A STUDY ON BINAURAL INTERACTION OF AUDITORY BRAINSTEM RESPONSE IN NORMALS

Reg.No.M9813

Independent Project as a part fulfilment of first year M.Sc, (Speech and Hearing), submitted to the University of Mysore, Mysore

ALL INDIA INSTITUTE OF SPEECH AND HEARING

MYSORE 570 006

MAY 1999

असतो मा सद्गमय ।

तमसो मा ज्योतिर्गमय ।

मृत्योर्मा अमृतं गमय ।

Dedicated

mummy, pappa
and
Pranam.

CERTIFICATE

This is to certify that this Independent Project entitled : A STUDY ON BEVAURAL INTERACTION OF AUDITORY BRAINSTEM RESPONSE IN NORMALS is the bonafide work in part fulfilment for the degree of Master of science (Speech and Hearing) of the student with Register **No.M9813.**

Mysore
May, 1999

Dr. (Miss) S. Nikam
Director
All India Institute of
Speech and Hearing
Mysore 570 006.

CERTIFICATE

This is to certify that this Independent Project entitled : **A STUDY ON BINAURAL INTERACTION OF AUDITORY BRAINSTEM RESPONSE IN NORMALS** has been prepared under my supervision and guidance.

Mysore
May, 1999

C.S. Vanaja
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DECLARATION

This Independent Project entitled : **A STUDY ON BINAURAL INTERACTION OF AUDITORY BRAINSTEM RESPONSE IN NORMALS** is the result of my own study under the guidance of Ms.Vanaja C.S., 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.

Mysore
May, 1999

Reg.No.M9813

ACKNOWLEDGEMENTS

/ express my deepest gratitude to Ms. Vanaja C.S. Lecturer in Audiology, All India Institute of Speech and Hearing, Mysore, for her constant help and guidance while carrying out the project. Ma 'm, your unflagging patience and dedication is amazing.

I extend my gratitude toDr.(Miss) S. Nikam, Director, All India Institute of Speech and Hearing, Mysore, for granting me permission to carry out this project.

Mummy and Pappa, The abundance of love and care showered upon by you amazes me. I can't thank you enough for having kept so much of trust and faith in me.

Pranam, you've been a brother in the true sense of the world. There is only one word I can think to describe you -'WOW!'1 wouldn't trade you for the world.

Kirti, Raji, Achu and Chamu, thanks for helping me realize what friendship is all about. You guys will always occupy a special place in my heart.

Hia, you have been a HUGE ^blessing in disguise'. "What would I have done during times that mattered, without you?" is an understatement, or rather an under question, (got it?!)

Sanyu, my co-fantasizer, ; वो लम्हे वो पल हम बरसों याद करेंगे ।

Mili and Sari, you 'II never realise how much I've relied on you guys. Thanx a ton for being around whenever I've needed you.

The Trendsetters, you 're unforgettable. How can I ever stop missing that adorable bunch of 31 that managed to create history in all possible ways in just 3 years?

Sajith, Manoj, K.P and Jockey - thanx for all those fun filled times. You guys are great at lifting up flagging spirits.

Sapna, Savitha and Uma , you guys are special to me in your own ways, please don't ever change.

Anju, Suja, Anusha, Milind and Chandan, the times spent with you will be cherished forever.

Radhika, Smitha, Sonia, Archana and Prachi, I've loved the moments spent with you guys.

Neha, Kavitha, Kiru, Kripa, Srivatsan, Amit, Siddarth, Mukesh, Mukundan, Rampo and Adithi, you guys are a breath of fresh air. Keep spreading cheer and happiness to those around you........as you always do.

Thanks tothe fivesome'- for making the special camp so special.

To the "JUST DO IT" class, Never knew we could have so many funfilled moments. Love you guys.

Thank you, Rajalakshmi Akka for the wonderful typing. I admire your never ending stamina and dedication to work.

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INTRODUCTION

Auditory evoked responses/waveforms are obtained by stimulating the auditory nervous system either through one ear i.e. monaurally or through both the ears i.e. binaurally. The effects of monaural versus binaural stimulation on auditory evoked responses (AER) particularly the auditory brain responses have been studied to some extent, yet differences in the neurophysiologic mediation of the two presentation modes, the potential clinical value of comparing monaural versus binaural AER recording and even the existence of a true binaural interaction remains unclear.

In binaural stimulation, clicks are presented simultaneously to both ears and the responses are recorded monaurally. Binaural stimulation, results jnjncreased amplitudes of the later^ waves at all intensities; since binaural stimulation increases the amplitude of wave V but not wave I, the IV-V vs IV-I amplitude is increased with binaural as compared with monaural stimulation.

If each ear and its neural connections functioned independently of the other ear and its neural connections, the summed monaural waveform would be equal to the waveform obtained by binaural stimulation. But it is seen that, when the predicted/calculated binaural waveform is subtracted from the binaurally evoked waveform, the difference waveform is polyphasic, consisting of two positive peaks (Pi and P2) each followed by a negative peak(Ni and N2) (Silman and Silverman, 1991). Thus, BINAURAL INTERACTION in the auditory brainstem response can be defined

.as the difference between_the binaurally evoked ABB- waveform and a calculated binaural waveform created by algebraically summing the left and right monaurally evoked ABRs (Wilson, et al. 1985).

There is wide spread agreement on the fact that the main differences between the AERs elicited for monaural versus binaural stimuli (in animals and in humans) do not occur in the peripheral auditory system (Cochlea or VIII nerve). Rather, differences are first detected at the lowest CNS level mediating binaural input, within the pons in the lower auditory brainstem, and also at more rostral CNS levels (Ainslie and Boston, 1980; Dobie and Berlin, 1979; Wrege and Starr, 1981). The resultant polyphasic waveform representing binaural interaction, may reflect, in a complex way, neural activity underlying binaural processes such as localization and lateralization of binaural stimuli (Silverman, 1991).

Since first described by Jewett (1970) in recordings from anaesthetized cats, binaural interaction in auditory brainstem response has received considerable attention in the literature. The phenomena has been recorded in a variety of species; guinea pigs, cats, dogs, human adults and infants (Wilson, et al. 1985).

One manifestation of binaural interaction in ABR.recording, an enhancement of response amplitude for binaural versus monaural stimulation, was recognized by early experimental (Jewett, 1970) and clinical (Blegvad, 1975; Starr and Achor, 1975) investigations. For example, the average normal human subject shows wave V that range from 3 0% to as much as 200% greater than those for monaural stimuli

(Ainslie and Boston, 1980; Hall, 1981; Wrege and Starr, 1981) i.e. the binaural wave V amplitude is upto twice the monaural amplitude, resulting in a typical binaural to monaural wave V amplitude ratio of around 1.5 - 2.00.

Consistent evidence of a difference in some parameter of the actual binaural waveform versus the derived binaural (summed monaural) waveform would prove the existence of a true binaural interaction in the ABR. The existence of binaural interaction in ABR is, however controversial. Subtraction of the derived binaural (summed monaural) waveform from the actual recorded binaural waveform should, if there is no difference between the two, result in an essentially flat line, that is zero voltage across time. Differences in the predicted or derived binaural data versus actual binaural data consist of smaller wave V amplitude and shorter wave V latency for the actual binaural waveform than for the predicted binaural waveform. Hence this subtraction process usually does not produce a flat line, instead, it produces another waveform with a latency approximately in the wave V region - the BD (binaural difference) waveform, which is thought to reflect binaural interaction. The BD waveform typically consists of two positive (Pi and P2) and two negative (Ni and N2) peaks in the 4-6 msec, region, within +/-1 msec, •of ABR wave V. The major peak (negative) usually occurs at a latency slightly greater than for ABR wave V. BD peak amplitude is extremely modest, usually no more than 10-20% of the wave amplitude (i.e. 0.25 to 0.05 microvolts). There is no binaural interaction for the first three waves (I, II and III) of the ABR, as evidenced by the essentially flat line in the early portion of the BD waveform (Hall, 1990).

Need for the Study

Binaural ABR or binaural difference waveform may be used as an ectrophysiological index of binaural processes such as localization lateralization and fusion (Hall, 1990).

It can also be used as an objective technique in assessing binaural interaction in children with CAPD (Willeford and Billger, 1978). However before using it on clinical population, it is essential to study the factors affecting binaural ABR. One of the factors related to stimuli affecting ABR is intensity. But there is not much research on the effect of intensity on binaural interaction of ABR. Therefore the present investigation was carried out to study the binaural interaction at different intensities.

Aim of the study

1) To detect the presence of binaural interaction at 60 dB nHL and 30dBnHL.

2) To study the effect of intensity on binaural interaction.

REVIEW OF LITERATURE

In binaural ABR the sound stimuli are presented simultaneously to both ears and the responses are recorded monaurally. The effects of monaural versus binaural stimulation on AERs, particularly the ABR, have been extensively investigated clinically. Still, differences in the neurophysiologic mediation of the two presentation modes, the potential clinical value of comparing monaural versus binaural AER recordings, and even the existence of a true binaural interaction, remains unclear.

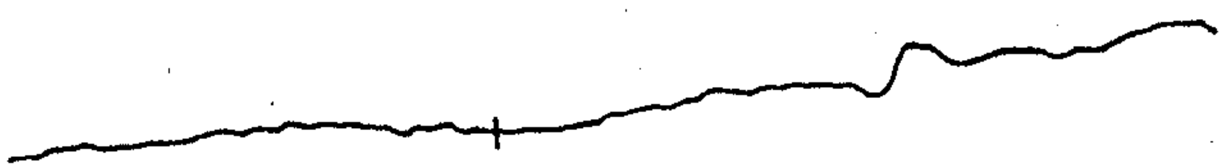
There is, however, widespread agreement on the fact that, the main differences between AERs elicited for monaural versus binaural stimuli (in animals and in humans) do not occur in the peripheral auditory system (cochlea or eighth nerve). Rather, differences are first detected at the lowest CNS level mediating binaural input, within the pons in the lower auditory brain stem, and also at more rostral CNS levels (Dobie and Berlin, 1979; Dobie and Norton, 1980).

In binaural stimulation, clicks are presented simultaneously to both ears and the responses recorded monaurally. Binaural stimulation results in increased amplitudes of the latter waves at all intensities. Since binaural stimulation increases the amplitude of wave V but not wave I, the IV-V: I amplitude ratio is increased with binaural as compared with monaural stimulation (Stockard, et al. 1978). The difference between the summed monaural responses from each ear (the predicted binaural waveform) and the binaural evoked responses should be obtained in order to observe the binaural interaction (Dobie and Berlin, 1979; Van Olphen et al. 1978). If each ear and its neural connections functioned independently of the other ear and its neural connections, the summed monaural waveform would be equal to the waveform obtained by binaural stimulation. When the predicted binaural waveform is subtracted from the binaurally evoked waveform, the difference waveform is polyphasic, consisting of two positive peaks (Pi and P2) and each followed by a negative peak (Ni and N2). This polyphasic waveform [fig A] representing binaural interaction may reflect, in a complex way, neural activity underlying binaural processes such as localization and lateralization of binaural stimuli.

OVERVIEW OF BINAURAL INTERACTION

Numerous terms are used to refer to normal differences in ABR waveforms of monaural versus binaural stimulation, including binaural interaction, summation augmentation, enhancement, or advantage. One manifestation of binaural interaction in ABR recording, an enhancement of response amplitude for binaural versus monaural stimulation, was recognized by early experimental (Jewett, 1970) and clinical (Blegvad, 1975; Starr and Achor, 1975) investigators. For example, the average normal human subject shows wave V amplitude values for binaural stimuli that range from 30% to as much as 200% greater than those for monaural stimuli (Hall (1981). In other words, the binaural wave V amplitude is upto twice the monaural amplitude, resulting in atypical binaural-to-monaural wave V amplitude ratio of around 1.5 -2.00. Clearly, there is substantial variability in this response parameter among normal subjects. Some

Fig A: Binaural Interaction Component Waveform



authors reported of no statistically significant difference between Wave V latency values for monaural versus binaural stimulation (Dobie and Norton, 1980), but others found either shorter wave V latency values for the binaural than for the monaural condition (Kelly-Ballweber and Dobie, 1984; Woods and Clayworth, 1985) or variable differences among subjects (Decker and Howe, 1981).

A majority of the investigators opine that, when the ABR waveform for right ear stimulation is added (usually digitally) to the waveform for left ear stimulation, the resultant summed waveform should minimally approximate in amplitude and latency the waveform actually recorded for binaural stimulation, (Hall, 1990). It is further suggested that replicated waveforms for right-ear and left-ear stimulation can be added digitally (A+B) to yield a derived ("calculated" or "predicted") binaural response waveform. This summed monaural waveform can then be compared in latency and amplitude with the actual waveform for binaural stimulation. If there is an effect unique to the binaural stimulus condition, then the binaurally stimulated ABR should differ from the summed monaural responses. This results in a binaural difference (BD) waveform (Hall, 1992).

Consistent evidence of a difference in some parameter of the actual binaural waveform versus the derived binaural (summed monaural) waveform would prove the existence of a true binaural interaction in the ABR. The existence of binaural interaction in ABR, is however, controversial. Subtraction of the derived binaural (summed monaural) waveform from the actual recorded binaural waveform should, if there is no difference between the two, result in an essentially flat line, that is, zero voltage across time. Differences in the predicted or derived binaural data (summed monaural waveforms) versus actual binaural data consist of smaller wave V amplitude and shorter wave V latency for the actual binaural waveform than for the predicted binaural waveform. Therefore, this subtraction process usually does not produce a flat line; instead, it produces another waveform with a latency approximately in the wave V region, the BD waveform, which is thought to reflect binaural interaction. The BD waveform typically consists of two positive (P1 and P2) and two negative (Ni and N2) peaks in the 4-6 msec, region, within +/-1 msec, of ABR wave V The major peak (negative) usually occurs at a latency slightly greater than for ABR wave V. Peak amplitude of the BD wave is extremely modest, usually no more than 10-20% of the wave amplitude (i.e. 0.25 to 0.05 7uV). There is no binaural interaction for the first three waves (I, II and HI) of the ABR as evidenced by the essentially flat line, in the early portion of the BD waveform (Hall, 1992).

The BD waveform has generated more interest than simple analysis of the monaural and binaural waveform (Dobie and Norton, 1980; Kelly-Ballweber and Dobie, 1984; Wilson, Kelly-Ballweber and Dobie, 1985; Wrege and Starr, 1981) because it is assumed to be of clinical evidence of binaural interaction, reflecting selective activation of brainstem neurons to binaural stimulation. However, there are clinical data implying that the apparent binaural interaction is miniscule at best. These other data suggest that the BD is often not detected even in normal subjects. When present, it may be a product of confounding factors in ABR recording, such as slight measurement variations in monaural versus binaural waveforms, cross-over of the acoustic stimulus at high intensity levels, inadvertent differences in effective intensity level for monaural versus binaural stimuli, or subtle right versus left brainstem asymmetry (eg. Ainslie and Boston, 1980; Decker and Howe, 1981). Furthermore Ainslie and Boston (1980) clearly concluded that there is no significant binaural interaction in the ABR when factors such as stimulus cross-over are controlled, yet this study is cited by others (eg.Kelly-Ballweber and Dobie, 1984; Wilson, Kelly-Ballweber and Dobie, 1985) as evidence in support of a binaural interaction in the ABR.

The factors influencing binaural interaction are many. Some of them that have been specifically investigated in studies are described as below :

1. Right Versus Left Ear Asymmetry

Some investigators comparing amplitude and latency values of ABR waves for right versus left monaural stimulation have found them equal (Ainslie and Boston, 1980; Woods and Clayworth, 1985). In contrast, Levine and McGaffigan (1983) found evidence of differences in ABR waveforms for stimuli presented to the right versus the left ear in a group of 32 neurologically and audiologically normal adult subjects. The most consistent right versus left ear ABR asymmetry, observed in all recording electrode arrays, consisted of significantly greater amplitude for wave HI. These differences were generally comparable for right versus left handed subjects. There was no stimulus ear difference for the VIII nerve ABR component wave L These authors speculate on the relevance of this ABR evidence of brainstem asymmetry to well recognized anatomic and functional cerebral asymmetry.

2. **Response Averaging and Acquisition**

The possible importance of differences in the number of stimuli averaged for monaural versus binaural conditions, or the sequence in which data for these conditions are gathered, is not known. In the majority of studies, an equal number of stimulus repetitions (usually either 1024 or 2048) are presented for each monaural and the binaural conditions. An exception was the study by Fowler and Leonards (1985) in which for each condition, (two monaural and binaural), three replicated waveforms were each averaged for 4000 stimuli, these were added before the usual binaural interaction paradigm was followed. Thus, the composite responses for each condition were based on 12,000 stimuli. Routine presentation of equal numbers of stimulus repetitions for each condition is logical because of the summed monaural response (predicted binaural waveform) and the actual binaural response. They are then produced with equivalent numbers of stimulus repetitions. First, Levine and McGaffigan (1985) repeatedly (about 25 times) interleaved (alternated) sequences of 256 presentations for each of the these stimulus conditions until the response for each condition was averaged for a total of 6400 stimuli, in most instances. The inter-leaving approach for stimulus presentation was used in order to equally distribute any changes in the subject state or EEG during the testing.

3. Filter Settings

The most commonly used band pass filter settings in studies of binaural interaction are 1, 10, 20 or 30 Hz to at least 3000 Hz (Ainslie and Boston, 1980; Levine and McGiffigan, 1985; Gerrill and Mrowinski, 1984; Levine, 1981; Willison, Kelly-Ballweber and Dobie, 1985) or slightly more restricted filter settings of 100 or 150 to 3000 Hz (Arlans, et al. 1981; Decker and Howe, 1981; Fowler and Leonards, 1985; Kelly-Ballweber and Dobie, 1989). Fowler and Broadard (1988) reported larger and more reliable binaural interaction components with a high pass filter setting of 150 Hz versus 30 Hz.

4. Electrode Array

Conventionally the inverting electrode in ABR recordings for monaural stimuli is located on the ipsilateral mastoid or earlobe. The inverting electrode site is an important factor in measuring BI with ABR and it cannot be selected arbitrarily. Early wave (II and III) may be out of phase for ABRs recorded with the inverting electrode on the mastoid (or earlobe) ipsilateral versus contralateral to the stimulus (Ainslie and Boston, 1980). Because the ABR recorded for binaural stimuli includes both the waveform for the conventional electrode array (with an electrode on the ear ipsilateral to the stimulus) and the waveform for the contralateral electrode array (which is also the stimulus ipsilateral array for the opposite ear), a binaural enhancement of about 67% for Wave V amplitude would be expected, strictly on the basis of electrode effects) even with no true BL Indeed different investigators have independently reported a binaural advantage on the order of 60-75% (Ainslie and Boston, 1980; Blegvad, 1975; Davis, 1986; Hall, 1981; Van Olphenetal. 1978). A recent report suggests that the BI wave amplitude distribution varies also as a function of noninverting electrode site (Jones and Van der Poel, 1990).

5. **Interaural Attenuation and Cross-Over**

With monaural stimulation, masking of the contralateral (non-test) ear can effectively eliminate the possibility of stimulus cross-over that occurs when stimulus intensity exceeds the subject's interaural attenuations. Masking is not possible with the binaural presentation mode because a stimulus must be delivered to each ear. Cross-over energy could contribute to the BD waveform. This concern is repeatedly expressed in reports of ABR binaural interaction (Ainslie and Boston, 1980, Furst et al, 1985; Levine, 1981 and Wilson et al. 1985). Stimulus cross over in effect, leads to a double stimulation of each ear, first with the original stimulus and then with the delayed stimulation (within a few milli seconds) by the crossed over sound. Consequently, the binaural difference waveform confounded by stimulus cross-over has a relatively large component appearing often with the usual BI components (Levine, 1981).

6. Stimulus Frequency

Fowler and Leonards (1985) evaluated BI in 24 normal hearing subjects and 5 patients with severe high frequency hearing-impairment, using 1000 Hz and 4000 Hz tone bursts. The 1000 Hz stimulus at the highest intensity level (100 dB SPL) was associated with a larger BI component. The BI appeared in the ABR wave V-VII latency region. BI morphology was comparable for normal hearing versus hearing-impaired persons for the 1000 Hz stimulus, even when there was an abnormal ABR or no ABR for the 4000 Hz stimulus. Wilson et al. (1985) studied BI with ABR, using filtered click stimuli with centre frequencies of 500, 2000 and 8000 Hz. Although there was no important amplitude difference for BI among stimuli, the BI waveforms were more distinct relative to background noise for the two higher frequency stimuli.

7. Stimulus Rate

The effects of increased stimulus rate on the BI were consistent with known rate effects on the ABR in general, according to Wilson et al. (1985). That is, with increasing rate, ABR latencies increased significantly for monaural, binaural, predicted (derived) binaural and BI wave components. The effect of rate on response amplitude for these stimulus conditions, was not statistically significant. Fowler and Broadard (1988) reported more reliable and robust BI components at a fast rate (50/sec) versus slower rates (10/sec or 25/sec). Levine (1981) reported greater BI amplitude for slow click rates (10 to 30/sec) than for faster ones. He recommended using a slower click rate in BI measurement in order to minimize the likelihood of acoustic stapedius reflex influence on the BI.

8. Stimulus Polarity

Consistent with expected rate effects on the ABR, Wrege and Starr (1981) reported shorter BI latencies for rarefaction than for condensation click stimuli. Wilson et al. (1985) also found shorter BI latencies for rarefaction versus condensation clicks but no amplitude differences in ABR recordings from guinea pigs. According to Rawool and Ballachanda (1996), latency values are also shorter for binaural stimulation without phase click stimulation (rarefaction to one ear and condensation to the other ear).

9. **Subjects Characteristics**

Subject age does not appear to exert an important influence on BI, as measured with ABR. Hosford-Dunn, et al. (1981) successfully recorded BI components from healthy full term neonates. Although the ABR latency, including that of the BI component, showed the expected age related prolongation, the overall morphology and amplitude of the BIC was comparable for newborns versus adults. Similarly Kelly-Ballweber and Dobie (1984) found no significant difference in BICs for younger (31-49 years) versus older (64-74 years) adult subjects. The effect of peripheral auditory status on BI has not been evaluated specifically, but Kelly-Ballweber and Dobie (1984) implied that the BI was observed less consistently in patients with high frequency impairment. There are no systematic investigations of the effect on BI of other subject characteristics such as gender, body temperature, state of arousal and drugs.

10. Acoustic Stapedius (Middle-Ear) Reflex

There is general consensus that the acoustic stapedial reflex has little or (probably) no effect on ABR differences for monaural versus binaural click stimulation, at least at relatively slow presentation rates (Hall, 1990). The possible influence of acoustic reflex activity onBI was closely scrutinized by Levine (1981). Arguing against an acoustic reflex factor, he noted that contraction of the middle ear muscles in response to acoustic stimulation attenuates mostly low frequency energy. The ABR, however is normally elicited by higher frequency components in the click spectrum. Also, attenuation takes place at the level of the middle ear, before cochlear activation, so all ABR components should be affected. These arguements remain speculative.

11. Interaural Stimulus Time and Intensity Differences

There are numerous psychophysical studies of the effects of stimulus intensity and time of arrival on binaural auditory perceptions, such as localization of sounds. Several groups of investigators have applied ABR in electrophysiologic assessment of either or both of these factors in binaural auditory function (Arslan et al. 1981; Furst et al. 1985; Gerull and Mrowinski, 1984; Jones and Van der Poel, 1990; Prasher, Sainz and Gibson, 1981; Wrege and Starr, 1981). Intra-aural time and/or intensity differences may produce alterations in later ABR waves (VI and VH) but the BI component may be a more sensitive index of these stimulus parameters (Hall, 1990).Furst et al. (1985) found a correlation between the first major peak in the ABR BI component and perceptions of interaural time and intensity differences, as measured psychophysically. The BIC was recorded when subjects perceived a binaural click stimulus as fused, that is, even though sets of click stimuli were presented to each ear separately, the subject heard only a single set. When the difference in the click arrival time between ear (interaural time difference) exceeded 1 msec. The click was perceived as moving to the leading ear and the BIC was no longer observed. As the intensity of clicks presented to one ear versus the other was varied, the perception of click moved toward the unattenuated (greater intensity) ear, and BIC amplitude decreased. When the interaural intensity difference was above 30-35 dB, the BIC was no longer recorded, and the subject perceived only a monaural stimulus (in the ear with the greater intensity level).

12. **Stimulus Intensity Level**

There are discrepancies among studies in the definition of intensity for monaural versus binaural stimuli. In the Decker and Howe (1981) study for example, behavioural hearing threshold, were first determined for right ear, left ear and binaural stimuli, and then ABR waveforms were recorded at a constant SL, such as 60 dB SL, above these individual thresholds. The rationale for this approach articulated by Decker and Howe (1981) is to reduce variables related to the stimuli and highlight neurophysiologic differences. At a fixed SPL (sound pressure level) for the intensity of stimulus presented to each ear, that is, without the SL correction, binaural stimulus intensity, because of summation within the CNS is approximately 5 dB greater than monaural stimulus intensity. Therefore, the actual binaural recording might show intensity related shorter latencies than the summed monaural (derived binaural) recording, which in turn contributes to the difference wave when the one version of binaural waveform is subtracted from the other. Conijn, Broca's and Van Zanten (1990) showed that binaural ABR thresholds were on the average 5.5 dB better (lower) than mean monaural ABR thresholds.

Binaural interaction mechanisms in the auditory brainstem were investigated and demonstrated long before the emergence of ABR (Hall, 1965; Kemp and Robinson, 1937). The anatomic origin of BI as detected by ABR however,is open to speculation (Jones and Vander Poel, 1990; Rawool and Ballachanda, 1990). Binaural stimulus related activity within certain auditory brainstem structures and pathways on ABR BI components, have been assessed in animal experiments (Fullerton and Hosford, 1979; Gardi and Berlin, 1981; Sontheimer, Carid and Klinke, 1985). The major anatomic regions of interest within the brain in this research are the medial nucleus of the trapezoid body, the lateral superior olive, the medial superior olive, and the inferior colliculus. There is no concensus however, regarding which structures mediate the ABR changes observed with interaural time and intensity differences in animals. Furthermore the anatomic source of the ABR BI component within the brainstem is unknown.

As noted, the monaural stimulation is preferable to binaural stimulation for neurodiagnostic applications of ABR (Chiappa, et al. 1979; Prasher and Gibson, 1980; Prasher and Gibson, 1981; Prasher, etaL 1982; Rosenhamer and Holmquist, 1983; Stockard et al. 1978).

The sensitivity of ABR to various pathologies is reduced with binaural stimulation because, a normal response can be observed if there is at least unilateral auditory brainstem integrity. However, lack of the normally expected ABR amplitude enhancement for binaural versus monaural stimulation has been reported for patients with varied disorders, including MS (Prasher, Sainz and Gibson, 1982) and spasmodic dysphonia (Hall, 1981).

Extensive investigation is required to ensure that binaural interaction is observed in all the subjects with normal hearing, before using it on clinical population. It is also important to establish the stimulus parameters using which binaural interaction can be studied. The present investigation was carried out to study the binaural interaction near threshold and at suprathreshold levels.

METHODOLOGY

The methodology of the present study is discussed under the following headings :

1. Subjects
2. Equipment
3. Test environment and
4. Procedure

Subjects

Thirty subjects (15 males and 15 females) in the age range of 17-28 years were selected for the present experimental study. The subjects had to satisfy the following criteria :

1. Audiologically normal ears (thresholds below 20 dB HL). The subjects should have had symmetrical hearing in both the ears.
2. No history of any otologic problem.
3. Negative history of epilepsy and other neurological complaints.

Equipment

1. Madsen OB 822 clinical audiometer (Two-channel) with TDH-39 earphones housed in MX 41 AR ear cushion.
2. Grason-Stadler GSI-33 Middle ear analyser (version 1)
3. Biologic Navigator auditory evoked potential system..

Hearing thresholds were obtained for both right and left ears at all octave frequencies (250 Hz - 8 kHz) using the OB 822 audiometer. The audiometer was calibrated for both air conduction and bone conduction prior to testing and subjective calibration was done everyday.

An immittance meter (GSI-3 3 version 1) was used to assess the middle ear function of the subject. The immittance meter was calibrated as per the recommendations of the manufacturer.

The Auditory Brainstem Response (ABR) measuring system used was the "Biologic Navigator" with EP 317 Software (5.44), a PC based system with a Radioear B-71 bone oscillator and TDH-39 earphones.

Test environment

The tests were carried out in a room with relatively less ambient noise
with adequate lighting and a comfortable temperature.

The subjects were seated on a comfortable chair; they were instructed to relax and not to carry out any motor movements.

Data Collection

All the subjects were first tested at frequencies 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz and 8000 Hz. Both air conduction and bone conduction thresholds were estimated, subjects whose thresholds were between -10 dB HL and +20 dB HL were selected for the study. Immittance evaluation was carried out for these subjects. Only subjects who had 'A' type tympanograms and reflexes between 70 dB HL and 110 dB HL at all frequencies were included for the study.

Recording of Waveforms

Surface electrodes were used here. Before attaching each electrode, the skin was cleaned with omniprep gel. Then a bit of the conducting paste was scooped on to the electrode so as to ensure optimum contact between the electrode and the skin.

Electrode Placement

Al and A2 - Inverting
Cz - Non-inverting
Fz - Common

The electrodes were held in place with adhesive plaster. Each electrode was plugged into the corresponding receptacle on the patient electrode cable from the electrode box. Inter electrode impedance was less than 2000 ohms.

The -test protocol used is as shown in Table A.

Table A : Test protocol

Parameters	Set-up
Transducer	Headphones
Type	Rarefaction Click
Maximum stimuli	2000
Rate	11.1/sec
Filter Setting	30 Hz - 3000 Hz
Time Window	10 msec.

Monaural ABR was recorded individually for both right and left ears. ABR waveform was then recorded for binaural stimulation. The monaural waveforms were then summated to give the DERTVED/CALCULATED BINAURAL ABR_

The difference between the ABR waveforms of the binaural stimulation and the derived monaural waveform was calculated, and the resultant obtained. This resultant was the BINAURAL INTERACTION COMPONENT (BIC).

This procedure was carried out at both threshold and suprathreshold levels i.e. 30 dBn HL and 60 dBn HL.

The binaural interaction of the ABR waveforms near threshold and suprathreshold levels was then compared in terms of amplitude and latency.

Thus, the following measures were computed :

1. Binaural interaction at threshold level.
2. Binaural interaction at suprathreshold level.
3. Differences (in terms of amplitude and latency) between the two interactions.

RESULTS AND DISCUSSION

The aim of the present study was to

i) detect the presence of binaural interaction component at 60 dB nHL and 30 dB nHL, and

ii) findout the effect of intensity on binaural interaction component at 60 dB nHL and 30dB nHL.

Binaural waveform

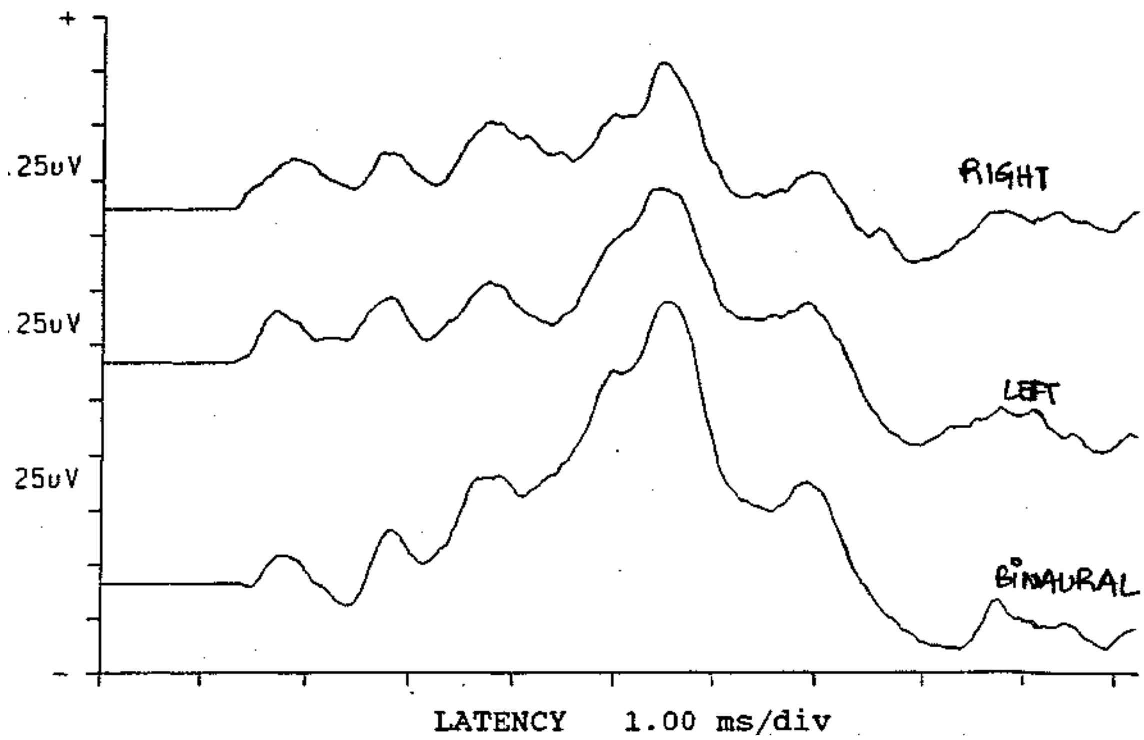
Monaural waveforms were obtained for both right and left ears at 60 dB nHL and 30 dB nHL. Fig. 1 shows the monaural right and left waveforms. and the binaural waveforms at 60dB nHL & 30 dBnHL.

An increase in amplitude was seen in the waveforms for binaural stimulation at both 60 dB nHL and 30dB nHL, indicating a binaural interaction at both near threshold and supra threshold levels. This is evident from Table 1 which gives the mean and standard deviation scores of wave V amplitude for monaural and binaural conditions. The average of both the right and left ear values was taken for monaural responses.

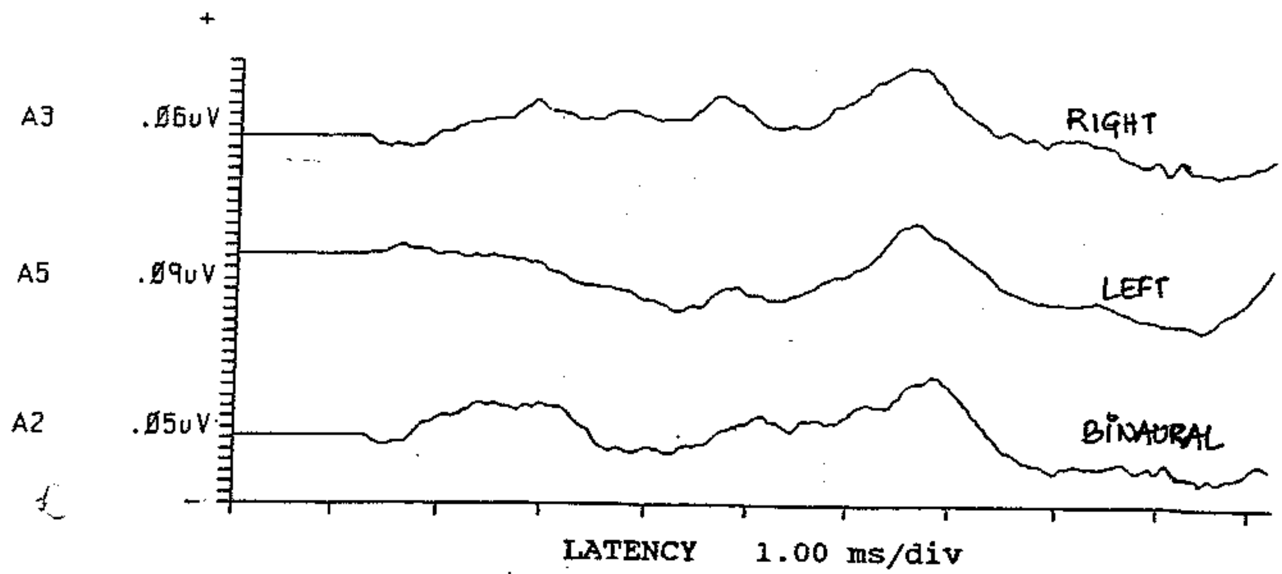
Table 1 : Mean and SD values of wave V amplitude for monaural and binaural stimulation.

	Mean	S.D.
Monoaural stimulation at 60 dB nHL	.403µV	.12
Binaural stimulation at 60 dBnHL	A76µV	.28
Monaural stimulation at 30dB nHL	.316µV	.37
Binaural stimulation at 30dB nHL	377µV	.3

FIG 1: MONAURAL RIGHT & LEFT WAVEFORMS & BINAURAL WAVEFORMS
At 60 dB nHL & 30dB nHL.



60 dB nHL



30dBnHL

The t-test resulted in a value of 7.41 at 60 dB nHL and 2.84 at 30 dB nHL. These values indicate that the difference between the amplitude of the monaural and binaural waveforms was statistically significant at 0.01 level.

This study is in accordance with the other reports in the literature.

Stockard (1978) reported that binaural stimulation results in increased amplitudes of the later waves at all intensities.

Van Olphen, Rodenberg and Vervey (1978) stated that the normal human subject showed wave V amplitude values for binaural stimuli that ranged from 30% to as muchras 200% greater than those for monaural stimuli.

The V-I amplitude ratio could not be calculated as the I peak was not detected in a majority of the subjects (which could be due to the fact that 60 dB nHL was used with headphones rather than insert receiver) and hence were not considered for statistical analysis.

Binaural Interaction Component

The difference between the binaural stimulation waveform at 60 dB nHL and the summed binaural waveform (monaural right + monaural left) at 60 dB nHL was obtained. The resultant difference waveform obtained is termed as the BINAURAL INTERACTION

COMPONENT.A similar procedure was carried out for the 30 dB nHL waveforms. The binaural interaction (BI) waveform consisted of two positive peaks (P1 and P2) each followed by a negative peak (Ni and N2)in the latency range of 2.68 - 7.48 msec.

Fig.3a and 3b show the BIC at 60 dB nHL and 30 dB nHL respectively.

BI at 60dB nHL was seen in 76.66% (23) of the subjects, while at 3 0 dB nHL, BIC was seen only in 16.66% (15) of the subjects. At 60dB nHL, BIC was seen to comprise of the 4 peaks P1, P2 and N1, N2 in all the subjects, however, at 30dB nHL, in two of the subjects, the positive peaks were detected while the negative peaks were unclear.

Table 2 shows the mean, range and standard deviation values for the BICs at 60 dB nHL and 30 dB nHL.

Table 2 : Mean, range and SD values of BICs at 60 dB nHL and 30dBnHL.

	PI	Nl	P2	N2
60dBnHL				
Mean(msec)	3.42	4.2	5.09	5.8
Range(msec)	2.68-5.64	3.52-6.64	4.4-6.62	4.8-7.48
SD	3.48	4.29	5.13	5.89
30dBnHL				
Mean(msec)	3.28	4.3	5.26	6.33
Range(msec)	2.56-4.56	3.24-5.44	4.32-6	5,24-7.44
SD	3.56	4.38	5.31	6.39

Fig 3a : BIC at 60 dB nHL

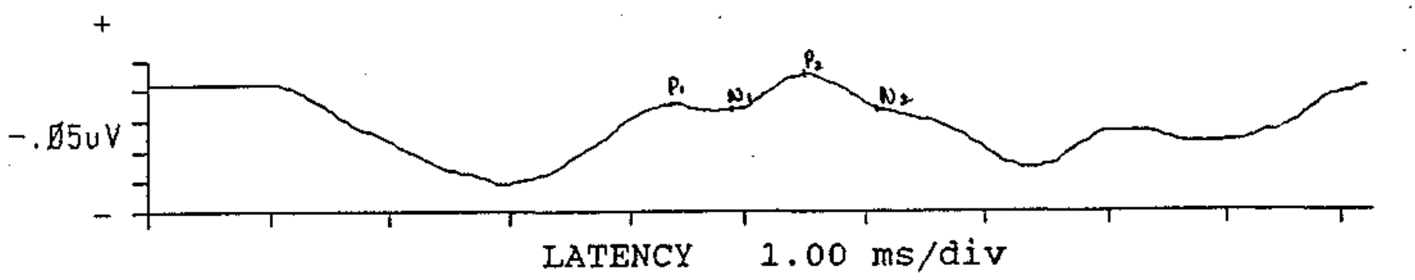
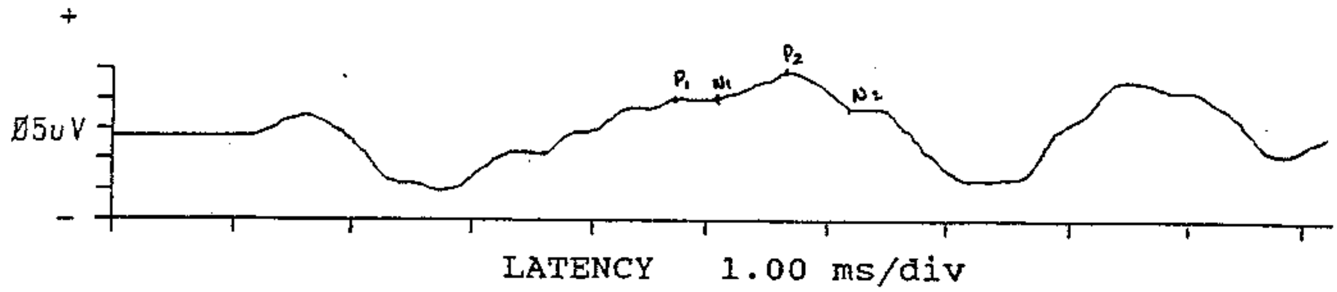


Fig 3b: BIC at 30dB nHL



These findings support those that are reported in the literature.

Hall (1990} stated that there is no BI for the first three waves (I, II and HI) of the ABR, as evidenced by the essentially flat line in the early portion of the BD waveform. Also that the peaks occurred in the latency range of 4-6 msec, within +/- 1 msec, of the ABR wave Y However in the present study, the BI waveform peaks were detected within a much wider range of 2.68 to 7.48 msec, for 60 dB nHL and 2.56 to7.44 for 30 dB nHL.

For the purpose of. statistical analysis, WILCOXON TEST FOR MATCHED PAIRS was carried out using NCSS software for the 5 subjects' data in whom BIC was obtained both at 60 dB nHL and 30 dB nHL.

The *I7J* values obtained are as given in Table 3.

Table 3 :*17J* values of the BIC.

$/Z_1/$	[PI 60 dB nHL vs. P_1 30 dB nHL]	=	0.69
$/Z_2/$	[NI 60 dB nHL vs. $N_1$30dBnHL]	=	0.5
$/Z_3/$	[P2 60 dB nHL vs. P_2 30 dB nHL]	=	0.14
$/Z_4/$	[N2 60 dB nHL vs. N_2 30 dB nHL]		0.10

The results show that none of the /Z/ values are significant with respect to intensity. However, it was observed that the BIC was not seen at 30 dB nHL for all the subjects. This intra subject variability in effect of intensity on BIC needs to be further investigated.

BI was not seen in 7 of the subjects and .there was no common trend observed across their data in terms of amplitude and latency. This absence of BIC in a small percentage (16.66%) of the subjects could not be explained inspite of the same methodology used for all the subjects.

Thus, the results of the study show that binaural interaction was seen in a majority of the subjects. Further, research is required to investigate the absence of BIC observed in the few subjects.

SUMMARY AND CONCLUSION

Binaural ABR can be used as an electrophysiological index of binaural processes such as localization, lateralization and fusion. In addition, it can also be used to assess binaural interaction in children with central auditory processing disorders.

Before being used on the clinical population, it would be essential to study factors affecting binaural ABR on normals. The present study aimed at:

i) detecting the presence of binaural interaction component at 60 dB nHL and 30 dB nHL, and
ii) finding out the effect of intensity on binaural interaction component at 60 dB nHL and 30 dB nHL.

In the present study, 30 subjects (15 males and 15 females) in the age range of 17-28 years having normal hearing were tested. Puretone behavioural thresholds were estimated using the Madsen OB 822 clinical audiometer (two channel) with TDH-39 earphones housed in MX 41 AR ear cushion. Immittance was carried out using the Grason-Stadler GSI-33 Middle ear analyzer (Version 1) and ABR waveforms were recorded using Biologic Navigator with EP 317 Auditory Evoked Potential software version 5.44.

ABR waveforms were recorded for both monaural and binaural stimulation at 60 dB nHL and 30 dB nHL, and the V peak amplitudes of the monaural and binaural waveforms were compared.

The difference between the summed binaural waveforms (right monaural + left monaural) and the binaural stimulation waveforms was called the BINAURAL INTERACTION COMPONENT (BIC).

The results were :

1) There was a significant increase in the wave V amplitude in the binaural waveforms as compared to monaural waveforms both at 60 dB nHL and 30 dB nHL. These results were statistically significant at 0.01 level.
2) The binaural interaction component was detected in 76.6% (23) of the subjects at 60 dB nHL and 16.66% (5) of the subjects at 30 dB nHL.
3) In the 5 subjects in whom BIC was detected at both 60 dB nHL and 30 dB nHL, the results show that there was no effect of intensity on BIC.

Implications of the study

1) The amplitude and latency values of the binaural stimulation waveforms can be used as normative data for binaural ABR.
2) The comparison of monaural and binaural ABR values can be used to detect CNS pathologies.

Limitations of the study

Stimulus artifacts could be reduced and wave generation could be enhanced by using insert receivers instead of headphones. Effect of intensity on BIC was studied only at two intensity levels. No behavioural tests were administered to check the presence or absence of the BIC.

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APPENDIX-I

Calibration of tonal stimuli for ABR testing.

Normal hearing level (nHL) refers to threshold of normal hearing subjects for click or brief tone stimuli. Zero dB nHL will differ for tones of different frequency and duration.

Procedure

A group often normal hearing subjects (5 males and 5 females) were taken. The behavioural thresholds for clicks was estimated at different frequencies. The behavioural thresholds in sound pressure level (SPL) was estimated 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 responses were observed. Their average behavioural threshold were taken as OdB nHL for that stimulus. In the present study OdB nHL refers to 40dB SPL.