IN ADULTS AND CHILDREN* is the bonafide work in part fulfilment for the degree of Master of Science (Speech and Hearing) of the student with Register No.M9707

Mysore

May, 1998

Dr.(Miss)S.Nikam

Director

All India Institute of Speech and Hearing

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CERTIFICATE

This is to certify that this Independent Project entitled *EFFECTS OF MONTAGES ON ABR IN ADULTS AND CHILDREN* has been prepared under my supervision and guidance.

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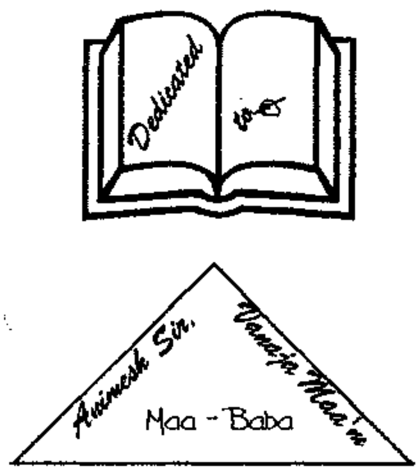
DECLARATION

This Independent Project entitled *EFFECTS OF MONTAGES ON ABR /N ADULTS AND CHILDREN* is the result of my own study under the guidance of Mr. **Animesh Barman.,** Lecturer in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysore and has not been submitted earlier at any University for any other diploma or degree.

Mysore

May, 1998 **Reg. No.M9707**


Dedicated to
Avimesh Sir,
Vanaja Maa'm
Maa - Baba

ACKNOWLEDGEMENT

I express my heartfelt gratitude and immense regards to ***Mr.Animesh Barman,*** my guide and Lecturer in Audiology, All India Institute of Speech and Hearing, Mysore, for his sincere care, guidance and encouragements which honed my idea of this project into the present form. I thank you Sir for all your criticisms and scoldings. They added glaze to my work.

I extend my feeling of gratitude to **Dr.(Miss)S. Nikam,** Dirctor, All India Institute of Speech and Hearing for granting me permission to carry out the project.

Bricks were made by Sir, you stacked them with cement to lay the foundation. I dedicate this piece of work, realistion of a dream to you. Thank you mam, for making me dream.

The moment I cried for my existence in this world and you picked me up, I realized, I am blessed. All these years this realization has become stronger and stronger to conclude you are the best parents a child can ever wish for. I promise to live up to your expectations.

I would like to express my gratitude towards training section for providing an access to the computer. But for which my statistical analysis would have never been complete.

When the ship is caught in storm, the crew looks up for the polar star. ***Hia,*** You are the polar star I looked at in the wrecks of my life. You will always be high like the star in my thoughts. My deep regards are due for you.

When the Sun was blazing and wounds were deep, no one other than you could nurse them to give me a stand again. Thank you ***Krithika*** for being in my life.

Anjana (magalu) your deep looks of care and concern were so comforting and assuring that it could bring the smile (grin) back to my face even when I was all under the world., If I were to write a dictionary, under the word "Friends", against eg. I would write Sanyu, Kamlesh, Anjana (CR) Pusu, and Suman Guys you all are so special to me in your own way, T can't but you in order. Thanks for all that we share.

My fellow Pandavs, it were you for whom world is a better place to live in. It is nice to walk up the stairs with our steps in synchrony. All those laughters and fights are really dear and memorable to me.

My dear Prakash, Saji, Binu,Siva, Ajith, Prarthana, its nice to have you all around to resort to any query I face. I liked the long discussions we had during various steps of this project.

Siddharth - you extended your help when I utterly needed one. Thank U all again.

Manosanna, JP, Rajeshanna, Rathna,Sara and Shibu. Your guiding friendship is one of the valuable things I earned here. Thank you for being such excellent seniors.

With all my regards I would like to thank Dr.J.W.Hall for providing an excellent text book with really exhaustive Bibliography in the form of Handbook of AER,

I would really like to thank the cute 'Nicolet Spirit' for storing my huge data in its memory without a say. Thanx 'Nicu'

Last and not the least , sincere thanks ar duet o Rajalakshmi Akka for her patient and neat typing to put my ideas 'Black and White'.

TABLE OF CONTENTS

		Page No.
I	INTRODUCTION	1 - 4
II	REVIEW OF LITERATURE	5-11
III	METHODOLOGY	12-16
IV	RESULTS	17-26
V	DISCUSSION	27 - 34
VI	SUMMARY AND CONCLUSION	35 - 37
	BIBLIOGRAPHY	38 - 42
	APPENDIX	

INTRODUCTION

The auditory evoked potentials are the electrical responses of the nervous system to auditory stimuli (Stapells, et al. 1985).

Auditory Brainstem Response (ABR), as it is otherwise called, has emerged as an important clinical tool with its unique diagnostic dimensions. Increasing popularity and extensive use of ABR may be attributed to its high objectivity, specificity, non-invasiveness. Clinically, ABR is most commonly used for :

i) Threshold estimation in difficult to test population without their active participation.

ii) Neurodiagnosis, in the sense, detection, localization and monitoring of auditory and neurological deficits.

For evaluation, the neural responses following an acoustic stimulation are picked up non-invasively through an array of surface electrodes till the level of brainstem.

The ABR consists of five main peaks and two more undifferentiated peaks as reported by Jewett and Williston (1971). These peaks occur within the first 10 ms. of stimulus onset depending on the intensity (Silman and Silverman, 1986; Jackobson, 1985). The ABR epoches are described in terms of, latency and amplitude. The latency and amplitude values in new borns and infants differ from adult values (Jackobson, Morhouse,"Johnhouse, 1982). Other technical aspects also effect ABR waveform. These factors include-

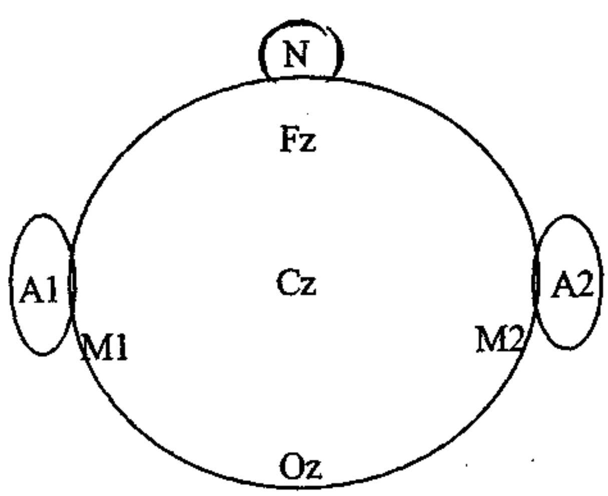
Stimulus parameters ;

Polarity, as stated by Stockard et al. (1979)
Rate (Don, Allen and Starr (1977), Jewett and Williston (1971), Chiappa, Gladston and Young (1979).
Type (Jackobson (1985), Hall (1992).

Filter settings, number of stimuli, electrode impedance etc. vary significantly and interestingly, recording montage also influences the quality of ABR waveforms.

A number of investigators have studied the effect of electrode placements on ABR recording. The international 10-20 system for electrode placement is as shown in the figure.

Fig.1



N being the nasion, F = forehead, C = Central, Fp = Frontal pole, T = temporal, M = Mastoid, A = earlobe, O= occipital. The mid saggital plane being represented by the subscript, the right side, by even numbers and the left by odd numbers.

Derbyshire et al. (1964) reported that best recording of ABR could be obtained by the placement of the recording electrode 3 cm lateral to the midline in the plane existing between the ears and the reference electrode on the contralateral earlobe or mastoid.

Vertex was found to be the best recording site by many researchers (McCandless and Best, 1964; Davis, 1939; Abe, 1954; Davis and Zerlin, 1966). Movement away from the vertex site by 6-10 cm in any direction has essentially no effect on ABR (Martin and Moore, 1977; Parker, 1981; Terkildsen, et al. 1974; Van Olphen et al. 1978).

Some investigators have recommended the upper forehead (Fz) for non-inverting electrode site (Beattie and Boyd, 1984; Coats, 1983; Suzuki, Hirai and Horiuchi, 1981), as this area is hair free and undisturbed by the placement of the ear phone.

Ipsilateral mastoid or earlobe is recommended as the inverting electrode site (Berlin and Dobie, 1979; Chiappa, et al. 1979; Davis, 1976b; Rowe, 1981; Stockard and Stockard, 1983).

The two major problems which are most often faced in clinical use of ABR are :

i) Wave ambiguity
ii) Poor wave morphology

These two factors limit the reliability of ABR in neuro-diagnosis wherein a definite detection of peaks is necessary. For confident and reliable identification of peaks, higher amplitude and a clear wave morphology are a must. Even the distinct resolution of IV-V complex is important in neurodiagnosis.

Liberature Shows

Different montages affect the amplitude of different peaks differently.

Also the IV-V resolution is different in different montages.

A correlation between the ipsilateral and contralateral waveforms is carried out for clear identification of wave V as the contralateral montage resolves IV-V complex significantly. It also reduces the amplitude of I and III peak and thus helps in the detection of I and III peaks in ipsilateral montage.

But the draw-back in using the contralateral montage is that though it resolves the IV - V complex, it reduces the amplitude of V peak.

Hence this study aims at

i) Finding the affect of different montages on ABR waveforms

ii) Finding an optimum montage combination which when used will give a confident identification of all the ABR peaks.

iii) Examining the difference in the effects of montages on ABR waveforms in children and adults.

REVIEW OF LITERATURE

Numerous stimulus and acquisition factors are known to effect the ABR morphology (Hall, 1992). Electrode placement used for the acquisition of waves affect the amplitudes-latency and polarity of wave components. Considering that large differences in the scalp distribution exist, it is expected that the ABR waveform morphology would differ with change in location. Also, this distribution is different in adults and children.

Vertex or the central area of the interaural plane is found to give the best recording or greatest amplitude when the reference electrode is placed on the ear lobe or mastoid (Derbyshire, 1964; McCandless and Best, 1964, Davis, 1939; Abe, Davis and Zerlin, 1964). Appleby (1964) working with infants found that amplitude was greater when recordings were obtained from the vertex with the reference electrode on the ear as opposed to the forehead or occiput. Cody et al. (1964) pointed out that responses recorded from the vertex are affected relatively less by changes in muscular tension. Decrease in the amplitude of the responses were noted with distance from vertex (Abe, 1954).

For the reference electrode, Goff et al. (1969) preferred the ear lobe over the chin, nasion, nose or mastoid process where as Davis (1966) preferred the ear lobe or mastoid placement because of high reproducibility and stability

Recently, a vertex to noncephalic electrode array is strongly recommended for clinical ABR recording by a host of neurophysiologists (Barratt, 1980; Hall et al. 1984; Jones and van der poel, 1990; McPherson, Hirasugi and Starr, 1985; Moller, 1985; Rossini et al. 1980;. Starr and Squires, 1982; Streletze et al. 1977;

Terkildsen and Osterhammel, 1981). Commonly used sites are the nape (back) of the neck, either sides of the neck, and the thorax (chest) specifically at the sternum. Among these three the thorax appears to be the least active with respect to intracranial neurophysiological activity. The major problem with the chest or shoulder area however is electrical interference from the heart (Hall, 1992).

The wave V may be 50% larger in amplitude in the noncephalic waveform than it is with the conventional array.The wave V is clearly separated from IV wave in the IV/V complex. This facilitates confident and accurate identification, and latency calculation for wave V in patients with CNS pathology (Hall, 1981). It was also found to be enhanced with the neck placement (Berlin and Dobie,1979) and with CVII placement(Beattie et al.1986; Hall et al 1984)

Wave II may also be more prominent in a vertex to noncephalic waveform than with the conventional array as reported by Starr and Squires (1982). But one major drawback in the use of multichannel recording including vertex to noncephalic placement, is greater latency variability for Wave I as pointed out by McPherson, Hirasugi and Starr(1985).

Wave I is reported to be enhanced with mastoid placement (Berlin and Dobie, 1979; Starr and Squires, 1982), with placement on the medial surface of the earlobe (Stockard et al. 1978). Stockard, Stockard and Coen (1983) reported this enhancement in recordings through horizontal montage i.e inverting electrode on the contralateral mastoid and noninverting on the ipsilateral, but Ruth et al. (1982) did not find any such enhancement.

In clinical practice, ABR is generally recorded between one electrode on the vertex (or forehead) and a second electrode on the ipsilateral mastoid (or earlobe). The location of the vertex electrode in this type of recording is apparently not an important factor (Hashimoto et al. 1981; Starr and Squires, 1982) at least in normal subjects. The site of the second electrode, however may be extremely important (Hall, 1984). Multichannel measurements may offer diagnostically useful information (Starr and Squires, 1982; Mizrahi et al. 1983; Terkildsen and Osterhammel, 1980).

To examine and evaluate the effects of this electrode placement, many studies using multichannel recording were done.

Muller and Stange (1971) obtained evoked responses from the contra and ipsilateral temporal lobe and the vertex. The reference electrode being on the glabella. The response was highest when recorded from the vertex. Lindsley (1969) examined the evoked auditory response of five subjects as recorded from the temporal region, vertex and inion, but was unable to classify or to correlate the obtained data. He also noted that the vertex again recorded larger amplitudes.

Although maximum wave V amplitude is recorded from a vertex site, studies of ABR topography indicate that the precise location of the noninverting electrode at least along the midline is not a major factor in the response (Hashimoto, Ishiyama(1982).

Ruhm (1971) subjected twelve persons to clicks presented every 4 sec. and recorded evoked responses from 3 recording sites : T3, T4 and Cz. He found that when left ear was stimulated, T4 recording site revealed larger responses than T3 but when right ear was stimulated, the two temporal sites did not show significant difference indicating hemisphere laterality effect.

Beattie, Beguwala, Mills and Boyd (1986) evaluated the effect of electrode placement on amplitude and latencies of the BAEPs. Ten electrode combinations were evaluated vertex being noninverting electrode for half of the subjects and Forehead (Fz) being for the other half. The inverting electrode location were ipsilateral mastoid, ipsilateral neck, seventh cervical vertebra. The common were contralateral mastoid, lower forehead, contralateral side of the neck.

The results showed that different montages did not have any effect on the latencies of the peaks, but amplitudes however, were however affected. For the non-inverting electrode location, vertex yielded a larger response than the forehead. Wave V was enhanced with the montages.

i) CVII as inverting with FPz common
ii) Ni as inverting with FPz common
iii) Ni as inverting with NCz common

Wave V was reduced with the montages,

i) Ni as inverting and Nc as common.
ii) Mi as inverting and FPz as common.

Wave I and III were not effected by the electrode placement.

Waveforms recorded with horizontal and with conventional arrays were also compared for infants less than eight months of age versus adults. Wave I was found to be equally effected for each array and each age group. Wave V was clear in the conventional i.e. ipsilateral montage for adults and in horizontal montage of infants. Whereas, there was no or little wave V in horizontal montage for adults. The fact that in infants, wave V was relatively greater in amplitude in horizontal montage than in conventional montage.lt 'was also noted that wave V in the infant horizontal recording had a significantly shorter latency(Hecox and Burkard, 1982).

It is also reported that infants yielding a well formed ABR with the ipsilateral array do not typically show a recognizable contralateral ABR waveform (Edwards, Durieux-Smith and Picton, 1985; Hecox, 1982; McPherson, Hirasugi and Starr, 1985). McPherson, et al. (1985) though, could observe a wave V in contralateral array but with a significantly longer latency than in ipsilateral array. In their study they compared the recordings through four montages; ipsilateral, contralateral, horizontal and noncephalic. Wave component latency of all arrays was greater for neonates than for adults. Furthermore, latency difference in waves among the electrode arrays were greater for neonates than for adults. They also found that the waveform morphology and component latency values were equivalent for a nasion to noncephalic versus vertex to noncephalic recording. But with nasion as noninverting site the IV component and the following negative troughs were not consistently identified. that defy traditional labeling in multielectrode waveforms from adult or neonates. These authors, for example, refer to component 'X', which was seen between the usual peaks I and II, and a 'Y' component which appeared to obliterate the traditional Wave II in the infants. Because the 'Y' peak wasminimal in adults, the traditional wave II usually remained prominent. The 'X' component similarly influenced adjacent traditional waves.

Differences in the contribution of each electrode array to the ABR are vividly demonstrated from a mastoid to noncephalic electrode pair versus a vertex to noncephalic electrode pair (Barratt, 1980; Hughes, Fino and Bagnon, 1981; Starr and Squires, 1982;

Stretetz, Katz, Mohenberger and Craco, 1977; Terkildsen and Osterhammel, 1981; Terkildsen, Osterhammel and hois in't Veld 1974). The mastoid to non-cephalic array consists only of early latency ABR components (I, II, III, IV) while all components are observed with the vertex to noncephalic array.

There are distinct differences in ABR wave latencies and amplitudes between vertex to mastoid or earlobe versus vertex to noncephalic electrode arrays. The three most pronounced ABR differences observed in the noncephalic versus the conventional electrode array are wave V amplitude enhancement, separation of wave IV and V and a more distinct wave component (Hall, et al. 1984; Kavanagh and Clark, 1989; Martin and Coats 1973; Martin and Moore 1977; McPherson, Hirasugi and Starr, 1985; Picton et al. 1974; Starr and Squires, 1982; Streletz, Katz, Hokenberger and Cracco, 1977; Van Olphen et al. 1978). But only Hashimoto's study made recording from all the electrode montages simultaneously.

Wave ambiguity is one of the major hurdles in the clinical use of ABR in neurodiagnosis. Use of specific montage to enhance or easily identify a specific wave is studied. Optimization of montages is also paid attention to, the goal being solicitation of maximum information as to theelectrical integrity of the auditory system from which to form the bases of an accurate diagnostic impression.

The electrode placements used by Hall (1984) i.e. vertex (Cz) referenced to ear mastoid is the best for thisoptimization purpose (Jackobson, 1985).

But multichannel measurements sometimes increase the sensitivity and accuracy of ABR in describing auditory CNS function (Hall, 1984). Also each peak representing the functioning of a specific part of the brainstem may be better recorded using different inverting electrode location. The different locations used are, contralateral or ipsilateralearlobe/mastoid, ipsilateral neck, and the spinal process ofthe seventh cervical vertebra. Different peaks were reported to be enhanced with each of these placements.

METHODOLOGY

To accomplish the aims of the study following methodology was planned.

Subjects:

Two groups were taken -

Group I - 30 adults aged between 16 to 30 years (mean age 22.3 years)

Group II - 30 children aged below 15 years (mean 10.55 years)

Selection Criteria :

i) Pure tone thresholds of less than 25 dB HL in the frequency range of 250 Hz to 8000 Hz (as recommended by ANSI 1969/ ISO 1978).

ii) Normal middle ear function: 'A' type tympanogram and normal reflexes on screening.

iii) No h/o otological symptoms (earache, discharge),

iv) No h/o audiological symptoms tinnitus, giddiness or hearing loss

Equipment:

Following equipment were used in the study:

a) Pure Tone Audiometer

A calibrated double channel clinical audiometer (OB-822) was used to assess the behavioural thresholds of all the subjects. Calibration was done prior to the study as per manufacturer's recommendation.

b) Immittance Audiometer

An immittance audiometer GS1-33 version 2 was used to assess the middle ear function of the subjects. Calibration was done as per manufacturer's recommendation.

c) ABR Recording Instrument

The system used for recording ABR was a computer based system. The software used was Nicolet Spirit Version 1.5.

Test Environment:

The tests were carried out in a room with ambient noise level within permissible level as recommended by ANSI, 1977.

The test room was air-conditioned to maintain a comfortable temperature and the subjects were provided with a cushion bed to lay on.

The lighting in the room was adequate.

Test Procedure :

The subjects were first screened for their pure tone thresholds in both ears using a two channel clinical audiometer.

The frequencies tested were 250 Hz to 8000 Hz at octave intervals.

Subjects with thresholds below 25 dB HL at the tested frequencies were screened for tympanogram and reflexes in both ears using an immittance audiometer (GSI-33).

Electrode Placement:

The electrode sites were cleaned using OMNI Prep Gel and a TEN-20 paste was used for conduction.

The common/ground electrode for all the montages was placed on the higher forehead (fz) others were placed on the vertex (Cz) both mastoid processes (Al and A2) and nape of the neck (CVII) which was taken as Oz.

a) Stimulus Parameters

Type : Broad Band Clicks

Broad band click was used to obtain a better waveform as click produces better synchronization.

Rate : 11.1/sec

11.1 /sec. to obtain a waveform with good morphology. Decimal value was taken to avoid the effect of 60 Hz electrical signal.

Polarity : Rarefaction

Rarefaction was used as it enhances the amplitude of wave I and condensation yields higher false positive cases. The alternate option may have phase cancellation and may yield higher cases of false negatives (Schwartz and Morris, 1990).

No.of stimuli : 1600

1600 to optimize the time spent versus morphology of the wave form.

Intensity : 80 dBnHL

80 dBnHL to acertain a intensity high enough to maximize neural discharge.

Transducer : Earphones

Earphones TDH-39 with supra-aural cups to deliver the sound through air-conduction.

b) Acquisition Parameters

No.of channels : Four

To record ABR from all the montages.

Montages : Cz - Al; Cz - A2; Al - A2; Cz - Oz

Cz.-Al; Contralateral Cz-A2; Ipsilateral
Al - Al; Horigantal Cz - Oz Noncephalic

High Frequency Cut off: 3000 Hz

As there is no appreciable ABR spectral energy above 3000 Hz..

Low Frequency Cut off: l00Hz

100 Hz as majority of the spectral energy of the early waves I-III is above 100 Hz. And to avoid contamination by 60 Hz electrical and myogenic activities.

Analysis time : 10msec.

Electrode impedance was less than 5 K.

Selection of the ear to be stimulated was done randomly.

Recordings with rejection rate less than 20% were taken.

The waveforms recorded were analysed as latency for all the waves and amplitude for the three major peaks, I, in, V wave. The IV-V interpeak latency was also noted down as a measure of how well the montages resolved the IV-V complex.

Mean and S.D (standard deviation) for each of these readings were calculated. To compare the noted parameters, unpaired t-tests were carried on between each of the montages.

RESULTS

With the planned methodology, latency and amplitude data were obtained for all montages. To compare the latencies and amplitudes obtained for each wave in different montages, an unpaired two tailed t-test for significance was carried out separately between each montage pair i.e.Cz-Al vs.Cz-A2; Cz-A1; A1-A2; Cz-Al vs Cz-Oz;Cz-A2 vs Al-A2;Cz-A2 vs Cz-Oz and A1-A2 vsCz-Oz.

In order to optimise a montage battery in terms of latency, amplitude and separation of peaks, separation between IV-V was also compared.

These comaprisons were carried out for 2 groups separately. t-values weighted against the degrees of freedom for different peaks in different montage are as tabulated.

	Peaks I	II	III	IV	V	Sep
CzAl-CzA2 (Contra-Ipsi)	.203 (56)	.028 (55)	.029 (58)	.684 (48)	.778 (58)	.942 (48)
Cz Al-Al A2 (Contra-Hor)	.919 (50)	.000 (54)	.188 (56)	.011 (37)	.088 (56)	.161 (37)
Cz Al-Cz Oz (Contra-Vert)	.117 (56)	.767 (53)	.438 (58)	.031 (35)	.258 (57)	.474 (51)
Cz A2-A1 A2 (Ipsi-Hor)	.371 (52)	.047 (53)	.940 (56)	.031 (35)	.155 (56)	.252 (35)
Cz A2-Cz Oz (Ipsi-vert)	.828 (58)	.052 (52)	.122 (58)	.539 (48)	.415 (57)	.616 (49)
A1 A2-Cz Oz (Hor-vert)	.294 (52)	.000 (51)	.364 (56)	.014 (37)	.458 (55)	.074 (38)

Table-1: Shows the level of significance and corresponding degrees of freedom of latencies for comparisons across the montages for adults (Group I).

Note: Highlited values indicate significant difference at .05 level.

	Peaks I	II	III	IV	V	Sep.
Cz Al-Cz A2 (Contra-Ipsi)	.850 (58)	.040 (58)	.235 (58)	.363 (58)	.007 (58)	.308 (53)
Cz Al-Al A2 (Contra-Hor)	.909 (58)	.000 (58)	.150 (58)	.727 (44)	.113 (58)	.331 (42)
Cz Al-Cz Oz (Contra-Vert)	.333 (58)	.434 (58)	.122 (58)	.214 (58)	.738 (58)	.988 (54)
Cz A2-A1 A2 (Ipsi-Hor)	.991 (58)	.009 (58)	.501 (58)	.810 (44)	.639 (58)	.127 (45)
Cz A2-Cz Oz (Ipsi-vert)	.212 (58)	.108 (58)	.803 (58)	.895 (58)	.254 (55)	.383 (57)
Al A2-Cz Oz (Hor-vert)	.429 (58)	.000 (58)	.594 (58)	.719 (44)	.713 (58)	.367 (46)

Table-2 Shows the level of significance and corresponding degrees of freedom of latencies for comparisons across the montages for children (Group II).

Note: Highlited values indicate significant difference at .05 level.

	Peaks I	Peaks III	Peaks V
Cz Al-Cz A2 (Contra-Ipsi)	.927 (56)	.495 (58)	.248 (58)
Cz Al-Al A2 (Contra-Hor)	.301 (53)	.580 (56)	.000 (55)
Cz Al-Cz Oz (Contra-Vert)	.433 (56)	.052 (57)	.001 (57)
Cz A2-A1 A2 (Ipsi-Hor)	.059 (53)	.228 (56)	.000 (55)
Cz A2-Cz Oz (Ipsi-vert)	.132 (56)	.215 (57)	.010 (57)
Al A2-Cz Oz (Hor-vert)	.572 (53)	.013 (55)	.000 (54)

Table-3: Shows the level of significance and corresponding degrees of freedom of amplitudes for comparisons across the montages for adults (Group I).

	Peaks I	III	V
CzAl-CzA2 (Contra-Ipsi)	.573 (58)	.572 (58)	.752 (58)
Cz Al-Al A2 (Contra-Hor)	.564 (58)	.003 (58)	.000 (58)
CzAl-Cz Oz (Contra-Vert)	043 (58)	.355 (58)	.008 (58)
Cz A2-A1 A2 (Ipsi-Hor)	622 (58)	.037 (58)	.000 (58)
CzA2-Cz Oz (Ipsi-vert)	.121 (58)	.771 (58)	.010 (58)
Al A2-Cz Oz (Hor-vert)	.055 (58)	.063 (58)	.000 (58)

Table-4: Shows the level of significance and corresponding degrees of freedom of amplitudes for comparisons across the montages for adults (Group II).

Note: Highlited values indicate significant difference at .05 level.

From table 1-4, it is evident that the -

Latency of wave 1 does not vary significantly among the montages in both the groups. But its amplitude varied significantly when compared between Cz Al & Al A2.

Latency of wave II in both the groups differed significantly in all the comparisons except between Cz Al vs.Al A2 and Cz A2 vs.Cz Oz.

Latency of III peak did not vary significantly in any of the comparisons except in Cz Al and Cz A2 in group I. Amplitude of HI peak as recorded in Al A2 montage significantly except Cz Oz where as in group II it differed from only Cz Oz. All other comparisons did not reveal any significant difference.

Latency for wave IV though did not vary among the montages, for group II did so in group I when Al A2 recordings for wave IV latency was compared with all the other montages individually.

For wave V though the latency did not differ significantly across montages except between.Cz Al and Cz A2 in children varied significantly in amplitude for all the comparison except between Cz Al and Cz A2 in both the groups.

Mean for the latencies and amplitudes for each of the peaks in different montages were calculated. As a measure of deviation, standard deviation was considered. Results are as shown.

			ADULTS		CHILDREN	
			Mean	SD	Mean	SD
I peak	*Cz-A1*	Latency	1.796	0.13	1.733	0.18
		Amplitude	.436	0.42	0.291	0.16
	Cz-A2	Latency	1.75	0.14	1.741	0.15
		Amplitude	0.444	0.20	0.315	0.16
	A1-A2	Latency	1.802	0.27	1.740	0.30
		Amplitude	0.343	0.18	0.293	0.18
	Cz-Oz	Latency	1.743	0.12	1.704	0.16
		Amplitude	0.370	0.17	0.393	0.22
II peak	*Cz-Al*	Latency	2.705	0.21	2.672	0.17
		Amplitude	-	-	-	-
	Cz-A2	Latency	2.611	0.17	2.588	0.13
		Amplitude	-	-	-	-
	A1-A2	Latency	2.501	0.22	2.445	0.26
		Amplitude	-	-	-	-
	Cz-Oz	Latency	2.694	0.13	2.641	0.12
		Amplitude	-	-	-	-

			ADULTS		CHILDREN	
			Mean	SD	Mean	SD
III peak	*Cz-A1*	Latency	3.537	0.19	3.541	0.15
		Amplitude	0.442	0.25	0.532	0.21
	Cz-A2	Latency	3.636	0.16	3.591	0.18
		Amplitude	0.489	0.29	0.570	0.30
	A1-A2	Latency	3.642	0.39	3.638	0.33
		Amplitude	0.409	0.20	0.735	0.29
	Cz-Oz	Latency	3.571	0.16	3.602	0.15
		Amplitude	0.586	0.31	0.592	0.29
IV peak	*Cz-A1*	Latency	4.678	0.26	4.775	0.16
		Amplitude	-	-	-	-
	Cz-A2	Latency	4.716	0.38	4.731	0.20
		Amplitude	-	-	-	-
	A1-A2	Latency	4.455	0.21	4.75	0.32
		Amplitude	-	- -		
	Cz-Oz	Latency	4.66	0.24	4.725	0.14
		Amplitude	-	-	-	

		ADULTS		CHILDREN	
		Mean	SD	Mean	SD
V peak	*Cz-A1* Latency	5.424	0.21	5.47	0.18
	Cz-A1 Amplitude	0.941	0.40	0.968	0.45
	Cz-A2 Latency	5.408	0.22	5.331	0.21
	Cz-A2 Amplitude	1.058	0.38	1.002	0.38
	A1-A2 Latency	5.32	0.25	5.363	0.32
	A1-A2 Amplitude	.459	0.21	0.612	0.25
	Cz-Oz Latency	5.364	0.19	5.387	0.17
	Cz-Oz Amplitude	1.341	0.43	1.279	0.43

Table-5: Shows the mean and SD of amplitudes and latencies of each peak in different montages.

Cz A1 gives longest wave II and V in both the groups and longest wave IV in adult, wave HI was found to be shortest in both the groups. Lowest amplitude for wave I and III was found in children in this montage.

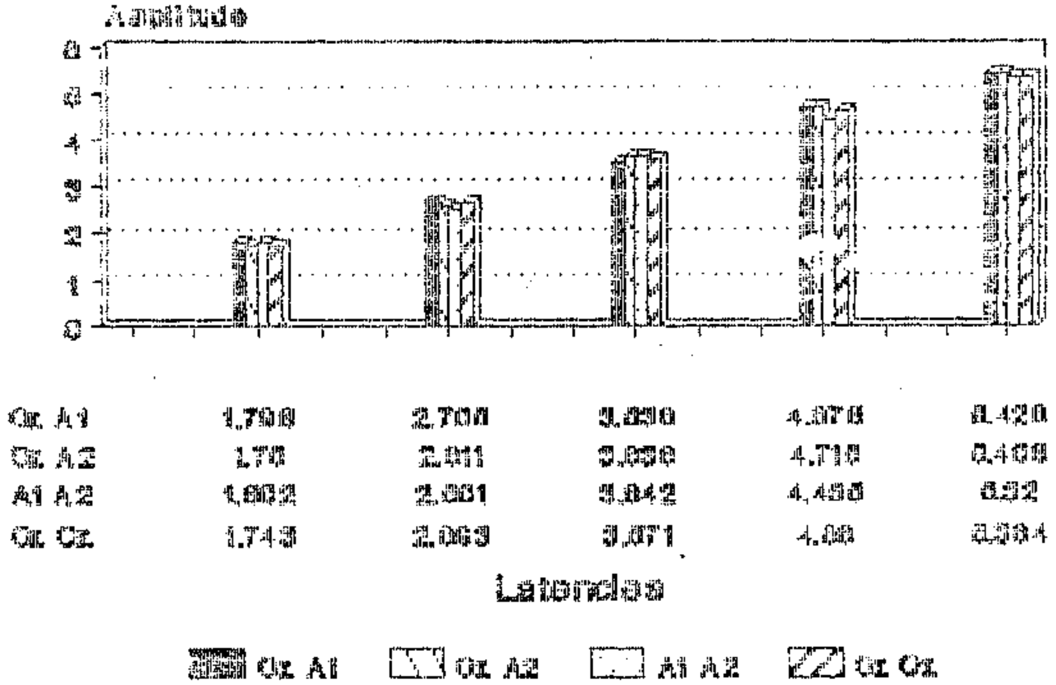
Cz A2 gives longest latency for wave IV in adult and for wave I in children. It also produces V peak with shortest latency in children. Highest amplitude for wave I was found in adults.

Al A2 gives longest latencies for wave I and DDE, where as shortest I and V peak in children. A1 A2 records lowest amplitude for I, in and V in adults and in children highest for HI and lowest V peak.

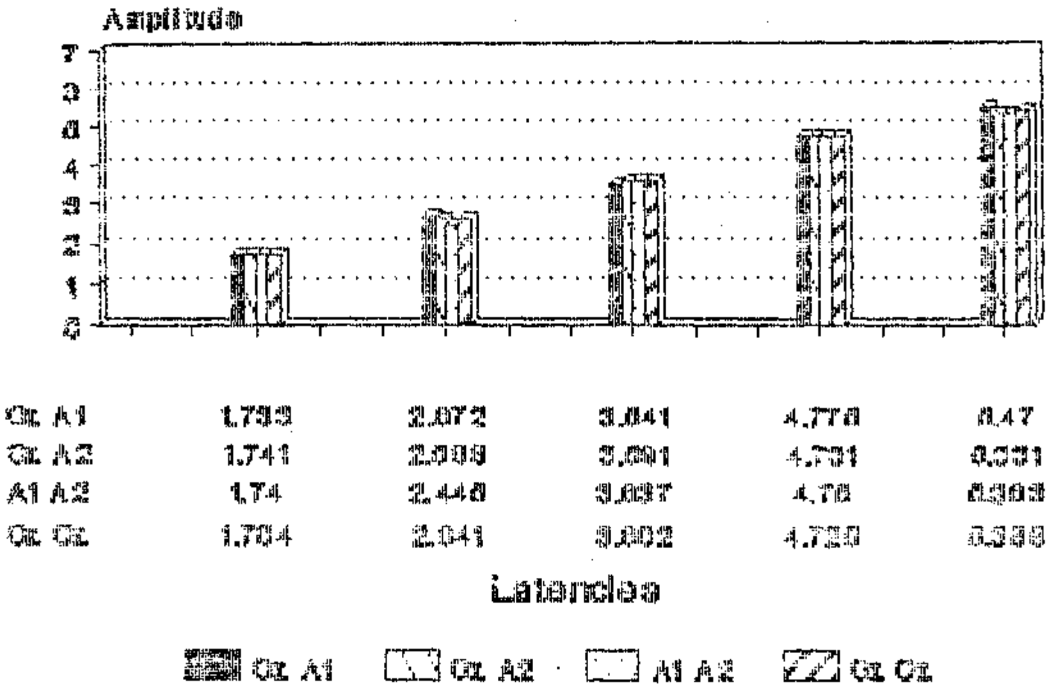
Cz Oz records shortest wave I in both the groups and wave V in children. In amplitude it records highest III and V peaks in adults whereas I and V in children.

To compare the latencies in different montages, bar graphs were plotted as in Graph I.

For the comparison of amplitude also the same was carried out and they are as seen in Graph EL To compare the latencies and amplitude recorded in a particular montage between the groups, bar graps in the same frame was plotted as in graph 3 and 4 shows that latencies of the earlier peaks i.e. I, II, and III are shorter in children and in all the montages except the HI peak in contralateral and vertical montages. The IV and the V peak longer in latency in children except for V peak in ipsilateral montage. The amplitude of the I peak was smaller in all the montages except in the vertical montage. Wave III was smaller in ipsilateral and contralateral montage and larger in the horizontal and vertical montages. Wave V is smaller in amplitude in the contralateral and horizontal montages whereas it is larger in ipsilateral and vertical montages.

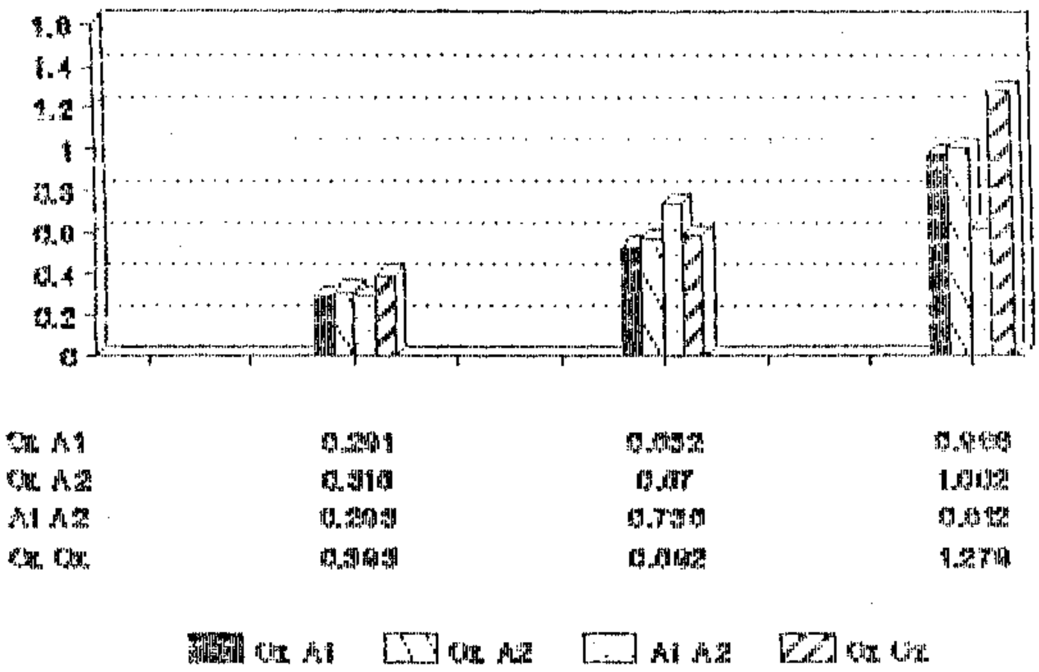


IN ADULTS

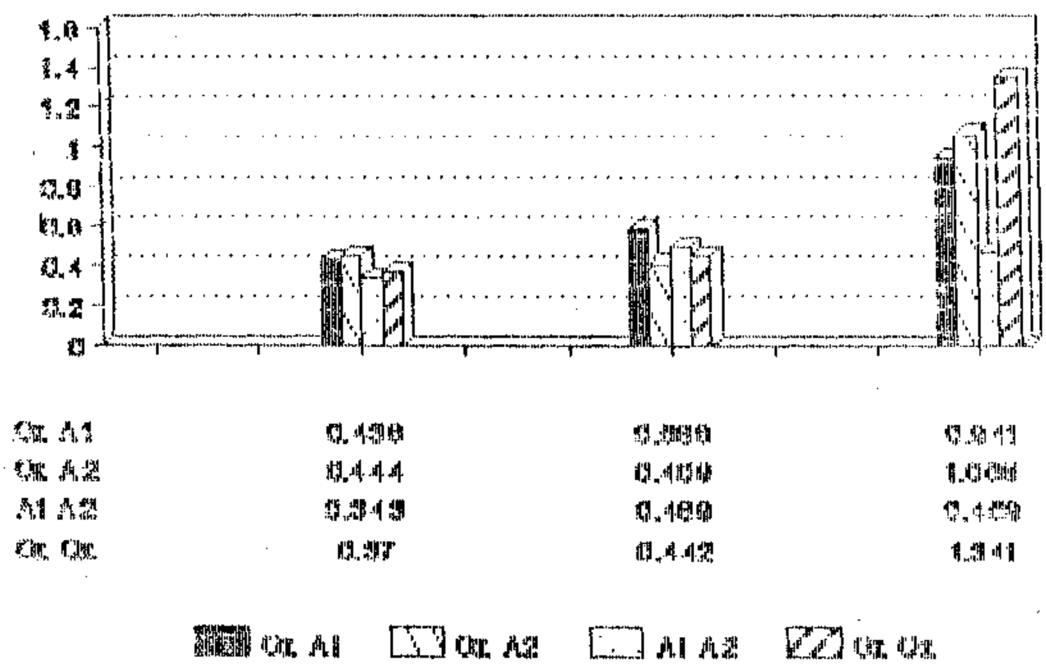


IN CHILDREN

Graph 1: Latency comparison in different montages.

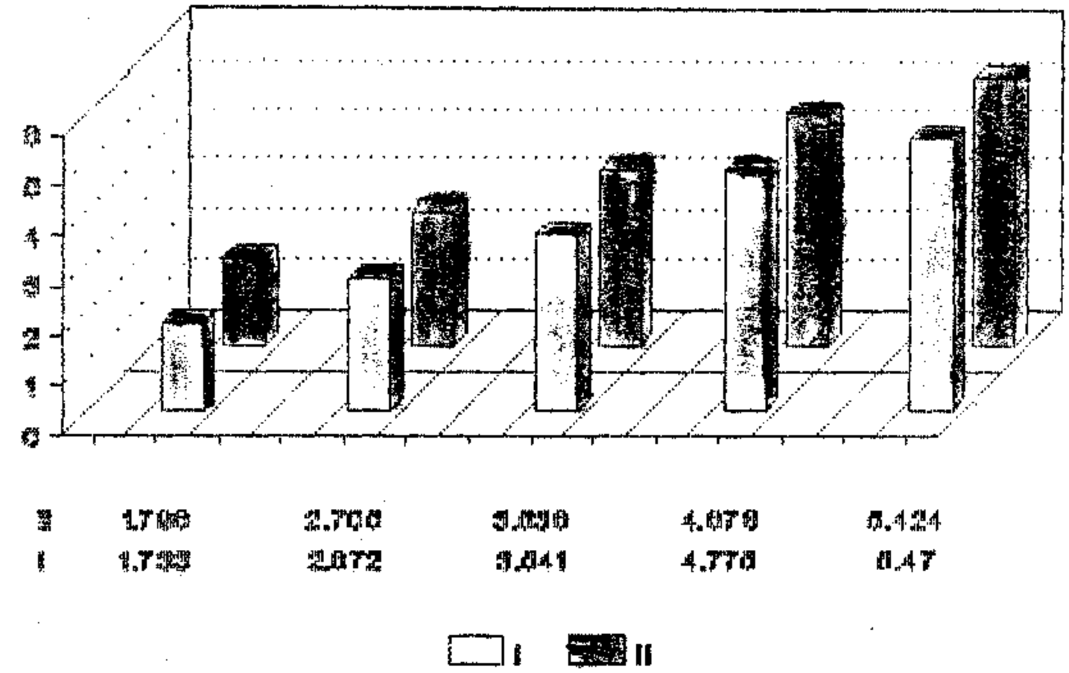


IN ADULTS

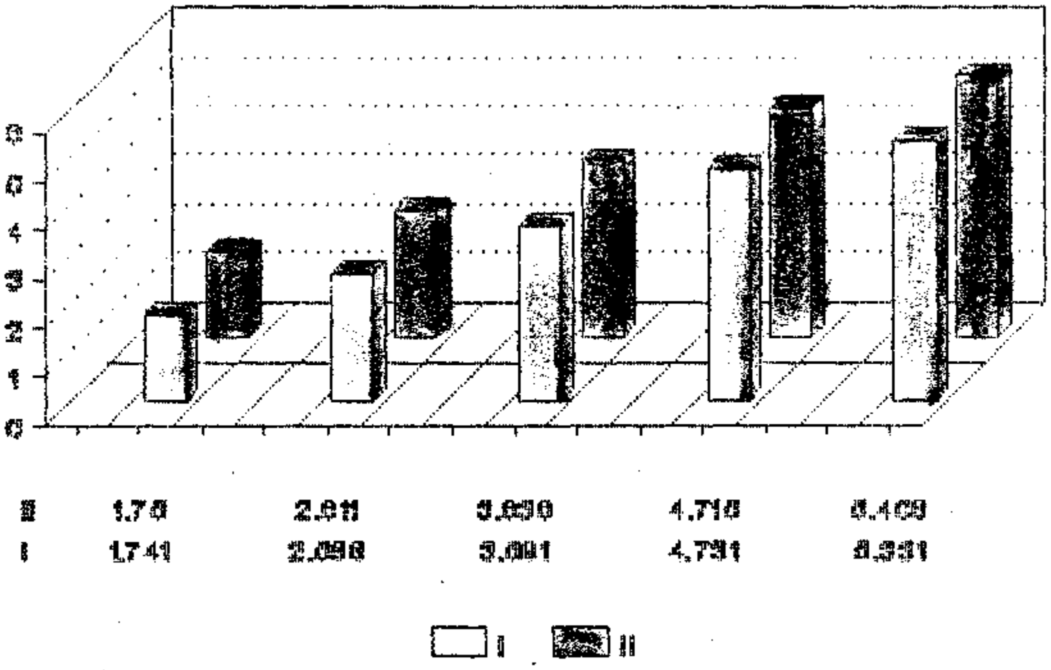


IN CHILDREN

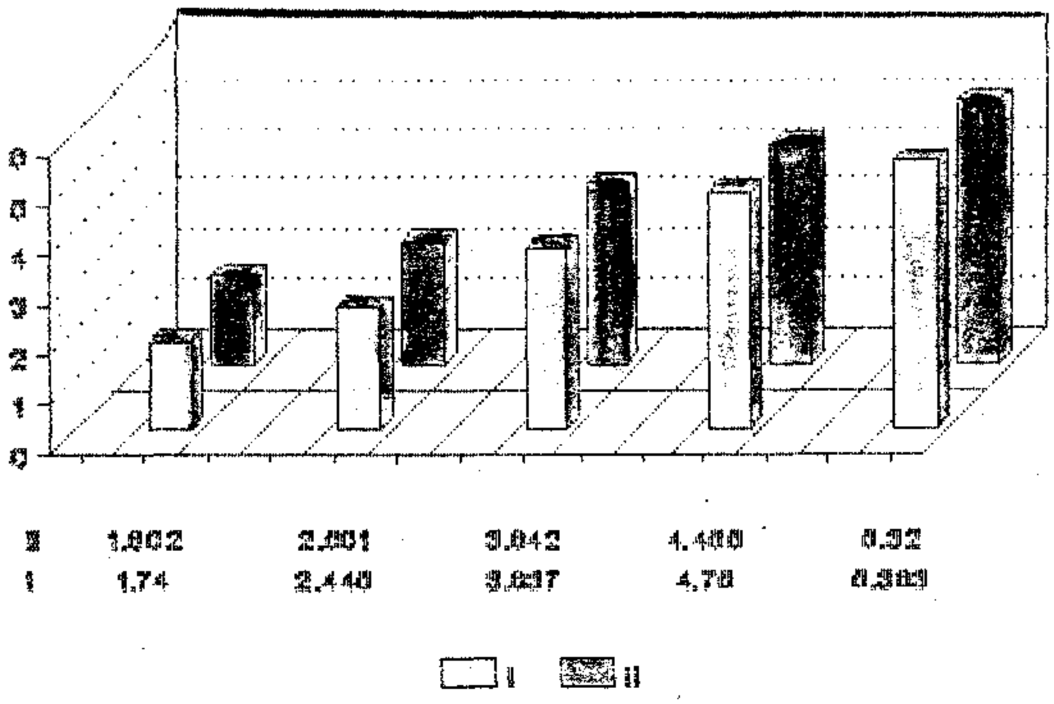
Graph 2 : Amplitude comparison in different montages.



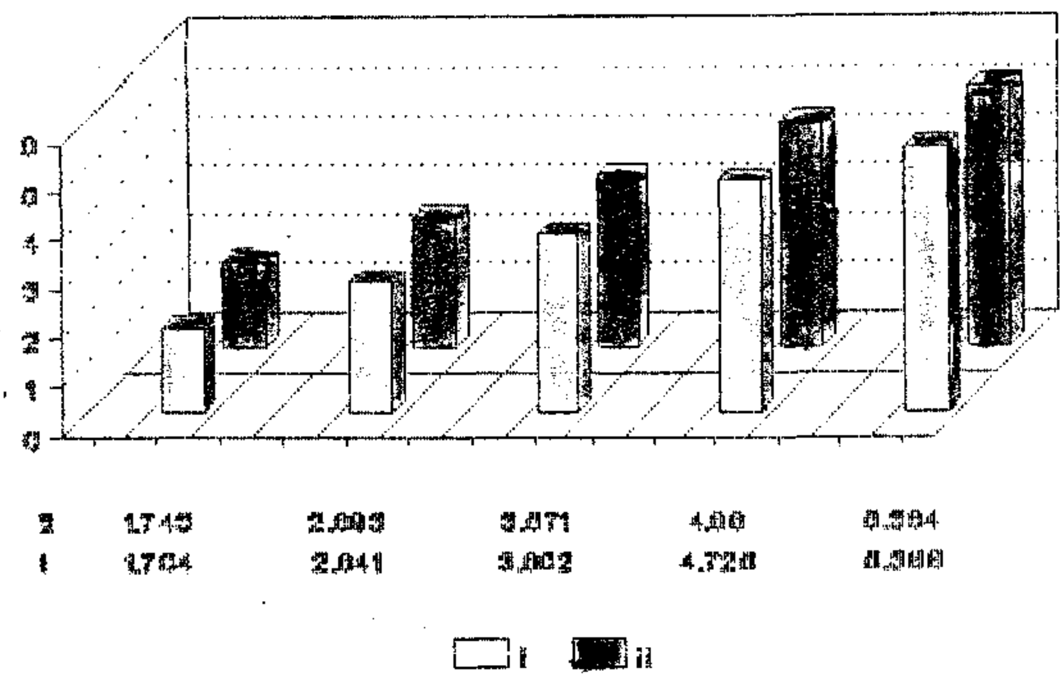
Comparison in Cz A1



Comparison in Cz A2

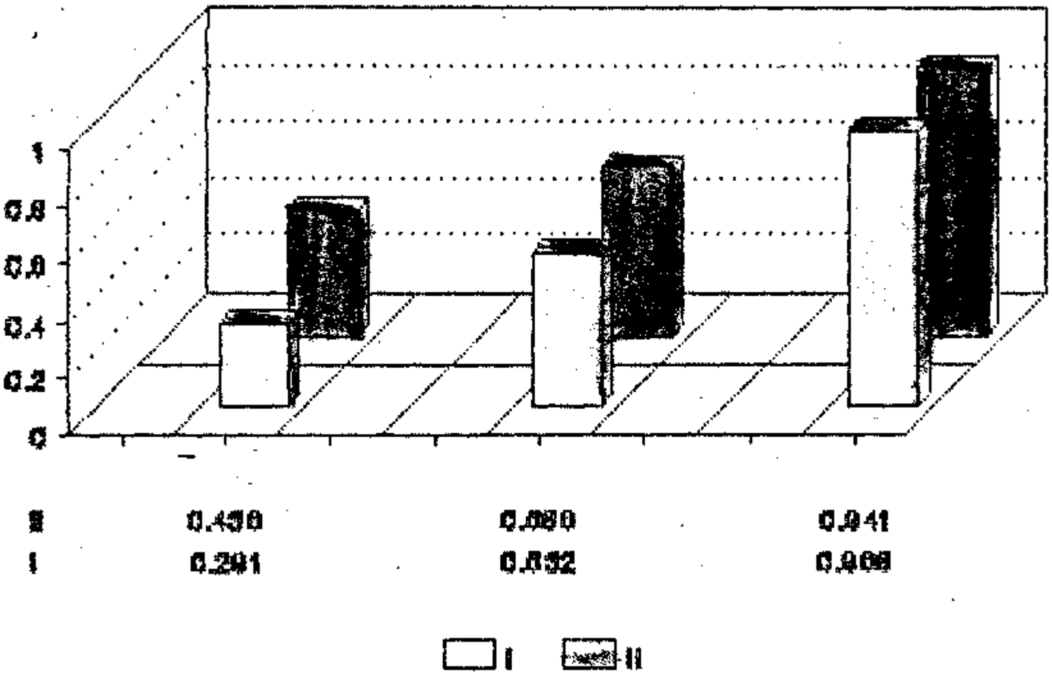


Comparison in A1 A2

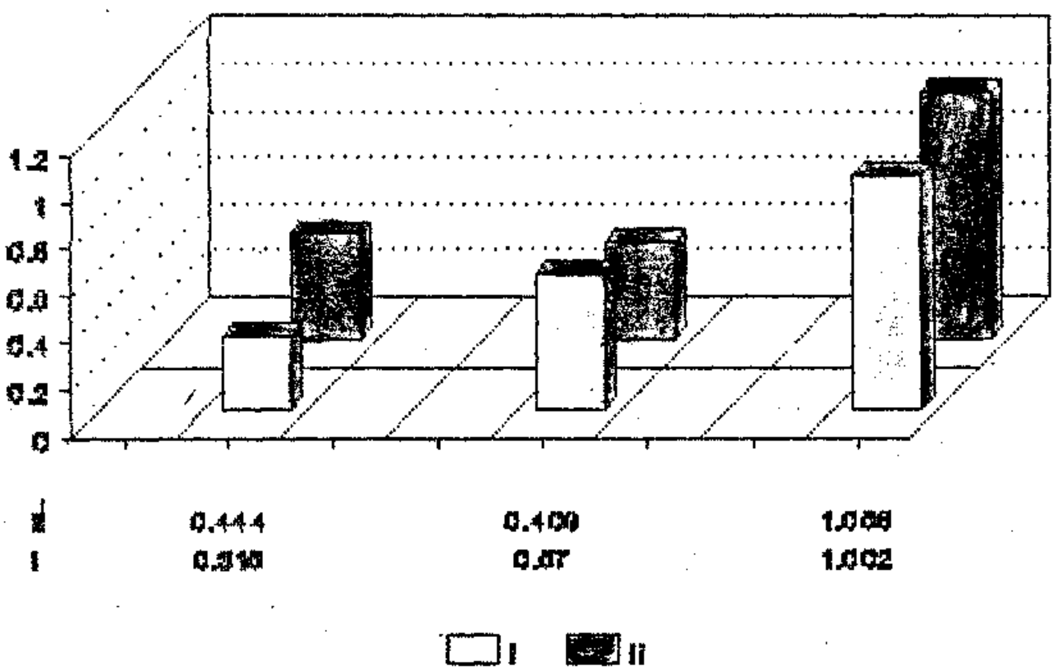


Comparison in Cz Oz

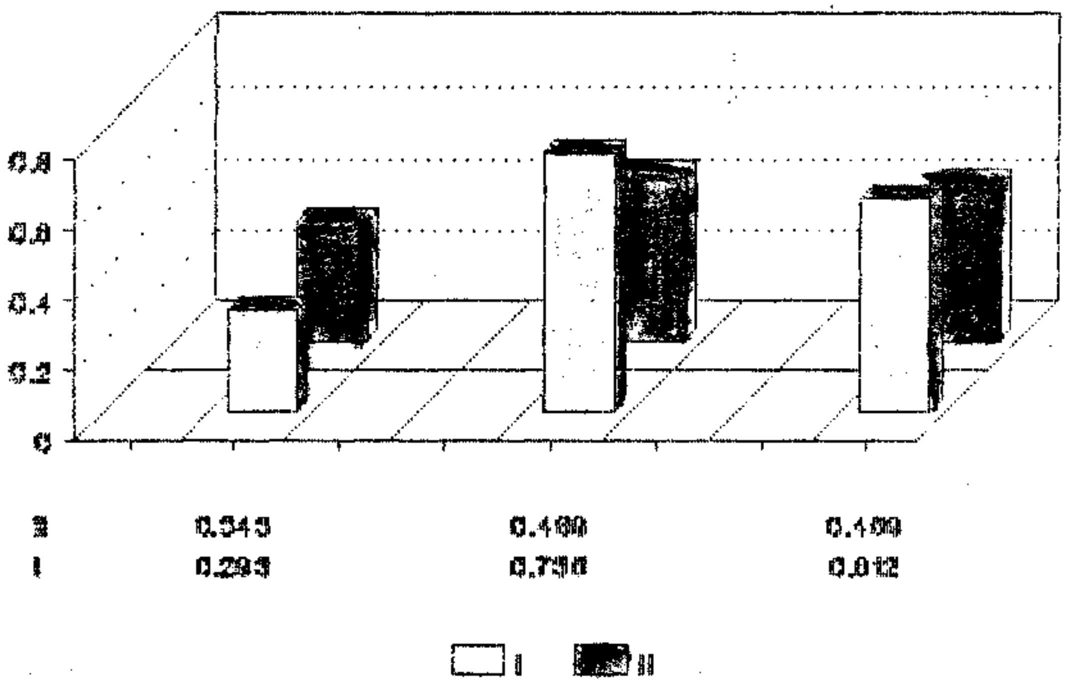
Graph 3 : Comparison of two groups in terms of latencies



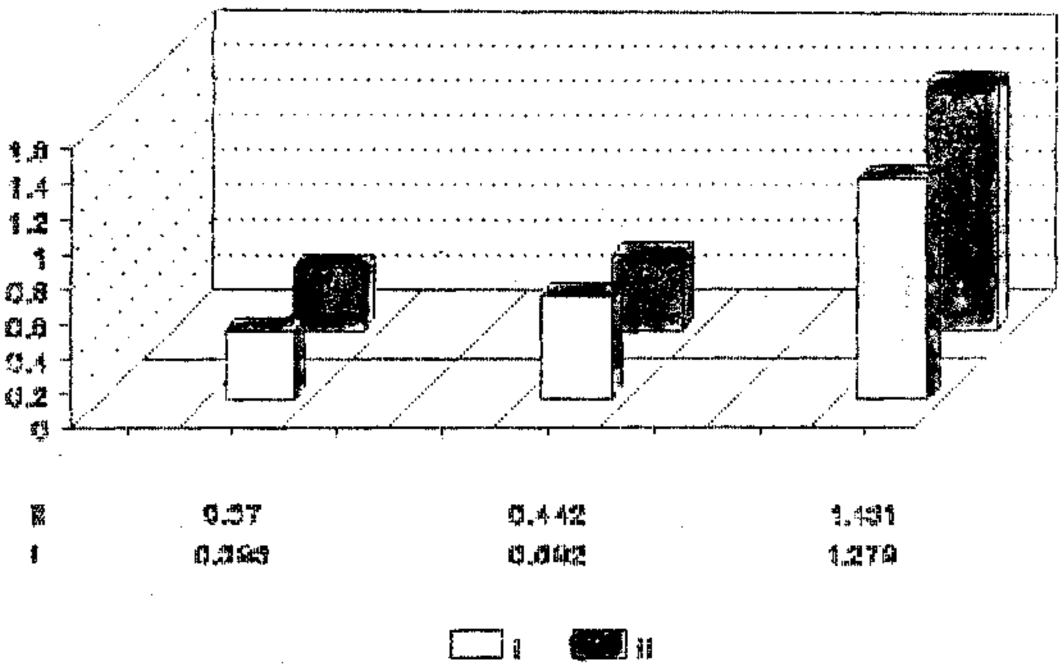
Comparison in Cż A1



Comparison in Cz A2



Comparison in A1 A2



Comparison in Cz Oz

Graph 4 :Comparison of two groups in terms of amplitude

DISCUSSION

From the above results of latencies and amplitudes of the different ABR peaks it is clear that the different electrode montages has a definite effect, on latencies and amplitudes of the different peaks. Separation of peaks (IV and V peak) was also influenced by the electrode placement. The bar graphs in the same frame depicted the comparison between the younger age grpup and the adults. Those comparisons show that the effects of electrode montage on ABR waveforms of the two groups are considerably different.

All these effects of electrode montage on ABR waveforms can be discussed in terms of *field analysis* refers to the description of the potentials generated because of the stimulated nerve action. The neurons when activated produce a small amount of action potentials. When this action potentials of different neurons are in synchrony, they add up in amplitude.

The separation of charges across the neurolemma during the excited phase is accumulation of opposite charges separated by a distance which is physically known as *DIPOLE*. These dipoles in the context of neurons are called as *NEURAL DIPOLES*. The neurons in the central auditory pathway are arranged or oriented in a particular fashion along the pathway orientation of these neurons gives an orientation to the dipole too (Hall, 1992).

These orientation are explained by the *SPATIO TEMPORAL MODEL* for dipole localization by Grandori (1986). He compared the findings of '*Dipole location method* (DLM)' and 3 *channel Lissajous' Trajectories* (3 CLT)' to conclude that the field obtained at the latency of wave I is present as a broad region of positive potentials spreading out contralaterally with respect to the stimulated

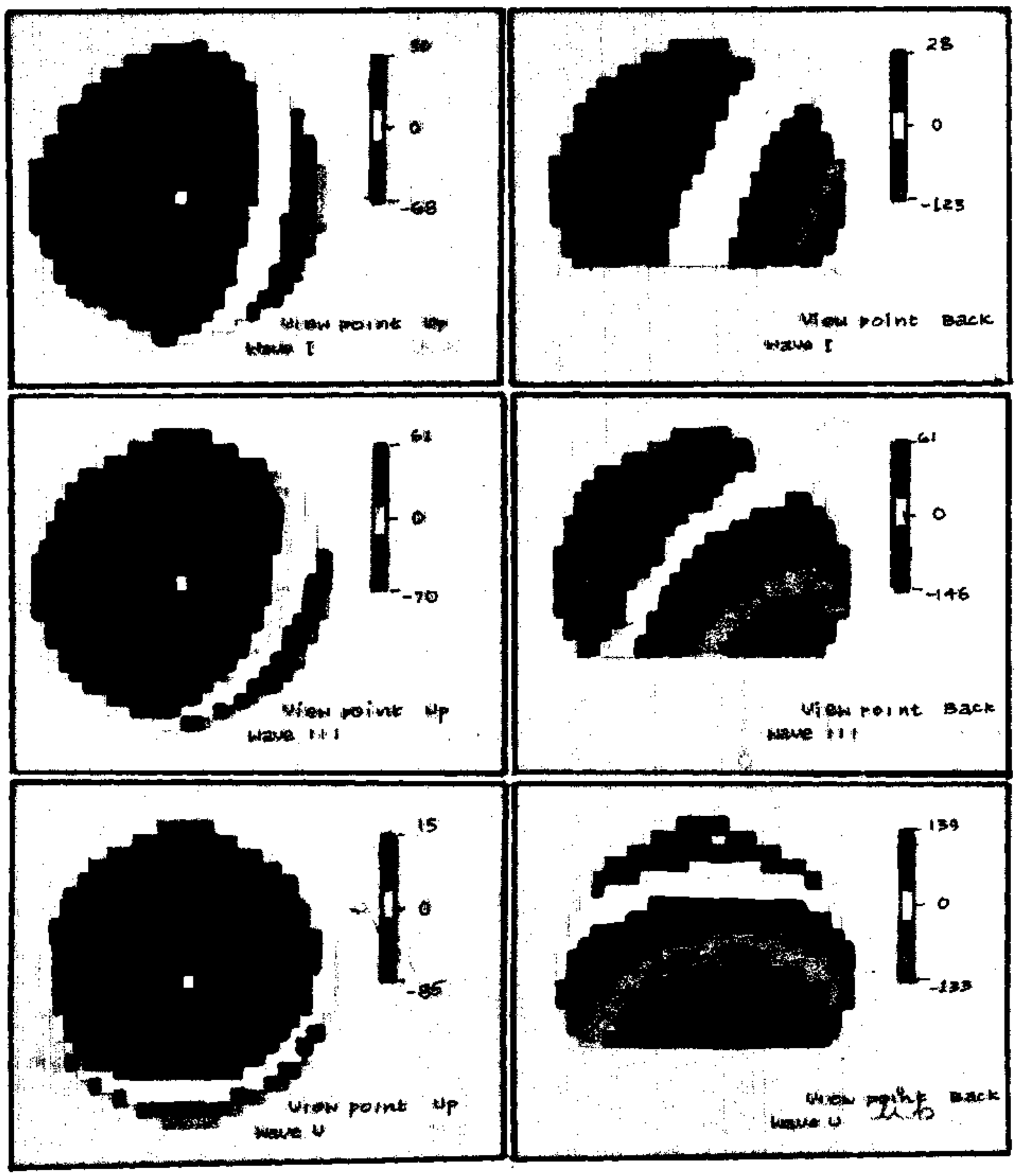


FIG. 1 SHOWING FIELD DISTRIBUTION OF DIFFERENT PEAKS DIPOLE

ear. The negative potentials are found maximally around and below the ipsilateral ear as seen in the fig. 1. showing the top and the posterior views.

For wave III as shown in the figure, negative potentials covers a large portion of the posterior hemisphere; minima are quite broad and are found on the stimulated side symmetrically. The positive maxima are found on the upper hemisphere approximately above the contra lateral ear.

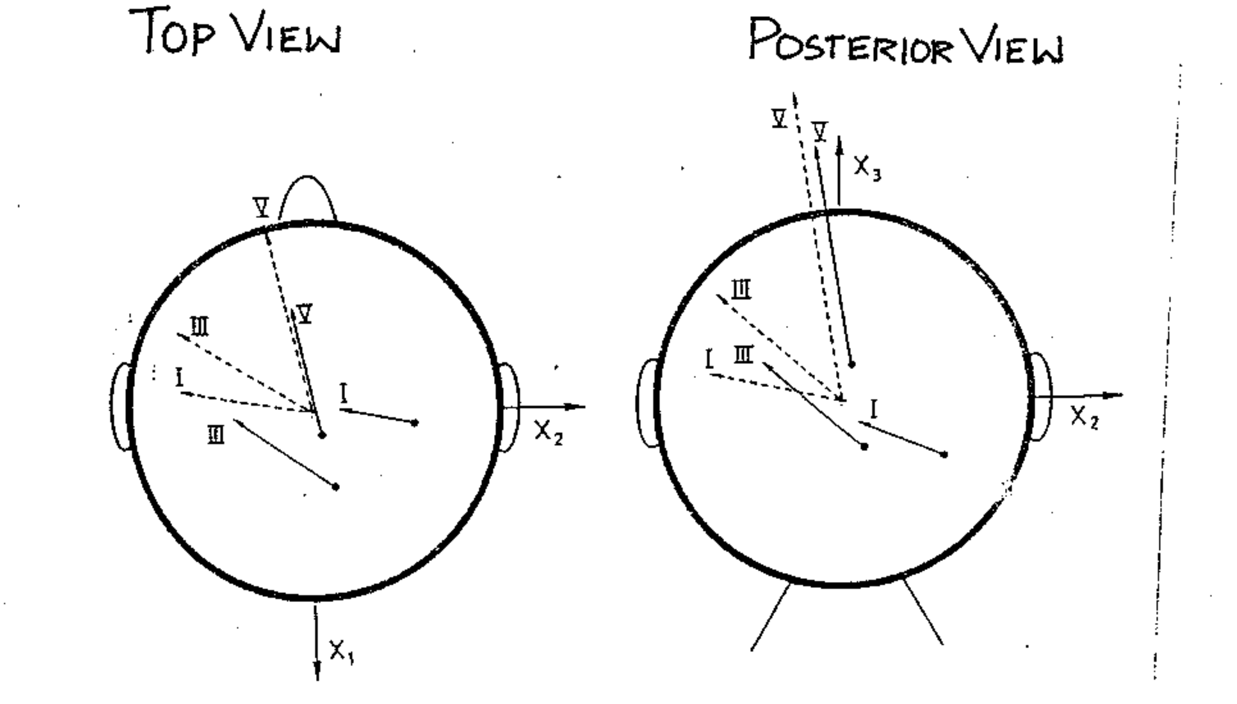
At the latency of wave V the field distribution is regular with a positive maximum located around the vertex. The top view in the figure shows only positive potential values, negative potentials are found over the lower hemipshere as seen in the view from back.

Figure 2 shows the close coincidence between results ofDLM and 3 CLT. The dipoles found by 3 CLT are shown by interrupted lines and DLM are in solid lines.

Thus, it is concluded that,

1. Wave I and HI has an ipsilateral location for the main source of activity.
2. Source of waves V is located near to the centre of the sphere with negligible component on to the horizontal plane

In ABR, what is measured is the electric potential existing between the two active electrodes (inverting and non-inverting). If the recording montage is in perfect alignment i.e. in 8 angle to the dipole axis, then the magnitude of the field measured is maximum. This is because the field measured is a cosine function of the magnitude of the dipole, the theta in function being the angle between the axis of the dipole for the recording montage.

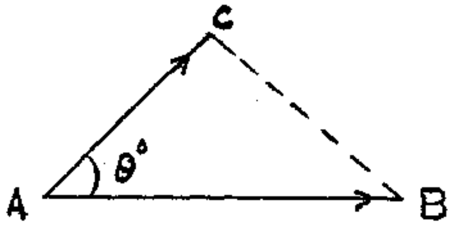


FIURE.2. SHOWING COINCIDENCE OF FINDINGS USING DLM AND 3 CLT

AC - field across the recording montage

AB - Field due to the dipole theta - angle between them.

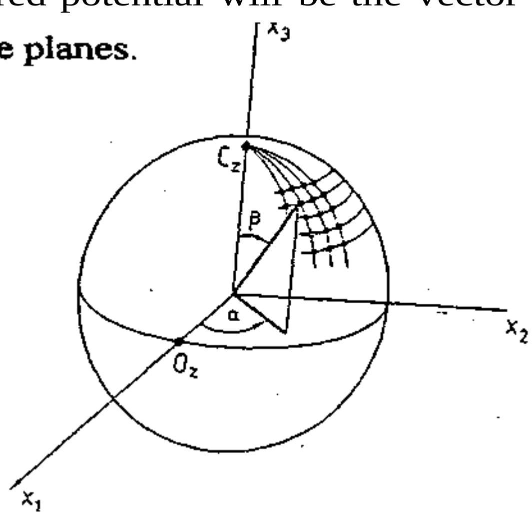
Therefore $\cos \theta = \frac{AC}{AB}$



Therefore AC = AB Cos θ

As the value of Cos θ is maximum when $\theta = 0$, recorded potential (AC) is maximum when the angle between the montage axis and the dipole axis is 0 degree. This angle to be measured as alpha (OC) and beta (B) as shown in the figure i.e. angle from both the planes. The measured potential will be the vector sum of the components from all the planes.

FIG. SHOWING MEASUREMENT OF ANGLES FROM DIFFERENT PLANES.



The dipole orientation as described can be correlated with the amplitude of the major ABR peaks obtained through 4 different montages having different axes.

Amplitudes of the major ABR peaks varied significantly across the montages as can be seen in Table 2 and 4 as well in the graph 2. It is seen that the wave 1 which has orientation somewhat parallel to the Cz A2 (ipsilateral) montage is recorded with the highest amplitude in this montage in adults and considerably higher in children. In contrast lowest amplitude is obtained in the contralateral montage which is nearly 90 degrees on both the planes to the I peak dipole.

The findings in this study regarding the amplitude of I peak is in agreement to the findings of Ruth et al (1982) that wave I is enhanced in vertical montages. Though it contradicts the studies reporting enhanced wave I in horizontal montage (Hecox 1982; Stockard 1983; McPherson et al 1985; Stuart et al 1996). Similarly, waves III having an relatively horizontal orientation is recorded as highest peak in the horizontal in children. It is statistically found to be significant when compared to all other montages as in table 3. Again in tune to the dipole orientation contralateral montage being nearly perpendicular to the dipole in both the plane produced the least amplitude in children. Similar finding was reported by Stuart et al in 1996, McPherson et al in 1985. However contrasting observation was made for the adults. This can be attributed to the subject factors, their subjects (neonates) being more similar to group II subjects i.e. children.

This study also supports the study of Beattie et al. (1986) stating that I and in wave amplitude in young adult subjects remained unaffected. In the present study also wave I remained unaffected by montages in both the groups whereas wave III showed lesser variability in adults than in children. However, in adults it was found to have the lowest amplitude.when mean was considered, but the comparisons with other montages failed to produce any significant difference except when compared to the Cz Oz (vertical) montage.

Wave TV having a vertical orientation is recorded maximally in the vertical montage in both children and adults. In contrast the horizontal montage which is nearly perpendicular to the V peak dipole, recorded the least amplitude in both the groups. The same was reported by Hall, 1981; Hall, 1984;, Mepherson, et al. 1985; Picton et al. 1974; Starr and Squires, 1982; Katz, et al. 1977; Van Olphen, 1978).

The Waves II and IV was observed to have relatively higher amplitude in the contralateral and vertical montages respectively. This study in tune with the previous reports (Stuart et al. 1996; McPherson et al. 1985) found that the amplitude of wave V was least in horizontal montage (A1-A2). The amplitude in contralateral montage was found to be lower than the ipsilateral as reported by Hughes, Fino and Gagnon (1981).

The latency differences in various montages is as shown in table 1 and 2 and in the graph 1 and 2.

Beattie et al. (1986) reported that there is no significant latency difference across different montages for the three major peaks, I, III and V. Similar observation was made in the present study except between ipsilateral and contralateral montages for children and contralateral and horizontal montages in adults. McPherson et al. also reported longer latency for contralateral when compared to ipsilateral as in observed in the present study.

In agreement with Hecox and Burkard (1982) this study found that horizontal montage recordings for wave V to be the shortest in latency in adults. In children shortest latency for V peak was recorded by ipsilateral montage followed by horizontal montage. The longest latency being in the contralateral montage in both the groups. This is consistent with Beattie et al. (1986) study. The contralateral montage recorded a longer latency as compared to the ipsilateral.

The stability of I, III and V peaks in terms of latency suggests that the fields for these peaks are distributed simultaneously all over the scalp. It has been proposed by Robinson and Rudge (1981) that, when there is a shift in the latency of a component of ABR, one of the three possibilities exists ;

(i) There is more than one active generator within a given pathway,
(ii) There is more than one pathway being activated in the generation of the waveform.
(iii) Both the above cases occur.

Resolution of the IV-V complex as shown in Table 1 and 2 did not vary significantly in both groups. But in Table 5 the mean comparison reveal horizontal montage as a better resolver of peaks than vertical montage which is in contrast to Hall et al. (1987). But another observation from Table 5 that the frequency of V peak was more in vertical montage than in horizontal helps solving the confusion. In addition it can also be noted from table 3 and 4 that the amplitude of V peak was much low in the horizontal. Thus this study also concludes vertical is better resolver of the than horizontal montage.

As per the results in the Graphs 5 and 6, it is obvious the relative amplitudes and latency in adults and children vary according to the type of montage used. The observed variance may be attributed to a partial phase shift in a dipole generating the wave component due to the structural changes accompanying maturation resulting in a reorientation of the dipole as suggested by Robinson and Rudge (1981).

However, the general observation in the study is ABR waveforms in different montages showed specific patterns which were observed while analysis of waveforms were done. The IV peak in adults was highly variable in terms of latency and amplitude. A fact to be noted was that, identification of IV peak in children was much easier than in adults, the percent detectability being 100, in all the montages except in the horizontal montages. The Cl A2 (ipsilateral) montage usually produce three big (I, III and V) waves in both groups which were easily identifiable.

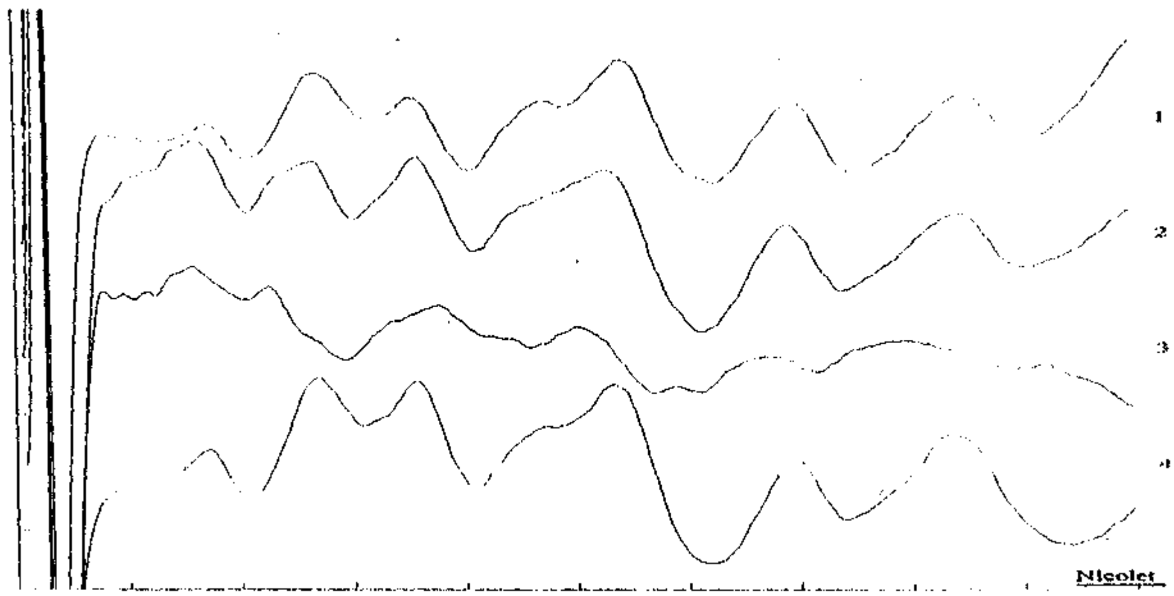
The contralateral montage produced a low amplitude for I peak and poor morphology for all the waves as compared to other montages in accordance to Stockard and Stockard (1983).

The horizontal montage showed variability between the children and the adult group. It produced the poor wave morphology and lowest V peak amplitude in adults. Low III peak amplitudes were also observed. But in children, the peaks recorded in horizontal montage were in agreement with previous findings (Hughes et al. 1982; McPherson et al. 1985; Picton, et al. 1974; Starr and Squirr, 1982). It also produced consistent high amplitude in III peak. The waveform morphology was also good in children. The V peak latencies were prolonged in both groups.

The Cz Oz (vertical) montage displayed consistent recordings for all the peaks, thus enhancing detectability of any peak at a given time. It was also consistent in producing a high V peak amplitude across subjects.

In spite of its low mean values (649 in Group I and 0.643 in Group II) the vertical montage was most efficient in producing easily detectable IV and V peak in comparison to the other montages.

These results could be accounted for by the relatively higher amplitude of IV peak in this montage as compared to others. Detectability of IV peak was evident from the high frequency of recorded IV peak latencies from this montage. The presence of II peak was least frequent as compared to other montages.

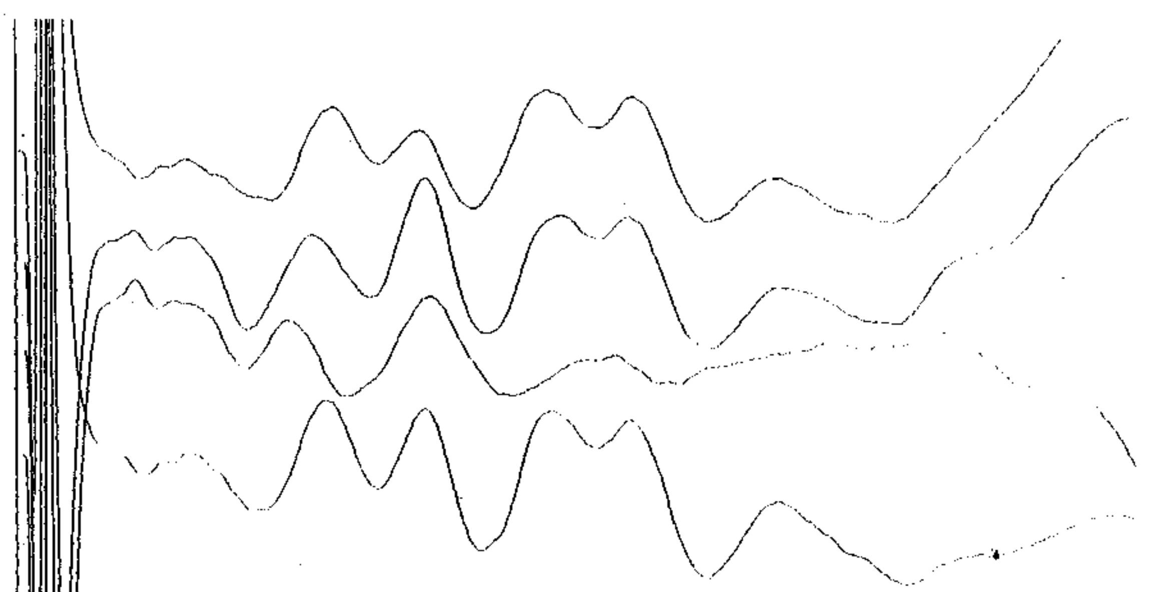


Sensitivity and Sweep Time Per Division

1 0.62 uV 1.0 msec 2 0.62 uV 1.0 msec 3 0.62 uV 1.0 msec 4 0.62 uV 1.0 msec

Wave	Elect	Date	Time	Remarks	Wave	Elect	Date	Time	Remarks
1	Cz–A1	17/07/97	05:09		2	Cz–A2	17/07/97	05:09	
3	A1–A2	17/07/97	05:09		4	Cz–Oz	17/07/97	05:09	

REPRESENTATIVE WAVEFORMS FOR ADULTS.



Sensitivity and Sweep Time Per Division

1 0.62 uV 1.0 msec 2 0.62 uV 1.0 msec 3 0.62 uV 1.0 msec 4 0.62 uV 1.0 msec

Wave	Elect	Date	Time	Remarks	Wave	Elect	Date	Time	Remarks
1	Cz–A1	17/07/97	14:19		2	Cz–A2	17/07/97	14:19	
3	A1–A2	17/07/97	14:19		4	Cz–Oz	17/07/97	14:19	

REPRESENTATIVE WAVEFORMS FOR CHILDREN.

SUMMARY AND CONCLUSION

ABR is a series of neuroelectric potentials evoked by an auditory stimuli and recorded within 10 ms. An ABR recording can be effected by numerous stimulus parameters like stimulus rate, intensity, type and number, and acquisition parameters like recording montage, analysis time etc.

A review of literature reveals many studies concluding recording montage as one of the important factors affecting ABR (Stuart, 1996, McPherson, 1985; Beattie, et al. 1986; Hecox, et al. 1982; Stockard et al. 1984).

The present study was taken with the following goals :

i) Finding the affect of different montages on ABR waveforms
ii) Finding an optimum montage combination which when used will give a confident identification of all the ABR peaks.
Hi) Examining the difference in the effects of montages on ABR waveforms in children and adults.

Sixty subjects in two subject, adults and children were taken for the study. ABR was recorded for each of these subjects in four different montages, viz. the ipsilateral (Cz A2), contralateral (Cz A1), horizontal (Al A2) and vertical (Cz Oz). The stimulus used was 1600 broad band click at 11.1 rate with 80 dB nHL intensity.

The wave recorded were analysed for latency of all the waves, amplitude of I,III, V waves and interpeak latency of IV and V wave.

Mean and SD for all the parameters were calculated. The significance of difference between the latencies and amplitude of each peak recorded through different montages was tested using an unpaired two tailed t-test. The findings of the study can be summarised below.

Amplitude for wave I and V was found to be high in the ipsilateral and in vertical montages for both adults and children. Wave in exhibited high amplitude in children but not in adults. In contrast, low amplitude for I and V peak was recorded in contralateral and horizontal montage. This implies that the montages which are more aligned to the orientation of the dipole axis recorded more amplitude for that particular wave.

Latencies of the major ABR peaks did not vary significantly across montages. But variation was present for the II and the IV peak. It can thus be concluded that the scalp distributions of the fields for the major peaks are diffused simultaneously in all directions whereas the same is not true for the weaker peaks.

The latencies of waves I, II and III were shorter in children in all montages except contralateral and vertical The IV and V peak had longer latency in children except for V peak in ipsilateral montage.

The amplitude for I peak was smaller in all the montages except in the vertical montage. In the ipsilateral and contralateral montages wave III was smaller. Smaller wave V amplitudes were seen in the contralateral and horizontal montages and larger in other two montages.

The different montage were ranked for the amplitude they produced for each of the 3 peaks and also by how much IV-V IPL they produced. Based on this, combination of the vertical, horizontal and ipsilateral montages was suggested to be the optimum, since it produced the highest amplitudes and good morphology for all the peaks and provided a distinguishable separation between IV and V peak. Hence use of this montage combination while recording ABR for the site of lesion testing will facilitate identification and marking of different ABR peaks.

Implications of the study

1. The montage combination propose can be used while doing multi-channel ABR recording for confident and accurate neurodiagnosis.
2. This study can be used to establish a normativedata for each of the montages.
3. Specific montages can be used for different uses of ABR. Keeping the findings of this study in consideration.
4. Studies on maturation effects on these different montage recorded ABR can be studied using a semilongitudinal design.
5. Many more montages with different orientation can be explored.
6. Effects of these montages on all peaks' amplitudes and IPL can be studied.
7. Generalization of these findings of these study to be tested on abnormal population.

Limitations

1. The number of subjects in each group was limited to 30 only.

2. Age of the subjects in group II i.e. children was high.

3. No of montages studies was limited to only four.

4. Amplitude data for only 3 peaks were collected.

5. Findings are limited only to normal hearing population.

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APPENDIX

Calibration of nHL For ABR Testing

In conventional pure tone behavioural audiometry behavioural threholds are expressed in dB HL units whereas ABR thresholds are expressed in dB nHL units. Normal hearing level (nHL) refers to normal threshold for click or brief tone stimuli. Zero dB nHL will varies depending on test environment and stimuli used.

Procedure

A group often normal hearing subjects (5 males, 5 females) were taken. The behavioural threshold for clicks was estimated. The behavioural threshold estimation was done using the same instrument and in the same test environment as the actual ABR testing. Threshold was defined as the lowest level at which 50% of the reponses were observed. Their average behavioural threshold was taken as OdB nHL for that stimulus. The nHL value obtained value for test room was 30 dB SPL.